AMHSR ORIGINAL ARTICLE

Relationship between Late Gadolinium Enhancement Extent in Cardiac Magnetic Resonance Imaging and Severity of Coronary Artery Disease in Old Myocardial Infarction

Mahmoud Faghih,[1] Korosh Rasekh,[1] Shabnam Madadi,[2] Amir Abbas Iashgari,[3] Sara Adimi,[4]

[1]Department of Cardiology, Besat Hospital, Tehran, Iran.
[2]Rajaie Cardiovascular Medical and Research Center, Iran University of Medical Sciences, Tehran, Iran.
[3]Director of educational affair in university medical branch of Tehran, MD and student of ph.D level sport physiology branch heart and respiratory
[4]University of Social Welfare and Rehabilitation Sciences, and student of ph.D level sport physiology branch heart and respiratory, Tehran, Iran.

ABSTRACT

Purpose: To assess the relationship between the severity of coronary arteries involvement and the extent and pattern of myocardial scars in Cardiac Magnetic Resonance of patients with history of remote myocardial infarction.

Materials and Methods: The Cardiac Magnetic Resonance images of sixty patients with history of remote ST segment or non-ST segment elevation myocardial infarction were reviewed. The patients were candidates for selective coronary angiography and referred for Cardiac Magnetic Resonance imaging in order to evaluate the myocardial viability.

Results: The age of patients with history of old myocardial infarction (n = 60), among whom 78.3% were male, averaged 61.2 (SD = 11.5). There was no association between the severity of coronary artery stenosis in each territory and the presence of myocardial scar detected by late Gadolinium enhancement of Cardiac Magnetic Resonance (for all three vessel territories *P* = .05). However, there was a significant association between the coronary artery runoff and the presence of late Gadolinium enhancement in Cardiac Magnetic Resonance (*P* value for left anterior descending coronary artery [LAD], left circumflex [LCX] and right coronary artery [RCA] was = .002, = .001 and = .001, respectively). A significant relationship was found between the pattern of scar in terms of being transmural or non-transmural and the severity of coronary artery stenosis (*P* = .001), while the pattern of scar was not associated with the coronary artery runoff (*P* = .2).

Conclusion: The results of this study support the hypothesis contending that the time window for revascularization will increase in the presence of antegrade coronary flow in the jeopardized myocardium, which causes a limitation in the infarct progression and subsequent lesser extent of myocardial scar.

Keywords: magnetic resonance imaging, cine; methods; myocardial infarction; diagnosis; hysiopathology; prognosis; severity of illness index; time factors.

AMHSR 2016;14:10-15
www.journals.ajaums.ac.ir

INTRODUCTION

Contrast enhanced Cardiac Magnetic Resonance (CMR) imaging is an accurate imaging modality for the non-invasive evaluation of coronary artery disease (CAD).[1-4] The myocardial tissue characteristics can be directly visualized by CMR and late Gadolinium enhancement (LGE) imaging. In CMR imaging, the presence and extent (degree and pattern) of myocardial scar tissue in patients with history of remote or recent myocardial infarction (MI) can be detected.[4-8] The extent of myocardial scar tissue in CMR has considerable prognostic significance in patients with CAD and is related to the severity of coronary lesions.[4,9-12]

In this study, we aimed to investigate the relationship between the severity of coronary involvement and the extent and pattern of myocardial scars in CMR of patients with history of remote MI.

MATERIALS AND METHODS

The CMR images of sixty patients with history of remote ST or non-ST segment elevation MI were reviewed. The patients were candidates for selective coronary angiography and referred for CMR imaging in order to evaluate the myocardial viability. The presence of MI was confirmed by reviewing the hospital records and considering American Heart Association (AHA) guidelines in diagnosis of acute MI.[13-16] Patients with history of coronary artery bypass graft (CABG) or percutaneous coronary interventions (PCI) were excluded. The study was approved by institutional research and ethics committee.

Coronary Angiography Protocol

The indication of coronary angiography was based on approved guidelines.[17-19] Selective coronary angiography was performed in all patients via femoral approach using Seldinger technique. The left and right anterior and posterior projections were obtained from left and right coronary arteries in all patients. The angiograms were assessed by an expert cardiologist, also the number of vessels involvements, severity of lesions and runoffs of stenotic coronary arteries were recorded.

