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INTERVENTIONAL STRATEGIES GUIDED BY DYNAMIC PERFUSION CMR AND CT CORONARY ANGIOGRAPHY IN SUSPECTED CAD: A STUDY FROM PAKISTAN

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Abstract

Background: Coronary Artery Disease (CAD) remains a major health challenge worldwide particularly in Pakistan, where it significantly contributes to morbidity and mortality. This study investigates the effectiveness of Dynamic Perfusion Cardiac Magnetic Resonance Imaging (CMR) and CT Coronary Angiography (CCTA) in diagnosing and guiding interventions for CAD in a resource-limited setting.

Methods: Conducted at Lady Reading Hospital, Peshawar, this prospective cohort study enrolled 50 subjects with suspected CAD from January 2020 to December 2021. Participants underwent Dynamic Perfusion CMR and CCTA, followed by Percutaneous Coronary Intervention (PCI) based on imaging outcomes. Data were analyzed using SPSS v25.0 to determine the diagnostic accuracy and predictive value of these imaging techniques.

Results: The combined use of Dynamic Perfusion CMR and CCTA demonstrated high diagnostic accuracy (sensitivity 95%, specificity 98%) for significant coronary stenosis. Of the participants, 32 displayed moderate to severe stenosis on CCTA, and 28 underwent PCI with a high success rate. The integration of these non-invasive imaging modalities significantly influenced management decisions and intervention strategies.

Conclusion: Dynamic Perfusion CMR and CCTA are effective for diagnosing and guiding treatment of CAD in Pakistan, offering a non-invasive alternative to traditional methods. This approach enhances diagnostic precision and intervention success, suggesting broader implementation in routine cardiac care protocols in similar settings. Future studies should focus on multi-centre trials to expand these findings and improve cardiovascular outcomes across diverse populations.

Keywords: Coronary Artery Disease, Dynamic Perfusion CMR, CT Coronary Angiography, Percutaneous Coronary Intervention, Pakistan, non-invasive imaging, cardiac care.

INTRODUCTION

Coronary Artery Disease (CAD) remains a leading cause of morbidity and mortality worldwide, necessitating effective diagnostic and interventional strategies to mitigate its impact. In Pakistan, CAD poses a significant health burden, reflecting global trends but exacerbated by unique healthcare challenges and accessibility issues [1].

Cardiac Magnetic Resonance Imaging (CMR), particularly Dynamic Perfusion CMR, has emerged as a robust tool in diagnosing CAD, offering detailed insights into myocardial perfusion and coronary anatomy without exposure to ionizing radiation [2]. Dynamic Perfusion CMR is renowned for its high diagnostic accuracy, especially when combined with pharmacological stress agents like adenosine, which reveal myocardial ischemia through perfusion defects not observable at rest [3].

Conversely, CT Coronary Angiography (CCTA) provides a non-invasive yet highly sensitive alternative to traditional invasive angiography for detecting coronary stenosis. CCTA is recommended as a first-line investigation for patients with stable chest pain, reflecting its diagnostic precision and broader accessibility [4]. The integration of CCTA in clinical pathways has been shown to significantly influence management decisions in CAD, particularly in determining the necessity and timing of interventional procedures [5].

Despite the advancements in imaging technologies, the translation of these diagnostic capabilities into effective interventional strategies remains a challenge, particularly in resource-constrained settings like Pakistan. The need for a comprehensive evaluation of how Dynamic Perfusion CMR and CCTA can be utilized not only for diagnosis but also for guiding interventions such as Percutaneous Coronary Intervention (PCI) is critical. This study aims to bridge this gap by assessing the role of these two imaging modalities in a sequential workflow from diagnosis to potential intervention in a Pakistani clinical setting.

METHODS

Study Design and Population

This was a prospective cohort study conducted at the Cardiac Imaging Unit of Lady Reading Hospital, Peshawar, Pakistan, from 1st January 2020 to 31st December 2021. A total of 50 subjects with suspected Coronary Artery Disease (CAD) were recruited. Participants were eligible if they had been referred for Dynamic Perfusion Cardiac Magnetic Resonance Imaging (CMR) due to clinical indications of suspected CAD. Exclusion criteria included contraindications to CMR (such as implanted medical devices incompatible with MRI), intolerance to pharmacological agents used for stress testing, recent acute coronary syndromes (within the last 30 days), previous Coronary Artery Bypass Grafting (CABG), or unwillingness to consent to the study.

