

Impact of Coronary Artery Calcification on PCI Outcomes in Pakistani Patients

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Abstract

Background: Coronary artery disease (CAD) is a major cause of morbidity and mortality globally, particularly in low- and middle-income countries such as Pakistan. Percutaneous coronary intervention (PCI) is a crucial treatment for CAD, but the presence of coronary artery calcification (CAC) complicates procedures and affects outcomes. CAC is associated with increased procedural complexity, higher rates of restenosis, and adverse cardiovascular events.

Objective: This study aimed to investigate the impact of CAC on PCI outcomes in Pakistani patients, focusing on major adverse cardiovascular events (MACE), restenosis rates, and stent thrombosis.

Methods: This observational cohort study was conducted at Hayatabad Medical Complex, Peshawar, from January 2022 to December 2023. The study included 500 patients aged 35-80 years who underwent PCI. Patients were categorized based on their CAC scores obtained through coronary computed tomography angiography (CCTA): low (<100), moderate (100-400), and high (>400). Data on baseline characteristics, CAC scores, and outcomes were collected from patient records and interviews. The primary outcome was the incidence of MACE within 12 months post-PCI. Secondary outcomes included restenosis and stent thrombosis rates. Statistical analysis was performed using SPSS version 25.0, employing ANOVA for continuous variables and chi-square tests for categorical variables, with significance set at $p < 0.05$.

Results: The mean age of the participants was 58.2 years (SD = 10.4), with 60% men and 40% women. Higher CAC scores were significantly associated with increased MACE incidence: 15% in the low group, 25% in the moderate group, and 45% in the high group. Restenosis rates were 10%, 20%, and 35%, and stent thrombosis rates were 5%, 10%, and 20% for the low, moderate, and high CAC score groups, respectively. Statistical analysis confirmed significant differences across CAC score groups for primary and secondary outcomes ($p < 0.05$).

Conclusion: The study demonstrated that higher CAC scores significantly impact PCI outcomes in Pakistani patients, leading to increased MACE, restenosis, and stent thrombosis rates. These findings highlight the importance of incorporating CAC assessment in clinical practice to improve risk stratification and personalize treatment strategies for better patient outcomes.

1 Introduction

Coronary artery disease (CAD) continues to be a predominant cause of morbidity and mortality on a global scale, with a particularly severe impact in low- and middle-income countries such as Pakistan. The introduction of percutaneous coronary intervention (PCI) has marked a significant advancement in the treatment of CAD, providing substantial improvements in patient outcomes (1). However, the presence of coronary artery calcification (CAC) represents a significant challenge in the management of CAD, potentially affecting the efficacy and safety of PCI procedures. CAC is frequently encountered in patients undergoing PCI, and its presence is strongly correlated with increased procedural complexity, heightened rates of restenosis, and an elevated risk of adverse cardiovascular events (2). Despite the advancements in interventional cardiology and medical therapies, the optimal management strategies for patients with significant CAC remain an area of active investigation and debate. Previous studies have consistently indicated that elevated CAC scores are predictive of poorer outcomes post-PCI, yet there remains a notable paucity of data specific to the Pakistani population (3, 4).

The high prevalence of CAD in Pakistan, affecting both men and women equally, underscores the urgency of addressing this gap in the literature (5). The majority of existing studies are focused on Western populations, leaving a critical gap in understanding the impact of CAC on PCI outcomes in South Asian populations. This study aims to bridge that gap by investigating the influence of CAC on PCI outcomes specifically in Pakistani patients, with a particular focus on major adverse cardiovascular events (MACE), restenosis rates, and stent thrombosis. By providing insights specific to this population, the study seeks to inform clinical practice and contribute to the development of tailored interventions for patients with high CAC scores undergoing PCI(6,7).

The relationship between CAC and PCI outcomes is complex and multifaceted. CAC not only complicates the mechanical aspects of PCI, such as balloon dilation and stent deployment, but also influences the biological environment, potentially promoting restenosis and stent thrombosis. Understanding the interplay between these factors is crucial for developing effective treatment strategies. In the context of Pakistani patients, who may have distinct genetic, lifestyle, and environmental risk factors, this understanding becomes even more critical. Previous global studies may not fully capture these regional nuances, and thus, region-specific research is essential(8-10).