CMR Protocol

Cardiac MRI with 1.5-Tesla Avanto Siemens device (Siemens Healthcare, Erlangen, Germany) with gadolinium based contrast agent (Magnevist) was conducted. The steady-state free precession sequences for cine images were done. Consecutive breath-hold short axis of the heart was used to obtain functional assessment: Perfusion MRI was performed at rest using a "first-pass" technique with fast intravenous injection of a gadolinium-based contrast agent.

Myocardial edema in the acute phase of MI was shown as a bright signal on T2-weighted images. Late gadolinium enhancement (LGE) images as a T1-weighted inversion recovery sequences were acquired 10 minutes after intravenous administration of gadolinium. The inversion time was chosen in a way to null the myocardial signal using "inversion time scout". The pattern of LGE was used to differentiate the two kinds of post-infarction necrosis (subendocardial and transmural LGE) based on whether the involvement of wall thickness is ≤ 50% or not.

Statistical Analysis

Statistical Package for the Social Science (SPSS Inc, Chicago, Illinois, USA) version 19.0 was used for all statistical analyses. One sample Kolmogorov-Smirnov test was used to assess normal distribution. Quantitative variables were expressed as mean (standard deviation) and categorical variables were expressed as number (percentage). To compare variables Chi square or Mann-Whitney tests were used if appropriate. To assess the sensitivity and specificity of CMR in prediction of coronary artery involvements 2*2 tables were used. *P* values less than .05 were considered significant.

RESULTS

Among 60 subjects of the study population, 47 (78.3%) patients were male. The mean (SD) of age was 61.2 (11.5), which fluctuated between 35 and 86 years of age. The mean (SD) of left ventricular ejection fraction (LVEF) by echocardiography and CMR was 26.8 (10.3) and 27.6 (11.6), respectively.

(**Table 1** (shows demographic and angiographic characteristics of the study population) **Table 2**) depicts detailed coronary angiographic findings of the study population. Left anterior descending (LAD), left

Table 1. Demographic and angiographic characteristics of the study population (n = 60).

Characteristics	Values
Age, mean (SD)	61.2 (11.5)
Sex, number (percent)	
Female	13 (21.7)
Male	47 (78.3)
Echo LVEF, mean (SD)	26.8 (10.3)
RWMA, number (percent)	
Anterior	12 (20)
Posterior	15 (25)
Anterior and posterior	33 (55)
Coronary involvement, number (percent)	
SVD	3 (5)
2VD	21 (35)
3VD	36 (60)

Abbreviations: SD, standard deviation; LVEF, left ventricle ejection fraction; RWMA, regional wall motion abnormalities; SVD, single vessel disease; VD, vessel disease.

Table 2. Coronary angiographic findings of the study population (n = 60).

Variables	Coronary Artery		
	LAD	LCX	RCA
Severity, number (percent)			
Patent	4 (6.7)	13 (21.7)	10 (16.7)
Mild	34 (56.7)	20 (33.3)	20 (33.3)
Moderate	19 (31.7)	16 (26.7)	16 (26.7)
Severe	3 (5)	11 (18.3)	14 (23.3)
Runoff: number (percent)			
Good	32 (57)	30 (63.8)	36 (72)
Fair	19 (34)	12 (25.5)	10 (20)
Poor	5 (9)	5 (10.6)	4 (8)

Abbreviations: LAD, left anterior descending coronary artery LCX, left circumflex ;RCA, right coronary artery

circumflex (LCX) and right coronary arteries (RCA) were involved in 93.3%, 78.3% and 83.3 % of subjects, respectively. Severe stenosis and poor runoff were observed in minority of patients (**Table 2**). **Table 3** depicts CMR findings of the study population. No association was found between the severities of coronary stenosis in each territory and the presence of myocardial scar detected by LGE of CMR (for all three vessel territories *P* .05). However, there was a significant association between coronary artery runoff and the presence of LGE in CMR (*P* value for LAD, LCX and RCA was < .002, < .001 and < .001, respectively). On the other hand, in patients who showed myocardial scar based on LGE in CMR, a significant association between the pattern of scar in terms of being transmural or non-transmural and the severity of coronary artery stenosis was seen (*P* = .001), while the pattern of scar was not associated with the coronary artery runoff (*P* = .2).

