

Diagnostic Accuracy of Coronary Artery Calcium Scoring in Detecting Significant Coronary Artery Stenosis Compared with Invasive Coronary Angiography

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Abstract

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Background:

Coronary artery disease (CAD) remains a leading cause of mortality, emphasizing the importance of early non-invasive diagnostic strategies. This study evaluated the diagnostic accuracy of coronary artery calcium scoring (CACS) in detecting significant coronary stenosis, using invasive angiography as the reference standard.

Methods:

Sixty-three patients who underwent both CACS and quantitative coronary angiography were retrospectively analyzed. The mean total CACS was 684.1 ± 1030.8 , and significant stenosis ($\geq 70\%$) was most prevalent in the left anterior descending artery (92.1%).

Result:

Spearman's analysis revealed positive correlations between CACS and angiographic stenosis in the right coronary artery ($\rho = 0.338$, $p = 0.007$), left anterior descending artery ($\rho = 0.492$, $p = 0.001$), and left circumflex artery ($\rho = 0.314$, $p = 0.012$). Receiver operating characteristic (ROC) analysis demonstrated moderate-to-good diagnostic performance, with area under the curve (AUC) values of 0.699 for RCA, 0.769 for LAD, and 0.690 for LCX.

Conclusions:

These findings indicate that CACS can serve as a reliable, low-cost, and non-invasive modality for preliminary screening and risk stratification of CAD, particularly in identifying patients who may benefit from invasive coronary angiography.

Introduction

Coronary artery disease (CAD) remains a major cause of morbidity and mortality worldwide, and its incidence continues to rise annually. Early assessment of coronary atherosclerosis is essential to identify high-risk individuals with comorbidities such as hypertension,

diabetes, and dyslipidemia. Detecting subclinical disease may improve prevention and optimize patient selection for invasive testing (Ferencik et al., 2022; Kumar & Bhatia, 2022; Yoshida et al., 2024).

Rinehart et al. (2024) and Wysocki et al. (2024) highlighted that coronary artery

calcium scoring (CACS), obtained from non-contrast CT, reflects the overall burden of calcified atherosclerotic plaque. Higher CACS values are generally associated with obstructive CAD, yet several studies report variable diagnostic accuracy across populations (Rinehart et al., 2024; Wysocki et al., 2024; Yamaura et al., 2022).

Liaquat et al. (2022) demonstrated a strong positive correlation between CACS and the severity of angiographically confirmed stenosis, particularly among patients with higher calcium burden. Conversely, Chen et al. (2023) emphasized that a zero calcium score does not entirely exclude the presence of significant stenosis, especially in younger patients with predominantly non-calcified plaques. These contrasting results highlight the need to re-evaluate the diagnostic reliability of CACS against the anatomical standard of invasive angiography (C. Chen et al., 2024; Liaquat et al., 2022; Rinehart et al., 2024).

Invasive coronary angiography remains the gold standard for determining the degree of luminal narrowing. However, few studies have directly compared CACS with angiographically proven stenosis in Indonesian populations (Rinehart et al., 2024; Wysocki et al., 2024; Yamaura et al., 2022). This study aims to evaluate the diagnostic accuracy of CACS in detecting significant coronary artery stenosis and to determine the optimal calcium score threshold using invasive angiography as the gold line reference.

Material And Methods

Retrospective cross-sectional diagnostic accuracy study was conducted at the Radiology Departments of Siloam Hospitals Kebon Jeruk and Lippo Village between January 2024 and June 2025. The study population comprised 63 patients who underwent both coronary artery calcium scoring (CACS) and invasive coronary angiography within 180 days. Eligible patients had complete imaging data, including Agatston-based CACS and quantitative coronary angiography (QCA) results. Exclusion criteria included prior coronary revascularization, congenital or structural heart disease, systemic inflammatory or metabolic disorders

affecting vascular integrity, and poor image quality.

Calcium scoring utilized a non-contrast 128-slice dual-source CT scanner (Siemens Somatom Drive, 0.625 mm slice thickness) analyzed with SyngoVia software. Invasive coronary angiography was performed using the Artis Q Ceiling system and evaluated quantitatively with Syngo Artis VD 12A230615. All images underwent independent review by two radiologists with at least five years of cardiovascular imaging experience, and differences were resolved by consensus to ensure interpretative consistency.

Continuous variables such as age, CACS, and stenosis percentage were summarized as mean \pm standard deviation or median (interquartile range). Categorical data were presented as frequency and percentage. Significant stenosis was defined as luminal narrowing $\geq 70\%$. Statistical analyses included Spearman's correlation to assess the relationship between CACS and angiographic stenosis, and receiver operating characteristic (ROC) curve analysis to determine the area under the curve (AUC), sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). The optimal cut-off was identified using the Youden Index. Statistical significance was defined as $p < 0.05$. Ethical approval was obtained from the Faculty of Medicine, Universitas Pelita Harapan, with a waiver of informed consent due to the retrospective design.

