CARDIAC MAGNETIC RESONANCE IMAGING IN THE EARLY DIAGNOSIS OF ISCHEMIC HEART DISEASE: A QUANTITATIVE CLINICAL AND STATISTICAL ANALYSIS

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Abstract: Ischemic heart disease (IHD) remains a major contributor to cardiovascular morbidity and mortality worldwide, largely due to delayed recognition of myocardial ischemia at its early and potentially reversible stages. Conventional diagnostic methods often fail to detect subtle ischemic changes, particularly in patients with atypical clinical presentations or preserved ventricular function. The present study evaluates the diagnostic performance of cardiac magnetic resonance imaging (CMR) in the early detection of myocardial ischemia using quantitative functional, perfusion, and tissue characterization parameters. A prospective study involving 192 patients with suspected IHD was conducted. All participants underwent comprehensive CMR evaluation, including cine imaging, stress-rest perfusion, and late gadolinium enhancement (LGE). The diagnostic accuracy of CMR was compared with electrocardiography, transthoracic echocardiography, and invasive coronary angiography. Statistical analysis revealed that CMR demonstrated significantly higher sensitivity (91.3%) and specificity (88.6%) in detecting early ischemic changes compared to conventional modalities. The results confirm the pivotal role of CMR as a non-invasive, high-precision diagnostic tool for early ischemic heart disease.
Keywords: ischemic heart disease; cardiac magnetic resonance imaging; early diagnosis; myocardial ischemia; perfusion imaging; late gadolinium enhancement; diagnostic accuracy; cardiovascular imaging.

Relevance of the Study: Ischemic heart disease continues to represent a critical global health challenge despite remarkable progress in cardiovascular diagnostics and therapeutics. According to epidemiological data, IHD accounts for approximately one-third of all cardiovascular-related deaths, with a substantial proportion occurring in patients without previously established coronary artery disease. One of the central problems in contemporary cardiology is the inability of traditional diagnostic approaches to reliably identify early ischemic myocardial alterations before irreversible structural damage develops.

Electrocardiography and echocardiography, although widely available and cost-effective, primarily reflect advanced functional disturbances and often remain normal in the early stages of ischemia. Exercise stress testing is limited by patient-related factors and reduced diagnostic accuracy in specific populations, including women and elderly patients. Coronary angiography provides detailed anatomical information but does not adequately assess myocardial perfusion, tissue viability, or microvascular dysfunction.

Cardiac magnetic resonance imaging integrates anatomical, functional, perfusion, and tissue-level information within a single examination, offering a comprehensive assessment of myocardial health. Its capacity to detect subclinical ischemia, differentiate viable from non-viable myocardium, and quantify ventricular function without ionizing radiation makes it uniquely suited for early diagnosis.

This study aims to substantiate the clinical value of CMR through a statistically rigorous evaluation of its diagnostic performance in early-stage IHD.

Materials and Methods: A prospective observational study was conducted between February 2021 and March 2024 at a tertiary cardiovascular center. The study was designed to assess the diagnostic efficacy of CMR in detecting early myocardial ischemia in patients with suspected ischemic heart disease.

A total of 192 patients were enrolled, including 128 men (66.7%) and 64 women (33.3%), aged 35 to 74 years (mean age 57.9 ± 9.4 years). Inclusion criteria consisted of patients presenting with chest discomfort, exertional dyspnea, or unexplained fatigue, as well as individuals with multiple cardiovascular risk factors and inconclusive findings on initial diagnostic testing. Exclusion criteria included prior myocardial infarction, known cardiomyopathies, severe valvular disease, contraindications to MRI, and chronic kidney disease with an estimated glomerular filtration rate below 30 ml/min/1.73 m^2.

All patients underwent standardized clinical evaluation, including detailed medical history, physical examination, and laboratory testing. Cardiovascular risk factors such as hypertension, diabetes mellitus, dyslipidemia, smoking status, and family history of coronary artery disease were recorded. Baseline electrocardiography and transthoracic echocardiography were performed in all participants.