Table 3. Cardiac Magnetic Resonance findings of the study population (n = 60)

Characteristics	Values
LVEF, mean (SD)	27.6 (11.7)
LVEDD, mean (SD)	198.5 (65.3)
LVESD, mean (SD)	139.7 (66.6)
RWMA: number (percent)	
Anterior	14 (23.3)
Posterior	15 (25)
Anterior and posterior	31 (51.7)
LGE: number (percent)	
LAD territory	51 (85)
LCX territory	33 (55)
RCA territory	33 (55)
Transmural scar: number (percent)	
LAD territory	35 (58.3)
LCX territory	17 (28.3)
RCA territory	17 (28.3)
Non-transmural scar: number (percent)	
LAD territory	16 (26.7)
LCX territory	16 (26.7)
RCA territory	16 (26.7)
Scar extent based on LGE	
Single vessel territory	17 (28.3)
Two vessel territory	28 (46.7)
Three vessel territory	15 (25)
Scar pattern	
Transmural	20 (33.3)
Non-transmural	11 (18.3)
Mixed	29 (48.3)

Abbreviations: CMR, Cardiac Magnetic Resonance; RCA, right coronary artery; LAD, left anterior descending coronary artery; LCX, left circumflex; LGE, late Gadolinium enhancement; RWMA, regional wall motion abnormalities; SD, standard deviation ; LVEF, left ventricle ejection fraction; LVEDD, left ventricle end-diastolic diameter ; LVESD, left ventricle end-systolic diameter

Diagnostic Accuracy of CMR in Prediction of Coronary Artery Stenosis

We found a specificity of 100% for CMR in the prediction of coronary artery stenosis in all three territories. However, the sensitivity of CMR in prediction of coronary artery stenosis was 91%, 70% and 66% for LAD, LCX and RCA involvements, respectively (**Table 4**).

DISCUSSION

In this study, a significant relationship was found between the coronary runoff and the presence of scar detected by LGE in CMR. We also showed an association between the severity of coronary stenosis and the pattern of scar in terms of being transmural or non-transmural. To the best of our knowledge, this is the first study which has investigated the relationship between severity of CAD and myocardial scar in CMR in patients with history of remote MI.

Among different studies about CMR in MI[5-7,9-11,20-22] Kim and colleagues investigated the CMR of 24 patients with acute MI in order to differentiate the chronic old myocardial scar from acute infarction. They also showed

Table 4. Diagnostic accuracy of CMR in predicting coronary artery lesions in patients with history of MI. Data are presented as percent.

Variables	Sensitivity	Specificity	PPV	NPV
LAD lesion	91	100	85	15
LCX lesion	70	100	55	45
RCA lesion	66	100	55	45

Abbreviations: LAD, left anterior descending coronary artery; LCX, left circumflex RCA, right coronary artery PPV, Positive predictive value .NPV, Negative predictive value

that distinctive features of old scar may exist in CMR and can be used in differentiating old and acute MI. However, they did not consider the pattern of coronary artery lesions in their study[11]

Bexell and colleagues[9], in a similar study, examined the relationship between the severity of proximal coronary stenosis, the amount of coronary collaterals and the myocardial scar extent in patients with history of chronic CAD.[9] They demonstrated a significant relationship between coronary artery stenosis and the extent of myocardial scar in the absence of MI history. They showed that myocardial scarring can be observed even in the presence of non-significant coronary lesions and extent of coronary collaterals is an important factor in the development of myocardial scar.[9]

In this study we found that the coronary artery runoff in patients with history of remote MI may be more important than the severity of coronary artery stenosis in myocardial scarring, also the importance of coronary stenosis severity is in transmurality of the scar.

Ortiz-Perez and colleagues examined acute MI patients treated by primary PCI by CMR and found that the TIMI flow and the presence of collaterals are two independent predictors of myocardial salvage index and transmurality.[10]

It has been shown in both experimental and clinical studies that early restoration of coronary blood flow in infarct-related artery results more myocardial salvage and lesser extent of scars.[9,10,20,23-26] Therefore, it is reasonable to consider a relationship between the extent of scar and the coronary artery runoff, as well as the transmurality and the severity of coronary stenosis.