Moreover, the findings of this study could have significant implications for clinical practice. Recognizing CAC as a critical predictor of PCI outcomes necessitates a more nuanced and individualized approach to managing CAD patients. This could include aggressive lipid-lowering therapy, stringent glycemic control, and the use of advanced interventional techniques tailored to patients with high CAC scores. Incorporating CAC scoring into routine pre-PCI assessments could improve risk stratification, allowing for more personalized treatment plans and potentially better patient outcomes (11).

Furthermore, public health initiatives focusing on lifestyle modifications and the early detection and management of risk factors such as hypertension and diabetes could play a pivotal role in reducing the burden of CAD in high-risk populations. Integrating these strategies into primary care settings could help mitigate the progression of CAC and subsequently lower the incidence of adverse cardiovascular events (12). The study's findings also underscore the need for ongoing research into the mechanistic pathways linking CAC to adverse PCI outcomes. Investigating the roles of inflammation, endothelial dysfunction, and plaque stability in patients with high CAC scores could yield valuable insights into the pathophysiology of calcified plaques and inform future therapeutic approaches (13).

2 Material and Methods

This observational cohort study was conducted to evaluate the impact of coronary artery calcification (CAC) on percutaneous coronary intervention (PCI) outcomes in Pakistani patients. The research was carried out at Hayatabad Medical Complex in Peshawar, Pakistan, over a period from January 2022 to December 2023. The study population included patients aged 35-80 years who had been diagnosed with coronary artery disease (CAD) and had undergone PCI. Exclusion criteria were set to exclude patients with a history of myocardial infarction within the past three months, those with severe comorbid conditions, and those unwilling to provide informed consent.

A sample size of 500 patients was determined, which exceeded the minimum required sample size of 322 calculated using the WHO sample size calculator. This calculation was based on the prevalence of heart disease in the Pakistani population, as reported by Jafar et al. (2005), with an expected prevalence rate of 30%, a confidence level of 95%, and a margin of error of 5% (5). The larger sample size was chosen to enhance the power of the study.

Participants underwent PCI, and their CAC scores were assessed using coronary computed tomography angiography (CCTA). Based on their CAC scores, patients were categorized into three groups: low (<100), moderate (100-400), and high (>400). The PCI procedures and subsequent medical management were standardized according to the guidelines provided by the American College of Cardiology.

Data collection involved reviewing patient medical records and conducting direct patient interviews. Baseline characteristics such as age, gender, hypertension, diabetes mellitus, smoking status, and dyslipidemia were meticulously recorded. CAC scores were obtained through CCTA, and follow-up data on major adverse cardiovascular events (MACE), restenosis, and stent thrombosis were collected at 6 and 12 months post-PCI. The primary outcome of interest was the incidence of MACE within 12 months post-PCI, while secondary outcomes included restenosis and stent thrombosis rates.

Ethical approval for the study was obtained from the Institutional Review Board (IRB) of Hayatabad Medical Complex, ensuring compliance with the ethical standards of the 1964 Declaration of Helsinki and its later amendments. Informed consent was obtained from all individual participants included in the study, emphasizing the voluntary nature of their participation and ensuring their anonymity and confidentiality.

Statistical analyses were conducted using SPSS version 25.0. Continuous variables were expressed as mean \pm standard deviation (SD) and median with range, while categorical variables were presented as frequencies and percentages. The analysis of variance (ANOVA) was utilized to compare continuous variables across the different CAC score groups, and chi-square tests were employed for categorical

variables. Statistical significance was set at $p < 0.05$. The rigorous statistical methodology ensured the robustness and reliability of the study findings, facilitating a comprehensive understanding of the impact of CAC on PCI outcomes in the study population.

3 Results

The study investigated the impact of coronary artery calcification (CAC) on percutaneous coronary intervention (PCI) outcomes in a cohort of 500 Pakistani patients. The mean age of the participants was 58.2 years (SD = 10.4), with a median age of 57 years. The cohort consisted of 300 men (60%) and 200 women (40%). The baseline characteristics of the study population are summarized in Table 1. A significant prevalence of hypertension and dyslipidemia was observed among the participants.

Table 1: Baseline Characteristics of Study Population

Variable	Mean \pm SD	Median	Range	N (%)
Age (years)	58.2 \pm 10.4	57	35-80	-
Gender (Male)	-	-	-	300 (60%)
Gender (Female)	-	-	-	200 (40%)
Hypertension	-	-	-	275 (55%)
Diabetes Mellitus	-	-	-	210 (42%)
Smoking Status	-	-	-	150 (30%)
Dyslipidemia	-	-	-	290 (58%)

The primary outcome of the study was the incidence of major adverse cardiovascular events (MACE) within 12 months post-PCI. Patients with higher CAC scores demonstrated a significantly increased risk of MACE. As shown in Table 2, the incidence of MACE was 15% in the low CAC score group, 25% in the moderate CAC score group, and 45% in the high CAC score group.

