## Original Article

# Resting-State Cardiac Magnetic Resonance Perfusion Imaging Accuracy in Diagnosing Patients With Coronary Artery Disease: A Comparison with Percutaneous Coronary Intervention

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## ABSTRACT

***Background:*** Myocardial ischemia may occur as a result of a variety of vascular and congenital conditions. There are different methods to assess ischemic myocardial tissue
This study aimed to assess the diagnostic accuracy of cardiac magnetic resonance imaging (CMR) in advanced coronary artery disease (CAD).

***Methods:*** Thirty patients with a predefined history of severe CAD underwent CMR with a 1.5 T CMR machine. The imaging protocol consisted of 4 steps: left ventricular functional imaging, T1-weighted contrast-enhanced magnetic resonance perfusion imaging, early gadolinium enhancement, and delayed gadolinium enhancement. The left ventricular functional indices and time-intensity curves (TICs) of the magnetic resonance perfusion imaging were calculated using a CMR analysis software tool. The TICs were drawn on 90 normal, early, and delayed gadolinium-enhanced territories under the guidance of percutaneous coronary angiography reports.

***Results:*** Overall, 90 territories were derived from the 30 patients. Fifty-two territories were diagnosed with significant CAD and 38 with a normal coronary status. Our analysis revealed 35 regions with flattened TICs (increased time to peak, deceased maximum intensity, and more time-lasting plateaus) and 17 with normal patterns in diseased territories. From the total 38 angiographically normal regions, 36 regions presented normal TICs and 2 showed diseased patterns. The diagnostic accuracy, sensitivity, specificity, positive predictive value, and negative predictive value of CMR were 78.8%, 67.3%, 94.7%, 94.59%, and 67.92%, respectively, in comparison with percutaneous coronary angiography.

***Conclusions:*** Resting-state CMR can be used to detect the presence of any severe/significant coronary artery lesion with an acceptable accuracy. ***(Iranian Heart Journal 2021; 22(1): 84-90)***

**KEYWORDS:** Magnetic resonance imaging, Coronary artery disease, Myocardial ischemia, Perfusion magnetic resonance imaging, Percutaneous coronary intervention

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Myocardial ischemia may occur as a result of a variety of vascular and congenital conditions such as coronary stenotic lesions and myocardial bridge.[2] When myocardial tissue is under hypoxic conditions, it enters an adaptation phase with a newly introduced oxygenation level. Adaptation is a limited process, and myocardial oxygenation degrades over myocardial tissue's endurance, which is followed by the myocardial necrosis phase. This process is termed "myocardial infarction".[3] Myocardial infarction reduces myocardial contractibility and function. Theoretically, ischemic myocardium is divided into 2 categories: stunned and hibernating.[5] Stunned myocardium is a result of acute myocardial ischemia with myocardial dysfunction, which responses positively to immediate reperfusion. The hibernating myocardium is defined as a long-term hypoperfused myocardium that may (or may not) respond positively to revascularization.[5, 6] In both stunned and hibernating myocardium, the metabolism of myocytes is degraded.[7] Studies have shown a strong correlation between the time course of hypoxia and myocardial response to revascularization.[6]

There are different methods to assess ischemic myocardial tissue such as percutaneous coronary angiography (PCA), stress-induced echocardiography, stress-induced radionuclide imaging, and stress-induced cardiac magnetic resonance imaging (CMR).[8, 9] PCA is the gold-standard method for the assessment of coronary arteries but with reasonably high radiation exposure. This method can detect even the smallest coronary lesions but suffers from a lower sensitivity in the detection of myocardial bridge.[10] Stress-induced radionuclide imaging is also a feasible tool in coronary artery disease (CAD) assessments and can detect myocardial perfusion defects with an acceptable range of sensitivity and specificity. Radionuclide imaging suffers from a number of disadvantages, including high specific radiation absorption rates, high false-positive results (due to diaphragmatic and breast shadows on left ventricular [LV] inferior wall), high false-negative results (due to balanced ischemia), and the time-consuming nature of this imaging procedure.[11-13] Stress-induced echocardiography is another CAD assessment option that evaluates myocardial ischemia indirectly via the analysis of cardiac contractility. For this purpose, echocardiography is performed following dobutamine administration. Stress-induced echocardiography has its own major limitations such as lower sensitivity in single-vessel disease evaluations. It also has several major advantages that make it a reliable option in CAD assessments, including its widespread availability, costless expertise, and biological safety.[14, 15]

