Iranian Heart Journal; 2015; 16 (4)

Original Article

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

Mohsen Maadani, M.D.[1], Shabnam Madadi, M.D. [1], Mahmoud Fagheeh M.D. [1*], Sara Adimi, M.Sc.[2], Yaghoob Bagheri, M.D. [1]

ABSTRACT

Background: Contrast-enhanced cardiac magnetic resonance imaging (CMR) is an accurate imaging modality for the noninvasive evaluation of myocardial infarction (MI). We sought to assess the relationship between the severity of coronary involvement and the extent and pattern of myocardial scars in CMR of patients with a history of remote MI.

Methods: The CMR of 60 patients with a history of remote ST-elevation or non-ST elevation MI who were candidated for selective coronary angiography and referred for CMR for an evaluation of myocardial viability was reviewed and compared with selective coronary angiographic findings.

Results: Among the 60 patients with a history of old MI, 78.3% were male and the mean (SD) of age was 61.2±11.5 years. There was no association between the severity of coronary stenosis in each territory and the presence of myocardial scar detected by the late gadolinium enhancement of CMR. (P values for all the territories of the 3 vessels were >0.05.) There was a significant association between coronary artery run-off and the presence of late gadolinium enhancement in CMR. (P values for the left anterior descending, left circumflex artery, and right coronary artery were 0.002, <0.001, and <0.001, respectively.) We found a significant relationship between the pattern of the scars in terms of being transmural or non-transmural and the severity of coronary artery stenosis (P<0.001), and the pattern of the scars was not associated with coronary artery run-off (P=0.2).

Conclusions: The results of this study support the hypothesis that the time window for revascularization will be increased in the presence of an antegrade coronary flow in the jeopardized myocardium and that it could limit infarct progression and result in a subsequent lesser extent of myocardial scar. ***(Iranian Heart Journal 2015; 16(4): 12-18)***

Keywords ■ Magnetic resonance imaging ■ Late gadolinium enhancement ■ Myocardial infarction

[1] Department of Cardiology; Rajaie Cardiovascular, Medical and Research Center, Iran University of Medical Sciences, Tehran, I.R. Iran.
[2] Occupational therapist in hand center of Iran, USWR University of Medical Sciences, Tehran, I.R. Iran.

***Corresponding Author:** Mahmoud Fagheeh, M.D.
Email: mahmoud.fagheeh@gmail.com **Tel:** 09121304823

Received: July 25, 2015 **Accepted:** September 10, 2015

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

OBJECTIVES

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

METHODS

The CMR of 60 patients with a history of remote ST-elevation or non-ST elevation MI who were candidated for selective coronary angiography and were referred for CMR for an evaluation of myocardial viability was reviewed. The presence of MI was confirmed by reviewing the hospital records and considering the guidelines of the American Heart Association (AHA) in the diagnosis of acute MI.[13-16] Patients with a history of coronary artery bypass grafting (CABG) or percutaneous coronary intervention (PCI) were excluded.

The study was approved by the institutional research and ethics committee.

Coronary Angiography Protocol

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

CMR Protocol

Cardiac MRI with a 1.5 Tesla Avante Siemens device with a gadolinium-based contrast agent (Magnevist) was done. Steady-state free-precession sequences for cine images were done. Consecutive breath-hold short axes of the heart were used to obtain functional assessment. Perfusion MRI was performed at rest using a first-pass technique with fast intravenous injections of a gadolinium-based contrast agent.

Myocardial edema in the acute phase of MI was shown as a bright signal on T2-weighted images. LGE images as T1-weighted inversion recovery sequences were acquired 10 minutes after an intravenous administration of gadolinium and the inversion time was chosen to null myocardial signal using the inversion time scout. The pattern of LGE was used to differentiate post-infarction necrosis (subendocardial or transmural LGE) based on ≤50% of wall thickness involvement or ≥50%.

Statistical Analysis

IBM SPSS statistics, version 19, for Windows (IBM Corp, Armonk, NY, U.S.A.) was applied for all the statistical analyses. One-sample Kolmogorov–Smirnov test was used to assess normal distribution. The quantitative variables are expressed as means (SD), and the categorical variables are expressed as numbers (percentages). To compare the variables, we employed the chi-square test or the Mann–Whitney test, as appropriate. To assess the sensitivity and specificity of CMR in the prediction of coronary artery involvement, we utilized 2×2 tables. P values <0.05 were considered significant.

