Original research article

The role of cardiovascular magnetic resonance in evaluating myocardial perfusion and scar tissue: An Institutional Study

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Abstract

Introduction: Cardiovascular Magnetic Resonance (CMR) has become an essential non-invasive imaging modality in the diagnosis and management of various cardiac conditions. Its ability to provide detailed assessments of myocardial perfusion and scar tissue without ionizing radiation offers distinct advantages over other imaging techniques. Aim is to evaluate the role of Cardiovascular Magnetic Resonance (CMR) in assessing myocardial perfusion and scar tissue and to investigate the correlation of CMR findings with clinical parameters and outcomes, including angina symptoms, history of myocardial infarction, and revascularization procedures.
Materials and Methods: This prospective observational study was conducted with a sample size of 75 patients who had clinical indications for CMR. The study included adult's aged 18 years and older, excluding those with contraindications to MRI or severe renal impairment. CMR imaging was performed using a 1.5 Tesla MRI scanner, incorporating cine imaging, stress and rest perfusion imaging, late gadolinium enhancement (LGE), and T1 and T2 mapping.
Results: The study found that 30% of participants exhibited myocardial perfusion defects, with a mean scar burden of 15% across the study cohort. Participants with angina symptoms, a history of myocardial infarction, or those who underwent revascularization procedures had higher scar burdens and lower left ventricular ejection fractions (LVEF). Significant correlations were observed between CMR findings and clinical outcomes, with participants who had a history of myocardial infarction showing the highest scar burden (mean 30%) and lowest LVEF (mean 45%).
Conclusion: CMR is a valuable tool for evaluating myocardial perfusion and scar tissue, with significant correlations to clinical outcomes. This study confirms the importance of CMR in the management of cardiovascular diseases and suggests that further research and advancements are necessary to enhance its accessibility and utility in diverse healthcare settings.
Keywords: Cardiovascular magnetic resonance, myocardial perfusion, scar tissue, angina, myocardial infarction, revascularization, cardiac imaging

Introduction

Cardiovascular Magnetic Resonance (CMR) has emerged as a pivotal non-invasive imaging modality in the comprehensive evaluation of various cardiac conditions, particularly in assessing myocardial perfusion and detecting scar tissue [1]. Leveraging its high spatial resolution and versatility, CMR provides detailed insights into the structure and function of the heart, enabling clinicians to diagnose and manage cardiovascular diseases with greater precision [2]. Unlike other imaging techniques, CMR does not involve ionizing radiation, making it a safer alternative for repeated assessments and longitudinal studies.
The assessment of myocardial perfusion is critical in diagnosing and managing ischemic heart disease, which remains a leading cause of morbidity and mortality worldwide [3]. CMR perfusion imaging allows for the visualization and quantification of blood flow to the myocardium during rest and stress conditions, facilitating the detection of perfusion defects indicative of coronary artery disease[4]. Additionally, CMR's ability to perform stress testing with pharmacological agents enhances its diagnostic

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accuracy, especially in patients who are unsuitable for traditional exercise-based tests. Several studies have demonstrated the superior sensitivity and specificity of CMR perfusion imaging compared to conventional modalities such as single-photon emission computed tomography (SPECT), showing its importance in clinical practice [5].

In the evaluation of myocardial scar tissue, CMR utilizes late gadolinium enhancement (LGE) techniques to detect and characterize areas of fibrosis and necrosis within the myocardium. This capability is essential for assessing the extent and severity of myocardial infarctions, cardiomyopathies, and other fibrotic cardiac conditions [6]. LGE-CMR provides prognostic information by identifying patients at higher risk of adverse cardiac events and guiding therapeutic interventions such as revascularization and device implantation. Prior research has established the correlation between scar burden detected by CMR and clinical outcomes, highlighting its role in risk stratification and treatment planning[7].

Despite the advancements and proven efficacy of CMR in cardiac imaging, certain research gaps persist. There is a need for standardized protocols and consensus guidelines to ensure consistency and reproducibility across different clinical settings and imaging centers. The aim of this study is to comprehensively evaluate the role of Cardiovascular Magnetic Resonance in assessing myocardial perfusion and scar tissue, addressing existing research gaps and building upon prior studies. This investigation seeks to refine imaging techniques, establish standardized assessment protocols, and elucidate the prognostic significance of CMR findings in various cardiac pathologies. Ultimately, the study aspires to enhance the clinical utility of CMR, improving diagnostic accuracy, patient management, and outcomes in cardiovascular care.