Stress-induced CMR is a promising method for myocardial ischemia assessments. Besides all the anatomical information that CMR provides regarding the heart and the great vessels, it yields valuable information about cardiac function, micro-structure, and perfusion status. None of the abovementioned modalities provides any information as comprehensively as CMR. In CMR ischemia assessments, there is a need for vasodilator pharmaceuticals and gadolinium-based contrast agent administration. A routine stress-induced CMR protocol may include: A) cardiac functional and contractility assessment, B) myocardial perfusion study under stress, C) early gadolinium-enhancement imaging, and D) delayed gadolinium-enhancement imaging.[16]

PCA detects coronary lesions with a high diagnostic accuracy rate and is considered the gold-standard method in the evaluation of patients with CAD. Nonetheless, it has a relatively low sensitivity in the detection of microvessel cardiac ischemic disease. Therefore, myocardial perfusion studies have become of great importance in this field. Myocardial perfusion studies are usually performed under stress-induced conditions, either by exercise or via the injection of stressor pharmaceuticals such as vasodilators. It is noteworthy that there is a strong contraindication for the administration of vasodilator drugs in patients with suspected severe CAD. Therefore, an imaging technique prior to stress-induced myocardial perfusion studies that helps clinicians rule out severe CAD seems necessary. Only a few studies have been conducted during the past decade to investigate the diagnostic potencies of resting-state CMR in the prediction of advanced CAD. In the present study, we aimed to address this issue by estimating the sensitivity, specificity, diagnostic accuracy, positive predictive value, and negative predictive value of resting-state CMR in advanced CAD diagnosis in comparison with PCA.

## METHODS

### Study Population

Thirty patients, comprised of 22 men and 8 women at a mean age of 67.46 years, with confirmed significant CAD underwent CMR for ischemia assessments at rest with a 1.5 T cardiac-specific Avanto Scanner (Siemens, Erlangen, Germany).

### Ethical Considerations

Prior to study commencement, the study protocol was approved by the Review Board and Ethics Committee of Iran University of Medical Sciences. The design and objectives of the study were explained to the patients, and written informed consent was obtained from those willing to participate in the study. Reassurances were given to the participants concerning the confidentiality and anonymity of their information. The conduct of the study was in complete adherence to the ethical considerations of the Helsinki declaration.

### Data Availability Statement

All the data of the patients are available upon request.

### CMR

The imaging protocol was identical for the entire study population. A 16-channel phased-array body RF coil was employed in all the patients. All the sequences were electrocardiography-gated either retrospectively or prospectively

### Cine Imaging

True-Fast Imaging with Steady State Precession (True-FISP) 2D breath-hold cine images were obtained retrospectively in the 2-, 3-, and 4-chamber views, as well as LV output tract and short-axis views, in all the patients to assess LV wall motion kinesis qualitatively and to measure its indices quantitatively.

### Contrast-Enhanced T1-Weighted Perfusion Imaging

Contrast-enhanced T1-weighted magnetic resonance perfusion imaging (MRP) data were acquired via a breath-hold turbo fast low-angle shot (turbo-FLASH) pulse sequence in 3 basal, midventricular, and apical short-axis, 2-chamber, and 4-chamber views.

### Late Gadolinium Enhancement (LGE)

LGE images were acquired 10 minutes after the administration of a 0.1 mmol/kg gadolinium-based contrast agent (Omniscan, GE Healthcare) by True-FISP phase-sensitive inversion-recovery (True-FISP PSIR) pulse sequence in the 2- and 4-

chamber and short-axis views. All the LGE images were acquired in the swapped phase direction again to eliminate any artifactual false-positives from the final analysis.

### Image Analysis

The acquired CMR images were analyzed both qualitatively and quantitatively by a cardiothoracic radiologist and a cardiologist using CMR software (Circle Cardiovascular Imaging, Calgary, Canada).[42] The first-pass time-intensity curves (TICs) of the contrast agent were drawn by a clinical CMR physicist on the normal remote, ischemic, and delayed-enhanced territories using the same software.

### Statistical Analysis

The results were presented as mean±SD for the quantitative variables and were summarized as frequencies (percentages) for the categorical variables. The categorical variables were compared using the $\chi^2$ test. A *P* value of 0.05 or less was considered statistically significant. All the statistical analyses were carried out using SPSS software, version 22, (IBM, Armonk, NY, US) on a coronary territorial basis to assess the diagnostic accuracy, sensitivity, specificity, positive predictive value, and negative predictive value of resting-state CMR in comparison with PCA.