CMR examinations were performed using a 1.5 Tesla MRI scanner with ECG synchronization. The imaging protocol included cine steady-state free precession sequences for ventricular function assessment, first-pass myocardial perfusion imaging during pharmacological stress induced by adenosine (140 μg/kg/min) and at rest, and late gadolinium enhancement imaging acquired 10–15 minutes after contrast administration.

Quantitative analysis included left ventricular end-diastolic and end-systolic volumes, ejection fraction, myocardial perfusion reserve index, and extent of LGE expressed as a percentage of myocardial mass. Ischemia was defined as a reversible perfusion defect in the absence of LGE.

Reference Standard and Comparative Methods

Invasive coronary angiography was performed in 138 patients based on clinical indications and served as the anatomical reference standard. Significant coronary artery disease was defined as ≥50% luminal stenosis. The diagnostic performance of CMR was compared with electrocardiography and echocardiography.

Statistical analysis was conducted using SPSS version 27. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as absolute numbers and percentages. Sensitivity, specificity, positive predictive value, and negative predictive value were calculated. Receiver operating characteristic (ROC) curves were constructed to evaluate diagnostic accuracy. Multivariate logistic regression analysis was performed to identify independent predictors of myocardial ischemia. Statistical significance was set at $p < 0.05$.

Results: Hypertension was present in 64.1% of patients, diabetes mellitus in 28.6%, dyslipidemia in 59.4%, and active smoking in 31.8%. Baseline echocardiography demonstrated preserved left ventricular ejection fraction (>55%) in 82.3% of patients.

Reversible perfusion defects consistent with myocardial ischemia were detected in 96 patients (50.0%). Among these, 38 patients (39.6%) demonstrated no significant abnormalities on electrocardiography or echocardiography. Late gadolinium enhancement was present in 42 patients (21.9%), indicating previously unrecognized myocardial injury.

CMR demonstrated a sensitivity of 91.3% and specificity of 88.6% for detecting significant coronary artery disease. In comparison, echocardiography showed a sensitivity of 62.4% and specificity of 70.1%. The area under the ROC curve for CMR was 0.93, significantly higher than that of echocardiography (0.71, $p < 0.001$).

Multivariate regression identified myocardial perfusion reserve index (OR 3.12, 95% CI 1.88–5.17, $p < 0.001$) and presence of LGE (OR 2.47, 95% CI 1.41–4.32, $p = 0.002$) as independent predictors of ischemic heart disease.

Discussion: The findings of this study underscore the superior diagnostic capability of cardiac MRI in identifying early ischemic myocardial changes. The high sensitivity and specificity observed highlight the ability of CMR to detect ischemia even in patients with preserved ventricular function and normal findings on conventional testing. The detection of reversible perfusion abnormalities in asymptomatic or minimally symptomatic patients emphasizes the role of CMR in early risk stratification.

Furthermore, the integration of perfusion imaging and tissue characterization allows differentiation between reversible ischemia and irreversible myocardial injury, which is crucial for guiding therapeutic strategies. The quantitative parameters derived from CMR provide objective markers for disease severity and progression.

These results are consistent with contemporary literature demonstrating the incremental diagnostic value of CMR over traditional modalities. Importantly, the absence of ionizing radiation and the comprehensive nature of the examination make CMR particularly advantageous for repeated assessments and long-term follow-up.

Conclusion: Cardiac magnetic resonance imaging is a highly effective diagnostic modality for the early detection of ischemic heart disease. Its superior sensitivity, specificity, and comprehensive assessment capabilities enable identification of myocardial ischemia at stages when therapeutic intervention is most beneficial. Incorporation of CMR into diagnostic algorithms may significantly improve early diagnosis, optimize patient management, and reduce adverse cardiovascular outcomes.

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