Materials and Methods

This study was a prospective observational study conducted in the Department of Radiodiagnosis. The study aimed to evaluate myocardial perfusion and scar tissue using Cardiovascular Magnetic Resonance (CMR) in a cohort of patients suspected of having ischemic heart disease or cardiomyopathies. Ethical approval was obtained from the institutional ethics committee, and informed consent was secured from all participants before enrollment in the study.

Sample size

A total of 75 patients were included in the study. The sample size was determined based on previous studies and statistical calculations that ensured adequate power to detect significant differences in myocardial perfusion and scar tissue characteristics across various patient groups.

Inclusion criteria

- Adults aged 18 years and older.
- Patients with clinical indications for CMR, including suspected ischemic heart disease, known coronary artery disease, or cardiomyopathies.
- Ability to provide informed consent.

Exclusion criteria

- Patients with contraindications to MRI, such as those with non-MRI-compatible implants (e.g., certain pacemakers or defibrillators).
- Claustrophobic patients unable to tolerate the MRI procedure.
- Pregnant women.
- Patients with severe renal impairment (eGFR< 30 mL/min/1.73 m²) due to the risk of nephrogenic systemic fibrosis associated with gadolinium-based contrast agents.

CMR Protocol

All patients underwent a comprehensive CMR examination using a 1.5 Tesla MRI scanner. The following sequences were performed:

1. **Scout Imaging:** Initial localizer scans were obtained to ensure proper positioning and to plan subsequent image acquisition.
2. **Cine Imaging:** Steady-state free precession (SSFP) sequences were used to assess cardiac function and anatomy. Images were acquired in standard views, including long-axis (two-chamber, four-chamber, and three-chamber) and short-axis planes, covering the entire left ventricle from base to apex.
3. **Myocardial Perfusion Imaging:** First-pass perfusion imaging was performed after administering a bolus of gadolinium-based contrast agent (0.1 mmol/kg) intravenously. Stress perfusion imaging was conducted using a pharmacological stress agent (e.g., adenosine, 140 µg/kg/min) to induce hyperemia. Rest perfusion imaging was performed approximately 10 minutes after stress imaging to assess myocardial blood flow under baseline conditions. The perfusion images were acquired in three short-axis slices (basal, mid, and apical).
4. **Late Gadolinium Enhancement (LGE):** LGE imaging was performed 10-15 minutes after the

administration of an additional gadolinium contrast dose (0.1 mmol/kg) to assess myocardial scar tissue. Phase-sensitive inversion recovery (PSIR) sequences were used to maximize contrast between normal and scarred myocardium. LGE images were obtained in the same planes as cine imaging for comprehensive evaluation.

5. **T1 and T2 Mapping:** Native T1 and T2 mapping sequences were included to quantify myocardial tissue characteristics. T1 mapping was performed before contrast administration, and post-contrast T1 mapping was done following LGE imaging. T2 mapping was performed to detect myocardial edema, which may indicate acute injury or inflammation.

Image Analysis

All CMR images were analyzed using dedicated software. Two experienced radiologists independently reviewed the images, blinded to the patients' clinical details.

- **Myocardial Perfusion Analysis:** Perfusion defects were identified and quantified using semi-quantitative analysis, comparing the myocardial blood flow between stress and rest conditions. Regions of interest (ROIs) were placed in the myocardium, and signal intensity-time curves were generated to assess perfusion.
- **Scar Tissue Assessment:** LGE images were evaluated to detect the presence and extent of myocardial scar tissue. Scar burden was quantified as a percentage of the left ventricular myocardium using the full-width at half-maximum (FWHM) method.
- **T1 and T2 Mapping:** Myocardial T1 and T2 values were measured, and abnormal regions were identified based on deviations from normal reference ranges.

Outcomes Measured

- Prevalence of myocardial perfusion defects.
- Quantification of myocardial scar burden.
- Correlation of CMR findings with clinical parameters and outcomes, including angina symptoms, history of myocardial infarction, and revascularization procedures.

Statistical Analysis

Data were analyzed using statistical software SPSS, version 25.0. Continuous variables were expressed as mean ± standard deviation, and categorical variables as frequencies or percentages. The primary outcomes were the presence and extent of myocardial perfusion defects and scar tissue. Comparative analyses were performed using t-tests or Mann-Whitney U tests for continuous variables and chi-square tests for categorical variables. Correlation analyses were conducted to evaluate the relationship between CMR findings and clinical outcomes.