## RESULTS

Overall, 90 territories were derived from 30 patients. Each patient's angiographic results were divided into 3 left anterior descending, right coronary artery, and left circumflex artery components. The CMR data were analyzed in a coronary-based territorial manner to make it possible to compare the results with the angiographic data. Out of the total number of territories, 52 were diagnosed as significant CAD and 38 as normal coronary regions. From the positive CAD territories, our analysis revealed 35 regions with flattened TICs (increased time to peak, deceased maximum intensity, and more time-lasting plateaus) and 17 with normal patterns. From the total 38 angiographically normal territories, 36 regions showed normal TICs and 2 showed diseased patterns. The statistical cross-tabulation analysis calculated the diagnostic accuracy, sensitivity, specificity, positive predictive value, and negative predictive value of CMR as 78.8%, 67.3%, 94.7%, 94.59%, and 67.92%, respectively, in comparison with PCA (Table 1).

**Table 1:** CMR vs interventional angiography cross-tabulation results

| | | | Angiography | | Total Frequency |
|---|---|---|---|---|---|
| | | | Positive | Negative | |
| CMR | Positive | Count | 35 | 2 | 37 |
| | | % within angiography | 67.3% | 5.3% | 41.1% |
| | Negative | Count | 17 | 36 | 53 |
| | | % within angiography | 32.7% | 94.7% | 58.9% |
| Total | | Count | 52 | 38 | 90 |
| | | % within angiography | 100% | 100% | 100% |

CMR, Cardiac magnetic resonance imaging

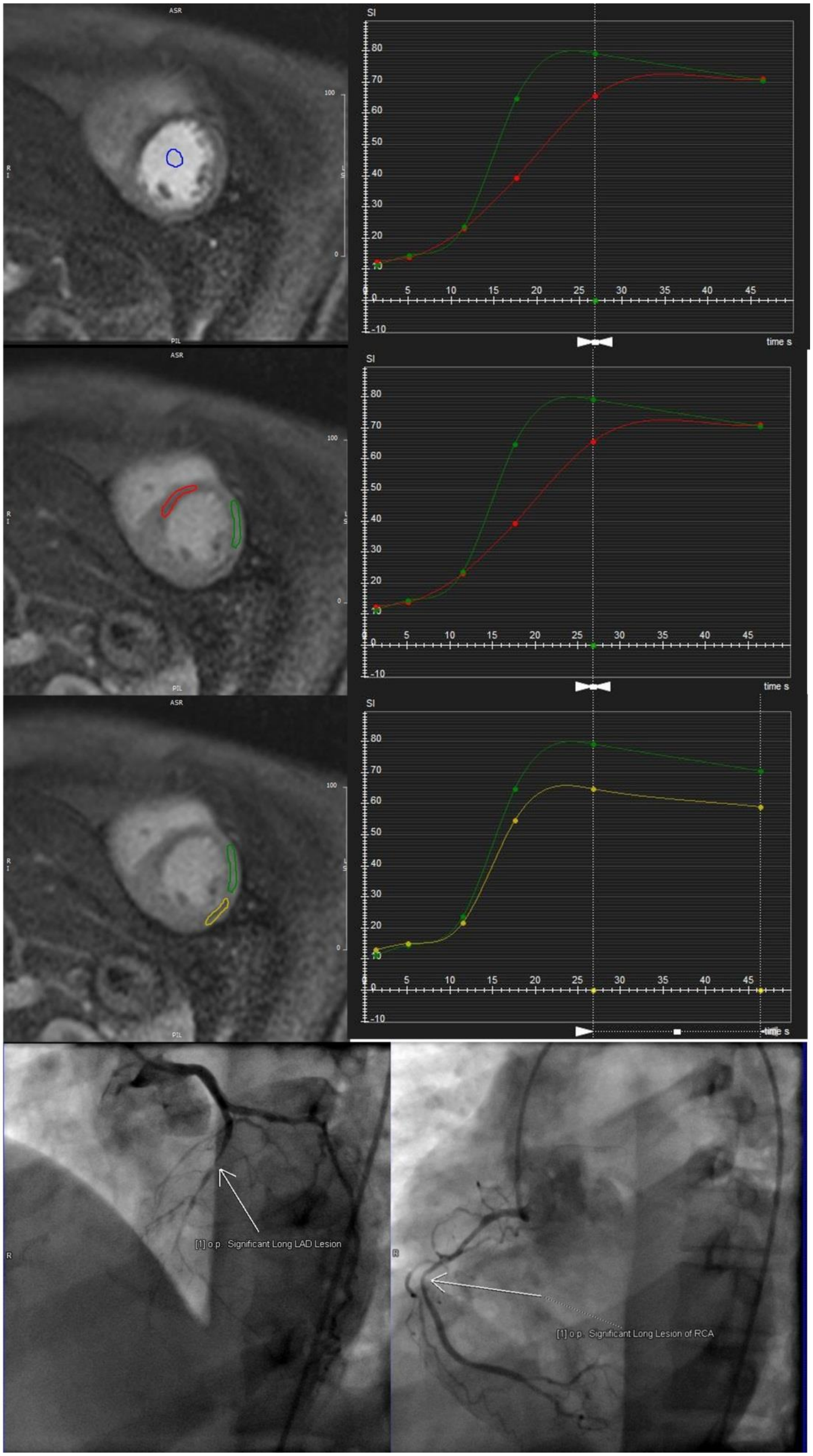
ASR
PIL
SI
time s
[1] o.p. Significant Long LAD Lesion
[1] o.p. Significant Long Lesion of RCA