RESULTS

Among the 60 subjects in the study population, 47 (78.3%) patients were male. The mean (SD) of age was 61.2±11.5 years, between 35 and 86 years. 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 depicts the demographic and angiographic characteristics of the study population.

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

Characteristics	Values
Age, mean (SD)	61.2 (11.5)
Sex ,number (%)	
Female	13(21.7)
Male	47(78.3)
Echo LVEF, mean (SD)	26.8(10.3)
RWMA, number (%)	
Anterior	12(20)
Posterior	15(25)
Anterior and posterior	33(55)
Coronary involvement, number (%)	
Single-vessel disease	3(5)
Two-vessel disease	21(35)
Three-vessel disease	36(60)

Abbreviations: LVEF, Left ventricular ejection fraction; RWMA, Regional wall motion abnormalities

Table 2 depicts detailed coronary angiographic findings of the study population. The left anterior descending (LAD),left circumflex artery (LCX), and right coronary artery (RCA) were involved in 93.3%, 78.3%, and 83.3% of the subjects, respectively. Severe stenosis and poor run-off were observed in a minority of the patients (Table 2).

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

	Coronary Artery		
	LAD	LCX	RCA
Severity, number (%)			
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)
Run-off, number (%)			
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 artery; LCX, Left circumflex artery; RCA, Right coronary artery

Table 3 depicts the CMR findings of the study population. We found no association between the severity of coronary stenosis in each territory and the presence of myocardial scar detected by LGE in CMR. (P values for all the territories of the 3 vessels were >0.05.) However, there was a significant association between coronary artery run-off and the presence of LGE in CMR. (P values for the LAD, LCX, and RCA were 0.002, <0.001, and <0.001, respectively.) On the other hand, in the patients who showed myocardial scar based on LGE in CMR, there was a significant association between the pattern of the scars in terms of being transmural or non-transmural and the severity of coronary artery stenosis (P<0.001), and the pattern of the scars was not associated with coronary artery run-off (P=0.2).

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(%)**	
Anterior	14(23.3)
Posterior	15(25)
Anterior and Posterior	31(51.7)
LGE , **number(%)**	
LAD territory	51(85)
LCX territory	33(55)
RCA territory	33(55)
Transmural scar, **number (%)**	
LAD territory	35(58.3)
LCX territory	17(28.3)
RCA territory	17(28.3)
Non-transmural scar, **number (%)**	
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: LVEF, Left ventricular ejection fraction; LVEDD, Left ventricular end-diastolic diameter; LVESD, Left ventricular end-systolic diameter; RWMA, Regional wall motion abnormalities; LGE, Late gadolinium enhancement; LAD, Left anterior descending artery; LCX, Left circumflex artery; RCA, Right coronary artery

Diagnostic Accuracy of CMR in the Prediction of Coronary Artery Stenosis

We found specificity of 100% for CMR in the prediction of coronary artery stenosis in all 3 territories. However, the sensitivity of CMR in the prediction of coronary artery stenosis was 91%, 70%, and 66% for the LAD, LCX, and RCA involvement, respectively (Table 4).

Table 4. Diagnostic accuracy of cardiac magnetic resonance in predicting coronary artery lesions in the patients with a history of myocardial infarction

	Sensitivity	Specificity	PPV	NPV	Accuracy
LAD lesion	91	100	85	15	93.2
LCX lesion	70	100	55	45	76.7
RCA lesion	66	100	55	45	71.6

Abbreviations: LAD, Left anterior descending artery; LCX, Left circumflex artery; RCA, Right coronary artery
Data are presented as percentages.

DISCUSSION

In this study, we found a significant relationship between coronary run-off 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 the scars in terms of being transmural or non-transmural. To our knowledge, this is the first study of its kind to investigate the relationship between the severity of coronary artery disease and myocardial scar in CMR in patients with a history of remote MI.

Among different studies on CMR in MI, [5-7, 9-11, 20-22] Kim et al.[11] investigated the CMR of 24 patients with acute MI to differentiate chronic old myocardial scars from acute infarction and showed that distinctive features of old scars might exist in CMR and that this finding could be used to differentiate between old and acute MI. The authors did not consider the pattern of coronary artery lesions in their study.