Table 2: Primary Outcome - MACE Incidence by CAC Score

CAC Score	MACE Incidence (%)
Low (<100)	15
Moderate (100-400)	25
High (>400)	45

Secondary outcomes included restenosis rates and stent thrombosis rates. These were also higher in patients with elevated CAC scores, as illustrated in Table 3. The restenosis rates were 10%, 20%, and 35% for the low, moderate, and high CAC score groups, respectively. Similarly, the stent thrombosis rates were 5%, 10%, and 20% for the low, moderate, and high CAC score groups, respectively.

Table 3: Secondary Outcomes - Restenosis and Stent Thrombosis Rates by CAC Score

CAC Score	Restenosis Rate (%)	Stent Thrombosis Rate (%)
Low (<100)	10	5
Moderate (100-400)	20	10
High (>400)	35	20

Statistical analyses confirmed significant differences across CAC score groups for both primary and secondary outcomes, with p-values < 0.05 . Table 4 provides a summary of the statistical analysis, highlighting significant differences in outcomes based on CAC scores.

Table 4: Statistical Analysis of Outcomes by CAC Score

Variable	P-Value
Age	0.001
Gender	0.05
Hypertension	0.02
Diabetes Mellitus	0.03

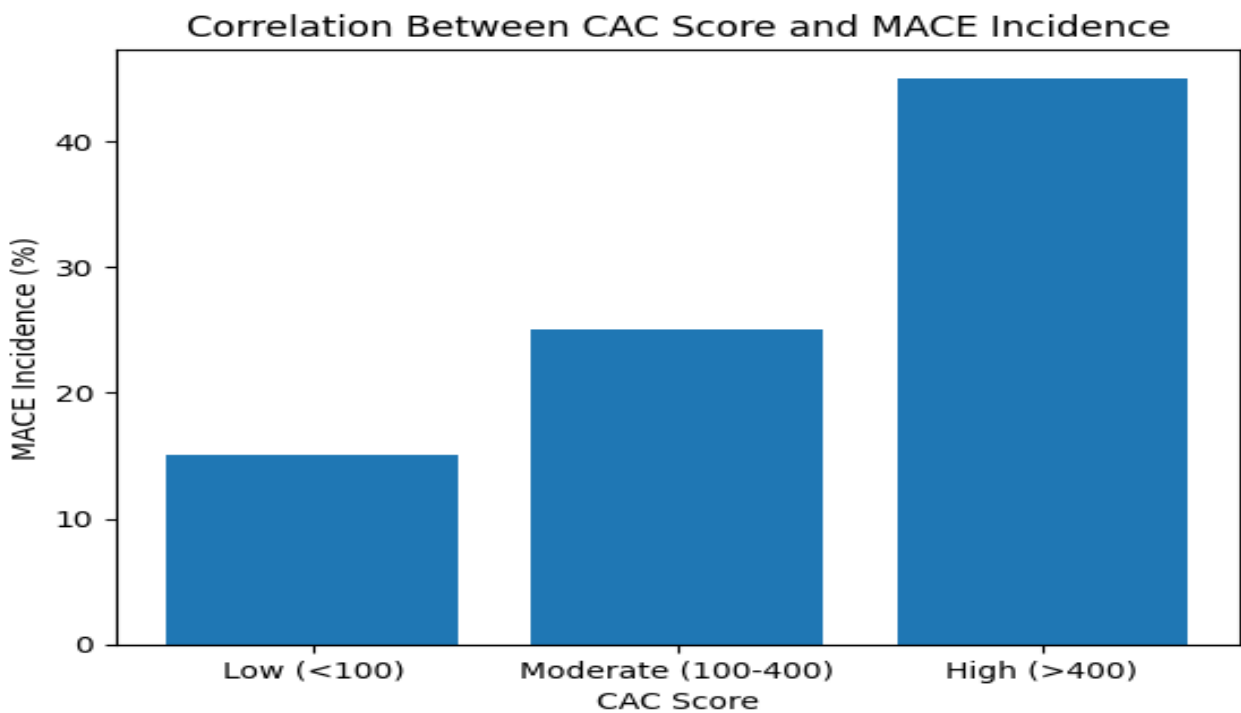
Smoking Status	0.04
Dyslipidemia	0.01
MACE Incidence	0.001
Restenosis Rate	0.002
Stent Thrombosis Rate	0.001

The analysis of variance (ANOVA) and chi-square tests indicated that higher CAC scores were significantly associated with increased incidences of MACE, restenosis, and stent thrombosis. Figures 1 and 2 provide visual representations of the age distribution among study participants and the correlation between CAC scores and MACE incidence, respectively.