A p-value of <0.05 was considered statistically significant.

Results

Table 1: Demographic and Clinical Characteristics of Study Participants by Myocardial Perfusion Defects

Category	Mean ± SD Age (Years)	Mean ± SD BMI (kg/m^2)	Mean ± SD LVEF (%)	Prevalence of Perfusion Defects (%)
Total Participants	65±8	28.5±4.5	55 ± 10	30
Participants with Perfusion Defects	67±9	29.3±4.7	48± 8	100
Participants without Perfusion Defects	63±7	27.8±4.3	60± 7	0

Table 1 presents the demographic and clinical characteristics of the 75 study participants, categorized by the presence or absence of myocardial perfusion defects. The overall mean age was 65 years, with a mean BMI of 28.5 kg/m^2 and a mean Left Ventricular Ejection Fraction (LVEF) of 55%. The prevalence of myocardial perfusion defects was 30%. Participants with perfusion defects had a slightly higher mean age (67 years) and BMI (29.3 kg/m^2), and a lower mean LVEF (48%), compared to those without perfusion defects, who had a mean age of 63 years, a mean BMI of 27.8 kg/m^2, and a higher mean LVEF of 60%. This data highlights the demographic and clinical differences between the two groups, suggesting potential risk factors associated with myocardial perfusion defects.

Table 2: Demographic and Clinical Characteristics of Study Participants by Myocardial Scar Burden

Category	Mean Age (Years)	SD of Age	Mean BMI (kg/m^2)	SD of BMI	Mean LVEF (%)	SD of LVEF	Mean Scar Burden (%)	SD of Scar Burden
Total Participants	65	8	28.5	4.5	55	10	15	5
Participants with Scar Tissue	68	9	29.1	4.8	50	9	25	7
Participants without Scar Tissue	63	7	27.9	4.4	60	7	0	0

Table 2 presents the demographic and clinical characteristics of the 75 study participants, categorized by the presence or absence of myocardial scar tissue as assessed by Cardiovascular Magnetic Resonance (CMR). The overall population had a mean age of 65 years, a mean BMI of 28.5 kg/m², and a mean Left Ventricular Ejection Fraction (LVEF) of 55%. Participants with detectable scar tissue were generally older (mean age 68 years), had a higher BMI (mean 29.1 kg/m²), and exhibited lower cardiac function (mean LVEF 50%) with a significantly higher mean scar burden of 25%. In contrast, participants without scar tissue were younger (mean age 63 years), had a lower BMI (mean 27.9 kg/m²), and better cardiac function (mean LVEF 60%) with no detectable scar burden. These findings suggest a link between older age, reduced LVEF, and increased myocardial scar burden, highlighting the impact of scarring on cardiac function.

Table 3: Correlation of CMR Findings with Clinical Parameters and Outcomes

Category	Mean ± SD Age (Years)	Mean ± SD BMI (kg/m²)	Mean ± SD LVEF (%)	Mean ± SD Scar Burden(%)
Total Participants	65±8	28.5±4.5	55±10	15±5
Participants with Angina Symptoms	68±9	29±4.6	48±9	20±6
Participants with History of Myocardial Infarction	70±8	29.2±4.7	45±8	30±7
Participants who Underwent Revascularization	69±7	28.9±4.5	50±9	25±6

Table 3 summarizes the correlation between Cardiovascular Magnetic Resonance (CMR) findings and clinical outcomes, including angina symptoms, history of myocardial infarction, and revascularization procedures. The overall cohort had a mean age of 65 years, BMI of 28.5 kg/m², LVEF of 55%, and a mean scar burden of 15%. Participants with angina symptoms were older (mean 68 years), had a higher BMI (mean 29.0 kg/m²), lower LVEF (mean 48%), and a scar burden of 20%. Those with a history of myocardial infarction had the highest mean age (70 years), the lowest LVEF (45%), and the highest scar burden (30%). Participants who underwent revascularization had a mean age of 69 years, LVEF of 50%, and a scar burden of 25%. These findings demonstrate that participants with more severe cardiac histories tend to have higher myocardial scar burdens and lower ejection fractions, underscoring the value of CMR in risk stratification and therapeutic planning.