A good specificity (100) for CMR in detecting coronary artery stenosis in patients with history of MI was also shown in this study. However, the sensitivity and diagnostic accuracy was higher in LAD lesion detection than in LCX and RCA. The diagnostic accuracy of CMR has been examined by Bernhardt and colleagues[27] They investigated patients with history of CABG and PCI and showed that diagnostic accuracy of CMR in CABG patients is lower.[27] In their study, the specificity of CMR for detecting coronary lesion was between 85% and 87% for different coronary vessels, which is much lower than the specificity we found. On the other hand, in our study, the sensitivity of CMR for detecting stenosis in each coronary vessel was also different from Bernhardt and colleagues' study, in which a higher sensitivity for RCA and LCX, but not LAD, was reported. Indeed, our study population has been chosen among patients with documented MI who had low ejection fractions and this dissimilarity in study population may explain the difference in specificity and sensitivity.

CONCLUSIONS

In conclusion, the results of this study support the hypothesis contending that the time window for revascularization will increase in the presence of antegrade coronary flow in the jeopardized myocardium, which causes a limitation in the infarct progression and subsequent lesser extent of myocardial scar. Therefore, the prognosis of patients who had early invasive strategies in the treatment of acute MI is better. CMR is a feasible method in the evaluation of patients with history of MI and has a good diagnostic accuracy in detecting coronary lesions particularly in LAD territory.

ACKNOWLEDGMENTS

Rajaie Cardiovascular Medical and Research Center supported the conduction of the study and provided the patients' data.

CONFLICT OF INTEREST

None declared.

REFERENCES

1. Nagel E, Klein C, Paetsch I, et al. Magnetic resonance perfusion measurements for the noninvasive detection of coronary artery disease. CIRCULATION. 2003;108:432-7.
2. Schwitter J, Nanz D, Kneifel S, et al. Assessment of myocardial perfusion in coronary artery disease by magnetic resonance: a comparison with positron emission tomography and coronary angiography. CIRCULATION. 2001;103:2230-5.
3. Kwong RY, Schussheim AE, Rekhraj S, et al. Detecting acute coronary syndrome in the emergency department

with cardiac magnetic resonance imaging. CIRCULATION. 2003;107:531-7.