**Figure 1:** Images were taken of a female patient, aged 41 years, who suffered from chest pain. A & B) The midventricular magnetic resonance myocardial perfusion short-axis view presents the blood-pool time-intensity curve (TIC) pattern (maximum signal intensity = 165 and time to peak = 13 s). C) The same myocardial perfusion short-axis image presents a hypoperfusion area in the mid-septal wall, the left anterior descending coronary artery (LAD) territory (red). D) The semi-quantitative assessment indicates a drop in the maximum signal intensity of TICs (70) and a longer time to peak (33 s) in the LAD region (red), thereby decreasing the upslope of the TICs in comparison with the remote myocardium (green). E) The same image shows a hypoperfusion area in the inferolateral region, the right coronary artery (RCA) territory (yellow). F) There is a significant change in the TIC pattern of the RCA territory (yellow: maximum signal intensity = 66 and time to peak = 23 s) in comparison with the normal remote myocardium (green: maximum signal intensity = 80 and time to peak = 23 s). G & H) Percutaneous coronary angiography depicts a long-segment significant stenosis in the proximal segment of LAD and the mid-potion of RCA, respectively.

## DISCUSSION

CMR plays a pivotal role in the diagnosis, risk stratification, and management of chronic myocardial ischemia or infarction. This imaging modality confers useful information regarding LV function, remodeling, edema, scar tissue size, and planning treatment strategies. In clinical routines, ischemia CMR is usually accomplished by the administration of vasodilator drugs; however, vasodilators are contraindicated in severe CAD due to their life-threatening effects. In these situations, case selection is important for ischemia imaging. Although there are numerous studies on the diagnostic accuracy of stress-induced CMR in patients with moderate CAD, only a few studies have thus far evaluated the role of resting-state CMR in cases with severe CAD. In this study, we aimed to address this issue by performing CMR on patients with confirmed severe CAD. We chose PCA as the gold-standard method. The sensitivity, specificity, and accuracy were 67.3%, 94.7%, and 78.8%, respectively. This high rate of specificity suggests that resting-state CMR could rule out severe CAD with reliable statistical power, while the low rate of sensitivity indicates that this method suffers from a high rate of false-negative results. Our results also suggest that resting-state CMR could be used before stress-induced MRI to detect patients with severe CAD who have contraindications for stress-induced imaging. This combination and its order are important because resting-state CMR enables the clinician to rule out severe CAD and administer the stressor pharmaceuticals with a higher level of confidence, which leads to a reduction in the rate of adverse effects. Moreover, resting-state CMR might be a noninvasive promising tool with good diagnostic accuracy for the diagnosis of severe CAD in scenarios where patients refuse invasive procedures. An example is shown in Figure 1.

## CONCLUSIONS

The results of the present investigation showed that resting-state CMR could reliably predict the presence of severe CAD with acceptable accuracy and high specificity. Therefore, this imaging modality could be potentially applicable to myocardial ischemia/viability assessments to rule out the presence of chronic or acute severe CAD.

### Conflict of Interest

There is no conflict of interest regarding the manuscript, nor is there any financial relationship with the organization that sponsored this research. The authors have full control of all primary data, which are available for review upon request.

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