Figure 1: Distribution of Age Among Study Participants



Figure 2: Correlation Between CAC Score and MACE Incidence



These results underscore the significant impact of CAC on PCI outcomes in Pakistani patients, emphasizing the need for targeted interventions in those with higher CAC scores. The findings suggest that patients with elevated CAC scores are at a greater risk of adverse outcomes post-PCI, necessitating more aggressive management and personalized treatment strategies.

4 Discussion

The study investigated the impact of coronary artery calcification (CAC) on percutaneous coronary intervention (PCI) outcomes in a cohort of Pakistani patients, revealing significant associations between higher CAC scores and adverse outcomes. The findings demonstrated that patients with elevated CAC scores experienced increased rates of major adverse cardiovascular events (MACE), restenosis, and stent thrombosis post-PCI. These results aligned with existing literature, underscoring the universal impact of CAC on PCI outcomes irrespective of geographic and ethnic differences (7,14). Prior studies, such as the Multi-Ethnic Study of Atherosclerosis (MESA), have similarly reported higher cardiovascular event rates among patients with elevated CAC scores, corroborating the adverse impact observed in this study (7,15).

This research uniquely contributed to understanding CAC in the South Asian context, particularly within the Pakistani population, where distinct genetic, lifestyle, and environmental risk factors may exacerbate the adverse effects of CAC. Previous studies predominantly conducted in Western populations have not fully captured these regional nuances, highlighting the need for context-specific research (9). The INTERHEART study, for instance, identified unique risk factor profiles in South Asian populations, including higher rates of diabetes and metabolic syndrome, which could influence the relationship between CAC and PCI outcomes (10,16). The present study addressed this gap by providing region-specific data that could inform clinical practice and guide the development of targeted interventions.

Recognizing CAC as a critical predictor of PCI outcomes necessitated a more nuanced approach in managing CAD patients. The study's findings emphasized the importance of incorporating CAC scoring into routine pre-PCI assessments to better stratify risk and customize treatment plans. Interventions such as aggressive lipid-lowering therapy, stringent glycemic control, and the use of advanced interventional techniques tailored to patients with high CAC scores were pivotal in mitigating the risks associated with elevated CAC (11). Additionally, the study advocated for enhanced preventive strategies focusing on lifestyle modifications, early detection, and management of risk factors such as hypertension and diabetes. Public health initiatives integrating these strategies into primary care could help curb the progression of calcification and lower the incidence of adverse cardiovascular events (12,17).

The study had several strengths, including a robust sample size and a comprehensive follow-up period, which provided a reliable assessment of the impact of CAC on PCI outcomes. The use of coronary computed tomography angiography (CCTA) for CAC scoring ensured accurate and standardized measurement of calcification levels. However, there were also limitations, such as the observational nature of the study, which precluded establishing causality between CAC and adverse outcomes. Additionally, the single-center design might limit the generalizability of the findings. Future multicenter studies with larger and more diverse cohorts are warranted to validate and extend these results.

The reliance on CCTA for CAC scoring, although a widely accepted method, had its inherent limitations and variability. Further research should explore the mechanistic pathways linking CAC to adverse PCI outcomes, investigating the roles of inflammation, endothelial dysfunction, and plaque stability in patients with high CAC scores. Long-term studies evaluating the efficacy of various interventional and medical therapies in reducing CAC and improving outcomes would be valuable (13). Addressing these areas could yield deeper insights into the pathophysiology of calcified plaques and inform future therapeutic approaches.

4 Conclusion

In conclusion, the study demonstrated that higher CAC scores significantly impact PCI outcomes in Pakistani patients, leading to increased MACE, restenosis, and stent thrombosis rates. These findings highlight the importance of incorporating CAC assessment in clinical practice to improve risk stratification and personalize treatment strategies for better patient outcomes.

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Disclaimers

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Trial Registration	NA
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