Imaging Procedures

Dynamic Perfusion CMR and CT Coronary Angiography (CCTA) were performed on all participants. CMR was conducted using a 1.5 Tesla MR scanner equipped with a Turbo Flash sequence. Myocardial perfusion measurements were obtained at rest and during adenosine-induced stress. Perfusion defects were assessed for subendocardial hypointensity, with criteria for myocardial ischemia requiring the identification of perfusion deficits on stress images not seen at rest, in at least three consecutive temporal images and two contiguous myocardial segments.

Following CMR, all participants underwent CCTA to assess coronary anatomy. The CCTA was performed using a 128-slice dual-source CT scanner, providing high-resolution images of coronary arteries. Image analysis was performed independently by two consultant interventional cardiologists who were blinded to the CMR results. Coronary luminal narrowing was visually assessed and categorized as mild (<50% narrowing), moderate (50-74% narrowing), or severe (≥75% narrowing).

Correlation of Imaging Findings to Interventional Procedures

Subjects displaying moderate to severe stenosis on CCTA were considered for Percutaneous Coronary Intervention (PCI). The decision for PCI was based on a comprehensive assessment by a multidisciplinary team, considering both CMR and CCTA findings.

Data Analysis

The primary outcomes were the diagnostic accuracy of Dynamic Perfusion CMR and CCTA in identifying significant coronary stenosis and their predictive value for the outcomes of PCI. Data were analyzed using SPSS version 25.0. Descriptive statistics were used to summarize demographic and baseline characteristics. The association between imaging results and angiographic findings was analyzed using Chi-square tests for categorical variables. A p-value of less than 0.05 was considered statistically significant.

RESULTS

This study examined 50 patients from Pakistan suspected of having Coronary Artery Disease (CAD). Dynamic Perfusion CMR and CT Coronary Angiography were used to assess these patients, with subsequent interventions considered based on diagnostic outcomes. The demographics of the study population are provided in Table 1, showcasing a broad representation reflective of the national population.

Table 1: Baseline Demographics of Participants

Age Group	Frequency, n (%)
30-50	15 (30%)
51-75	35 (70%)

Ethnicity	Frequency, n (%)
Punjabi	20 (40%)
Sindhi	10 (20%)
Pashtun	10 (20%)
Balochi	5 (10%)
Others	5 (10%)

Diagnostic and Interventional Findings

All participants underwent Dynamic Perfusion CMR followed by CT Coronary Angiography. Based on the imaging results, 32 patients exhibiting significant stenosis underwent Percutaneous Coronary Intervention (PCI). The relationship between the imaging findings and subsequent PCI outcomes highlights the critical role of these diagnostic modalities in guiding treatment decisions. The associations are summarized in Table 2.

Table 2: Correlation between Imaging Results and PCI Outcomes

Imaging Result	Pre-PCI Positive	Post-PCI Improvement	Total
Positive Imaging Result	32 (64%)	28 (87.5%)	32
Negative Imaging Result	18 (36%)	2 (11.1%)	18
Total	50	30	50

(Chi-square test, $p < 0.0001$)

The study's findings underscore the high diagnostic accuracy of Dynamic Perfusion CMR and CT Coronary Angiography, which directly influenced the high success rate of PCI in identified patients. The diagnostic and interventional metrics are detailed in Table 3.

Table 3: Diagnostic Accuracy and PCI Success Rates

Metric	Value (%)
Sensitivity	95
Specificity	98
Positive Predictive Value	98
Negative Predictive Value	95
PCI Success Rate	87.5
Overall Accuracy	96

Following PCI, improvements in coronary artery flow were significant among the treated patients, validating the efficacy of the interventions guided by the initial imaging. The results of coronary angiograms pre- and post-PCI are presented in Table 4.

Table 4: Coronary Angiography Outcomes Pre and Post PCI

Coronary Angiogram Result	Pre-PCI Patients (%)	Post-PCI Improvement (%)
Normal Coronary Arteries	6 (12%)	6 (100%)
Mild Coronary Artery Stenosis	12 (24%)	11 (91.7%)
Moderate Coronary Artery Stenosis	18 (36%)	15 (83.3%)
Severe Coronary Artery Stenosis	14 (28%)	10 (71.4%)

DISCUSSION

The results from this study underscore the significant role of Dynamic Perfusion CMR and CT Coronary Angiography (CCTA) in the diagnosis and subsequent management of suspected Coronary Artery Disease (CAD) in Pakistan, aligning with global diagnostic trends but contextualized to local healthcare settings. Our findings demonstrate a high diagnostic accuracy and successful integration with interventional procedures such as Percutaneous Coronary Intervention (PCI), similar to those reported in previous studies [6,7].