Discussion

The current study provides a comprehensive evaluation of the role of Cardiovascular Magnetic Resonance (CMR) in assessing myocardial perfusion and scar tissue, emphasizing its correlation with clinical outcomes such as angina symptoms, history of myocardial infarction, and revascularization procedures. The findings of the present study explains the growing importance of CMR as a non-invasive imaging modality that offers detailed insights into myocardial health, thereby playing a crucial role in the management of cardiovascular diseases.

One of the key strengths of CMR lies in its ability to simultaneously assess both myocardial perfusion and scar tissue with high spatial resolution and tissue characterization capabilities. This dual capability is particularly valuable in differentiating between viable and non-viable myocardium, which is essential for guiding clinical decision-making, particularly in patients with coronary artery disease (CAD) and heart failure [8].

In the present study, we observed that participants with myocardial perfusion defects, as detected by stress perfusion CMR, were more likely to have significant myocardial scar tissue, as evidenced by late gadolinium enhancement (LGE) imaging. This finding is consistent with the pathophysiological understanding that ischemia often leads to myocardial necrosis and fibrosis, which can be accurately detected and quantified using CMR [9]. The observed correlation between scar burden and clinical outcomes, such as the presence of angina symptoms and history of myocardial infarction, further highlights the utility of CMR in risk stratification and prognosis.

Our findings are in line with previous studies that have established CMR as a superior tool for assessing myocardial perfusion and scar burden[10]. A study by Scatteia and Dellegrottaglie demonstrated that CMR not only detects ischemic regions with greater accuracy compared to traditional imaging modalities like SPECT but also provides prognostic information that can guide therapeutic strategies [11]. Similarly, Wu et al. (2008) reported that the extent of myocardial scar detected by CMR is a critical determinant of long-term outcomes in patients with non-ischemic cardiomyopathy, which parallels our findings in a cohort with a broader spectrum of cardiac pathologies [12].

Moreover, the strong association between myocardial scar burden and clinical history of myocardial infarction observed in our study echoes the results of Kwong*et al*. (2006), who found that the presence of unrecognized myocardial scar was a predictor of adverse events, even in patients without overt symptoms of coronary artery disease[13].This reinforces the notion that CMR can uncover subclinical disease and provide insights that are not apparent through other diagnostic methods.

The clinical implications of these findings are significant. The ability of CMR to accurately quantify

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myocardial scar burden and assess perfusion defects provides clinicians with essential information for making informed decisions about patient management [14]. Patients with CAD, CMR can help determine the extent of ischemic but viable myocardium, guiding revascularization strategies. In patients with heart failure, the quantification of scar burden can help identify those at higher risk of arrhythmias, potentially influencing decisions regarding the use of implantable cardio-verter-defibrillators [15].

Furthermore, the correlation between increased scar burden and lower left ventricular ejection fraction (LVEF) observed in this study suggests that CMR findings could be instrumental in predicting which patients might benefit from more aggressive therapeutic interventions, such as advanced heart failure therapies or heart transplantation [16]. The comprehensive nature of CMR, which includes both functional and structural assessment, makes it an invaluable tool in the personalized management of cardiovascular disease.

While the findings of this study are promising, several limitations need to be addressed. The relatively small sample size may limit the generalizability of the results. Additionally, the cross-sectional nature of the study means that causality between CMR findings and clinical outcomes cannot be definitively established. Longitudinal studies with larger populations are necessary to validate these findings and to explore the temporal relationship between myocardial scar development and clinical deterioration.

Moreover, while CMR is a powerful tool, its use is currently limited by factors such as cost, availability, and the need for specialized training. These limitations are particularly pertinent in resource-constrained settings, where access to advanced imaging modalities may be limited. Future research should focus on developing more cost-effective and accessible CMR technologies, as well as on training programs that can expand the use of CMR in diverse healthcare settings.

Conclusion

In conclusion, this study highlights the critical role of CMR in the assessment of myocardial perfusion and scar tissue, demonstrating significant correlations with clinical outcomes such as angina symptoms, history of myocardial infarction, and revascularization procedures. The findings align with previous research, confirming the prognostic value of CMR in cardiovascular disease management. Despite challenges in accessibility and standardization, CMR remains a cornerstone of advanced cardiac imaging, offering unparalleled insights that can guide personalized treatment strategies. Continued research and technological advancements are necessary to expand the clinical utility of CMR and to make this powerful imaging modality available to a broader range of patients worldwide.

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