4. Kim HW, Farzaneh-Far A, Kim RJ. Cardiovascular magnetic resonance in patients with myocardial infarction: current and emerging applications. J Am Coll Cardiol. 2009;55:1-16.
5. Wu KC, Zerhouni EA, Judd RM, et al. Prognostic significance of microvascular obstruction bymagnetic resonance imaging in patients with acute myocardial infarction. CIRCULATION. 1998;97:765-72.
6. Stork A, Muellerleile K, Bansmann PM, et al. Value of T2-weighted, first-pass and delayed enhancement, and cine CMRto differentiate between acute and chronic myocardial infarction. EUR RADIOL. 2007;17:610-7.
7. Abdel-Aty H, Zagrosek A, Schulz-Menger J, et al. Delayed enhancement and T2-weightedcardiovascular magnetic resonance imaging differentiate acute from chronic myocardial infarction. CIRCULATION. 2004;109:2411-6.
8. Eitel I, Desch S, Fuernau G, et al. Prognostic significance and determinants of myocardial salvage assessed by cardiovascular magnetic resonance in acute reperfused myocardial infarction. J Am Coll Cardiol. 2010;55:2470-9.
9. Bexell D, Setser RM, Schoenhagen P, et al. Influence of coronary artery stenosis severity and coronary collateralization on extent of chronic myocardial scar: insights from quantitative coronary angiography and delayed-enhancement MRI. Open Cardiovasc Med J. 2008;2:79-86.
10. Ortiz-Pérez JT, Lee DC, Meyers SN, Davidson CJ, Bonow RO, Wu E. Determinants of myocardial salvage during acute myocardial infarction: evaluation with a combined angiographic and CMR myocardial salvage index. JACC Cardiovasc Imaging. 2010;3:491-500.
11. Kim KA, Seo JB, Do KH, et al. Differentiation of recently infarcted myocardium from chronic myocardial scar: the value of contrast-enhanced SSFP-based cine MR imaging. Korean J Radiol. 2006;7:14-9.
12. Ahn JM, Yoon SH, Roh JH, et al. Trends in Outcomes of Revascularization for Left Main Coronary Disease or Three-Vessel Disease With the Routine Incorporation of Fractional Flow Reserve in Real Practice. Am J Cardiol.2015;116:1163-71.
13. O'Gara PT, Kushner FG, Ascheim DD, et al. 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol. 2013;61:e78-140.
14. Anderson JL, Adams CD, Antman EM, et al. 2012 ACCF/AHA focused update incorporated into the ACCF/AHA 2007 guidelines for the management of patients with unstable angina/non-ST-elevation myocardial infarction: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol. 2013;61:e179-347.
15. Wright RS, Anderson JL, Adams CD, et al. 2011ACCF/AHA focused update incorporated into the ACC/AHA 2007 Guidelines for the Management of Patients with Unstable Angina/Non-ST-Elevation Myocardial Infarction: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines developed in collaboration with the American Academy of Family Physicians, Society for Cardiovascular Angiography and Interventions, and the Society of Thoracic Surgeons. J Am Coll Cardiol. 2011;57:e215-367.
16. King SB 3rd, Smith SC Jr, Hirshfeld JW Jr, et al. 2007 Focused Update of the ACC/AHA/SCAI 2005 Guideline Update for Percutaneous Coronary Intervention: a report of the American Collegeof Cardiology/American Heart Association Task Force on Practice Guidelines: 2007 Writing Group to Review New Evidence and Update the ACC/AHA/SCAI 2005 Guideline Update for Percutaneous Coronary Intervention, Writing on Behalf of the 2005 Writing Committee. CIRCULATION. 2008;117:261-95.
17. Montalescot G, Sechtem U, Achenbach S, et al. 2013 ESC guidelines on the management of stable coronary artery disease: the Task Force on the management of stable coronary artery disease of the European Society of Cardiology. Eur Heart J. 2013;34:2949-3003.
18. Pitt B, Waters D, Brown WV, et al. Aggressive lipid-lowering therapy compared with angioplasty in stable coronary artery disease. Atorvastatin versus Revascularization Treatment Investigators. N Engl J Med. 1999;341:70-6.
19. Fihn SD, Gardin JM, Abrams J, et al. 2012 ACCF/AHA/ACP/AATS/PCNA/SCAI/STS Guideline for the diagnosis and management of patients with stable ischemic heart disease: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines, and the American College of Physicians, American Association for Thoracic Surgery, Preventive Cardiovascular Nurses Association, Society for Cardiovascular Angiography and Interventions, and Society of Thoracic Surgeons. J Am Coll Cardiol. 2012;60:e44-e164.
20. Ingkanisorn WP, Rhoads KL, Aletras AH, KellmanP, Arai AE. Gadolinium delay edenhancement cardiovascular magnetic resonance correlates with clinical measures of myocardial infarction. J Am Coll Cardiol. 2004;43:2253-9.
21. Friedrich MG. Tissue characterization of acute myocardial infarction and myocarditis by cardiac magnetic resonance. JACC Cardiovasc Imaging. 2008;1:652-62.
22. Tomanek RJ. Developmental progression of the coronary vasculature in human embryos and fetuses. Anat Rec (Hoboken). 2015.
23. Yan AT, Shayne AJ, Brown KA, et al. Characterization of the peri-infarct zone by contrast-enhanced cardiac magnetic resonance imaging is a powerful predictor of post-myocardial infarction mortality. CIRCULATION. 2006;114:32-9.
24. Choi KM, Kim RJ, Gubernikoff G, Vargas JD, Parker M, Judd RM. Transmural extent of acute myocardial infarction predicts long-term improvement in contractile function. CIRCULATION. 2001;104:1101-7.
25. Rahimi K, Banning AP, Cheng AS, et al. Prognostic value of coronary revascularisation-related myocardial injury: a cardiac magnetic resonance imaging study. Heart. 2009;95:1937-43.
26. Ingkanisorn WP, Rhoads KL, Aletras AH, KellmanP, Arai AE. Gadolinium delayed enhancement cardiovascular

magnetic resonance correlates with clinical measures of myocardial infarction. J Am Coll Cardiol. 2004;43:2253-9.

27. Bernhardt P, Spiess J, Levenson B, et al. Combined assessment of myocardial perfusion and late gadolinium enhancement inpatients after percutaneous coronary intervention or bypass grafts: a multicenter study of an integrated cardiovascular magnetic resonance protocol. JACC Cardiovasc Imaging. 2009;2:1292-300.

Corresponding Author:
Sara Adimi,
University of Social Welfare and Rehabilitation Sciences, and student of ph.D level sport physiology branch heart and respiratory
Tel: +98 9123082153
E-mail: sara_adimi@yahoo.com

Received: October 2015
Accepted: February 2016