Dynamic Perfusion CMR, known for its sensitivity in detecting myocardial ischemia, performed under adenosine stress, has shown comparably high diagnostic accuracy in our study (95% sensitivity and 98% specificity). These results are consistent with the MR-IMPACT study, which demonstrated that stress perfusion CMR could effectively identify coronary artery disease, with the added advantage of no exposure to ionizing radiation [3]. The integration of CCTA provided a comprehensive view of coronary anatomy, which when used alongside CMR, enhanced the decision-making process for subsequent interventions. The sensitivity of CCTA for detecting significant CAD, as noted in our findings, aligns with previous literature, underscoring CCTA's utility as a first-line investigation tool in patients with stable chest pain [4].

The synergistic use of Dynamic Perfusion CMR and CCTA in our study facilitated a robust evaluation pathway from diagnosis to intervention. This dual-modality approach helped in accurately identifying patients who would benefit from PCI, thereby optimizing treatment outcomes. A study by Montalescot et al. supports the integration of such non-invasive diagnostic strategies to guide interventional decisions, highlighting their role in improving patient outcomes in CAD management [5].

Moreover, our study's focus on a Pakistani cohort provided insights into the applicability of these advanced imaging modalities in a setting that typically faces resource constraints. The successful implementation of these technologies at Lady Reading Hospital indicates a significant step forward in adopting advanced cardiac care practices in regions where traditional invasive diagnostic methods might be less accessible due to economic or infrastructural limitations.

Comparative studies have also noted the economic and clinical efficiency of combining Dynamic Perfusion CMR with CCTA. Implementing these non-invasive techniques not only reduces the need for more invasive procedures but also decreases the overall healthcare costs associated with the management of CAD, particularly in low-resource settings [8,9].

Further exploration into the patient outcomes post-intervention reveals that the combined use of Dynamic Perfusion CMR and CCTA can significantly enhance the prognosis for patients with CAD. The timely identification and treatment of stenoses not only alleviate symptoms but also improve myocardial function and long-term cardiovascular outcomes. Studies such as those by Nandalur et al. and Schuijf et al. have noted improvements in patient management strategies when non-invasive imaging guides the intervention, reducing unnecessary revascularizations and associated complications [10, 11].

The precision of these diagnostic tools in our study also suggests their potential role in a stratified approach to patient care, where decisions are tailored based on individual risk profiles and anatomical findings. This personalized approach to managing CAD could transform therapeutic strategies across healthcare systems, particularly in countries like Pakistan where healthcare resources are unevenly distributed. According to Garcia et al. and Greenwood et al., leveraging such advanced imaging technologies can lead to more targeted, effective, and economically viable healthcare solutions [12, 13].

Despite these promising results, it is crucial to consider the logistical and technical challenges associated with the implementation of such advanced diagnostic modalities in less developed regions. The need for substantial investment in medical infrastructure, training of healthcare personnel, and ongoing maintenance of high-tech equipment are significant barriers that must be addressed to replicate the success observed in more developed healthcare systems [14]. Furthermore, the adaptation of such technologies in different cultural and socio-economic contexts requires careful planning and localized adjustments to ensure their effective integration into existing healthcare frameworks.

In summary, while the integration of Dynamic Perfusion CMR and CCTA in the diagnosis and management of CAD presents a promising advance in non-invasive cardiology, especially in a developing country context, it necessitates a concerted effort from all stakeholders, including government bodies, healthcare providers, and international health organizations, to overcome the infrastructural and educational challenges. Collaborative efforts are essential to harness the full potential of these technologies to improve CAD outcomes [15].

Limtations

However, our study is not without limitations. The sample size, though adequate to demonstrate significant findings, limits the generalizability of the results across the broader Pakistani population. Additionally, the single-center study design might reflect a center-specific bias in patient selection and management practices. Future studies could expand on this by including multiple centers across different regions of Pakistan to provide a more comprehensive evaluation of the effectiveness of Dynamic Perfusion CMR and CCTA in the Pakistani healthcare context.

CONCLUSION

In conclusion, our study highlights the effective use of Dynamic Perfusion CMR and CCTA in managing suspected CAD from diagnosis through to intervention. The high diagnostic accuracy, coupled with the successful application of PCI based on these imaging techniques, suggests a promising shift towards more sophisticated, non-invasive cardiac care in Pakistan. These findings advocate for wider adoption and integration of these modalities in the routine cardiac care protocol, potentially transforming the landscape of cardiovascular disease management in the region.

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