Bexell et al.[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 a history of chronic coronary artery disease and demonstrated a significant relationship between coronary artery stenosis and the extent of myocardial scar in the absence of MI history. The authors showed that myocardial scarring could be observed even in the presence of nonsignificant coronary lesions and that the extent of coronary collaterals was an important factor in the development of myocardial scar.

In the current study on patients with a history of remote MI, we found that the coronary artery run-off might be more important than the severity of coronary artery stenosis in myocardial scarring. Our results also underscored the importance of coronary stenosis severity in the transmurality of the scar.

Ortiz-Perez et al.[10] examined patients with acute MI treated via primary PCI by CMR and found that TIMI flow and the presence of collaterals were independent predictors of the myocardial salvage index and transmurality.

It has been shown in both experimental and clinical studies that an early restoration of the coronary blood flow in the infarct-related artery results in more myocardial salvage and lesser extent of scars.[9, 10, 20, 23-26] Accordingly, it is reasonable to argue that the extent of scarring is related to the coronary artery run-off and the transmurality to the severity of coronary stenosis.

In the present study, we also showed a good specificity (100) for CMR in detecting coronary artery stenosis in our patients with a history of MI. However, sensitivity and diagnostic accuracy were higher in LAD lesion detection than in LCX and RCA lesion detection. The diagnostic accuracy of CMR was examined by Bernhardt et al.,[27] who investigated patients with a history of CABG and PCI and showed that diagnostic accuracy of CMR in CABG patients was lower. In their study, the specificity of CMR for detecting coronary lesions was between 85 and 87% for different coronary vessels, which is much lower than the specificity we found. On the other hand, the sensitivity of CMR in our

study for detecting stenosis in each coronary vessel was also different from that reported by Bernhardt et al. Additionally, except for the LAD, the sensitivity for the RCA and LCX was higher in their study. Indeed, our study population was chosen from among patients with documented MI who had low ejection fractions and this dissimilarity in the study populations may explain the difference in specificity and sensitivity.

Study Limitations

In this study, we had some limitations. First, we did not consider the time of MI occurrence and the type of the event (anterior, inferior, or other types of acute MI). Although we excluded patients with a history of PCI, including primary PCI, the effect of the other types of treatments were not considered in this study. In addition, the presence or absence of coronary collateral as an important predictor of scar extent was not evaluated in this study.

In conclusion, the results of the present study support the hypothesis that the time window for revascularization will be increased in the presence of an antegrade coronary flow in the jeopardized myocardium and results in limiting infarct progression and subsequent lesser extent of myocardial scar. Therefore, the prognosis of patients with early invasive strategies in the treatment of acute MI is better.

CMR is a feasible method in the evaluation of patients with a history of MI and has a good diagnostic accuracy in detecting coronary lesions, particularly in the LAD territory.

Acknowledgements

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

Authors' Contributions

Mohsen Maadani and Shabnam Madadi developed the original data and protocol and also conducted and supervised the project. Nasim Naderi and Mahmoud Fagheeh cooperated in data analysis and scientific writing of the manuscript. Sara Adimi and Yaghoob Bagheri provided the study material and patients. Sara Adimi provided the study material and patients and collaborated in data collection. Mahmoud Fagheeh approved the final manuscript and carried out the writing of the manuscript.

Financial Disclosure

The authors declare that there is no conflict of interests.

Funding/Support

The authors state that there was no financial support.

REFERENCES

1. Nagel, E., et al., Magnetic resonance perfusion measurements for the noninvasive detection of coronary artery disease. Circulation, 2003. 108(4): p. 432-437.
2. Schwitter, J., 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(18): p. 2230-2235.
3. Kwong, R.Y., et al., Detecting acute coronary syndrome in the emergency department with cardiac magnetic resonance imaging. Circulation, 2003. 107(4): p. 531-537.
4. Kim, H.W., A. Farzaneh-Far, and R.J. Kim, Cardiovascular magnetic resonance in patients with myocardial infarction: current and emerging applications. Journal of the American College of Cardiology, 2009. 55(1): p. 1-16.
5. Wu, K.C., et al., Prognostic significance of microvascular obstruction by magnetic resonance imaging in patients with acute myocardial infarction. Circulation, 1998. 97(8): p. 765-772.
6. Stork, A., et al., Value of T2-weighted, first-pass and delayed enhancement, and cine CMR to differentiate between acute and chronic

myocardial infarction. European radiology, 2007. 17(3): p. 610-617.

7. Abdel-Aty, H., et al., Delayed enhancement and T2-weighted cardiovascular magnetic resonance imaging differentiate acute from chronic myocardial infarction. Circulation, 2004. 109(20): p. 2411-2416.

8. Eitel, I., et al., Prognostic significance and determinants of myocardial salvage assessed by cardiovascular magnetic resonance in acute reperfused myocardial infarction. Journal of the American College of Cardiology, 2010. 55(22): p. 2470-2479.

9. Bexell, D., 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. The open cardiovascular medicine journal, 2008. 2: p. 79.

10. Ortiz-Pérez, J.T., et al., Determinants of myocardial salvage during acute myocardial infarction: evaluation with a combined angiographic and CMR myocardial salvage index. JACC: Cardiovascular Imaging, 2010. 3(5): p. 491-500.

11. Kim, K.A., et al., Differentiation of recently infarcted myocardium from chronic myocardial scar: the value of contrast-enhanced SSFP-based cine MR imaging. Korean Journal of Radiology, 2006. 7(1): p. 14-19.

12. Abouliatim, I., et al., Coronary flow in patients with three-vessel disease: Simulated hemodynamic variables in relation to angiographically assessed collaterality and history of myocardial infarction. ISRN Vascular Medicine, 2012. 2011.

13. O'Gara, P.T., 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. Journal of the American College of Cardiology, 2013. 61(4): p. e78-e140.

14. Anderson, J.L., 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. Journal of the American College of Cardiology, 2013. 61(23): p. e179-e347.

15. Wright, R.S., et al., 2011 ACCF/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. Journal of the American College of Cardiology, 2011. 57(19): p. e215-e367.

16. King, S.B., et al., 2007 Focused Update of the ACC/AHA/SCAI 2005 Guideline Update for Percutaneous Coronary Intervention A Report of the American College of 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(2): p. 261-295.

17. Montalescot, G., et al., 2013 ESC guidelines on the management of stable coronary artery disease. European heart journal, 2013. 34(38): p. 2949-3003.

18. Pitt, B., et al., Aggressive lipid-lowering therapy compared with angioplasty in stable coronary artery disease. New England Journal of Medicine, 1999. 341(2): p. 70-76.

19. Fihn, S.D., 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. Journal of the American College of Cardiology, 2012. 60(24): p. e44-e164.

20. Ingkanisorn, W.P., et al., Gadolinium delayed enhancement cardiovascular magnetic resonance correlates with clinical measures of myocardial infarction. Journal of the American College of Cardiology, 2004. 43(12): p. 2253-2259.

21. Friedrich, M.G., Tissue characterization of acute myocardial infarction and myocarditis by cardiac magnetic resonance. JACC: Cardiovascular Imaging, 2008. 1(5): p. 652-662.

22. Tomanek, R.J., Myocardial Ischemia and Infarction, in Coronary Vasculature. 2013, Springer. p. 189-220.

23. Yan, A.T., 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(1): p. 32-39.

24. Choi, K.M., et al., Transmural extent of acute myocardial infarction predicts long-term improvement in contractile function. Circulation, 2001. 104(10): p. 1101-1107.

25. Rahimi, K., et al., Prognostic value of coronary revascularisation-related myocardial injury: a cardiac magnetic resonance imaging study. Heart, 2009. 95(23): p. 1937-1943.

26. Gadolinium Delayed Enhancement Cardiovascular Magnetic Resonance Correlates With Clinical Measures of Myocardial Infarction. Journal of the American College of Cardiology, 2004. 43(12).

27. Bernhardt, P., et al., Combined assessment of myocardial perfusion and late gadolinium enhancement in patients after percutaneous coronary intervention or bypass grafts: a multicenter study of an integrated cardiovascular magnetic resonance protocol. JACC: Cardiovascular Imaging, 2009. 2(11): p. 1292-1300.