Result

63 patients met eligibility requirements and were included in the final analysis. The mean age of participants was 56.3 ± 7.9 years (range 39–78 years). Males comprised 79.4% ($n = 50$) of the study population, and females 20.6% ($n = 13$). The mean total coronary artery calcium score (CACS) was 684.1 ± 1030.8 (range 0–6425). Mean segmental calcium scores were 224.9 ± 386.0 for the right coronary artery (RCA), 28.5 ± 71.6 for the left main (LM), 303.7 ± 402.9 for the left anterior descending (LAD), and 127.0 ± 359.1 for the left circumflex artery (LCX).

Table 1. Patient Characteristics (n = 63)

Characteristic	Mean ± SD (Range) / n (%)
Age (years)	56.3 ± 7.9 (39–78)
Sex	
Male	50 (79.4)
Female	13 (20.6)
Total CACS	684.1 ± 1030.8 (0–6425)
CACS RCA	224.9 ± 386.0 (0–1620)
CACS LM	28.5 ± 71.6 (0–299)
CACS LAD	303.7 ± 402.9 (0–2358)
CACS LCX	127.0 ± 359.1 (0–2660)
RCA stenosis (≥70%)	24 (38.1)
LM stenosis (≥70%)	0 (0.0)
LAD stenosis (≥70%)	58 (92.1)
LCX stenosis (≥70%)	21 (33.3)

The distribution of stenosis severity across coronary segments indicated that 24 patients (38.1%) had significant stenosis in the RCA, while 39 (61.9%) were non-significant. All patients (100%) had non-significant stenosis in the LM segment. Significant stenosis was found in 58 patients (92.1%) in the LAD and in 21 patients (33.3%) in the LCX.

Spearman's rank correlation demonstrated positive associations between CACS and angiographically confirmed stenosis severity in several segments. The CACS for the RCA correlated significantly with RCA stenosis ($\rho = 0.338$, $p = 0.007$), while the LAD segment showed a stronger correlation ($\rho = 0.492$, $p = 0.001$). A moderate positive correlation was also observed in the LCX (ρ

$= 0.314$, $p = 0.012$). Correlation analysis for the LM segment was not applicable since no significant stenosis was observed in this artery.

Table 2. Spearman's Correlation Between CACS and Stenosis Severity (n = 63)

Coronary Segment	Spearman's ρ	p-value
RCA	0.338	0.007
LM	–	–
LAD	0.492	0.001
LCX	0.314	0.012

Receiver Operating Characteristic (ROC) curve analysis evaluated the diagnostic performance of CACS for detecting significant stenosis (≥70%) based on quantitative coronary angiography. The area under the curve (AUC) for the RCA was 0.699 (95% CI: 0.563–0.835; $p = 0.008$), indicating moderate discriminative ability. The optimal cut-off value of 52 yielded a sensitivity of 79.2% and specificity of 61.5%, with a positive predictive value (PPV) of 55.9% and a negative predictive value (NPV) of 82.8%.

For the LAD, the AUC reached 0.769 (95% CI: 0.537–1.000; $p = 0.047$), reflecting good discriminative performance. A CACS threshold of 11.3 provided sensitivity 89.7% and specificity 60.0%, with PPV 92.0% and NPV 35.0%. The LCX segment showed an AUC of 0.690 (95% CI: 0.559–0.820; $p = 0.015$), with an optimal threshold of 9.8 yielding sensitivity 85.7%, specificity 52.4%, PPV 47.4%, and NPV 88.0%. The LM segment was excluded from ROC analysis because no significant stenosis was observed.

Table 3. ROC Analysis of CACS for Detection of Significant Coronary Stenosis (n = 63)

Segment	AUC (95% CI)	p-value	Cut-off	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
RCA	0.699 (0.563–0.835)	0.008	52.0	79.2	61.5	55.9	82.8
LM	–	–	–	–	–	–	–
LAD	0.769 (0.537–1.000)	0.047	11.3	89.7	60.0	92.0	35.0
LCX	0.690 (0.559–0.820)	0.015	9.8	85.7	52.4	–	–

CACS demonstrated statistically significant correlations with angiographically confirmed stenosis across the RCA, LAD, and LCX segments. Diagnostic accuracy analysis revealed moderate predictive performance for RCA and LCX and good accuracy for LAD. No evaluable data were available for LM due to the absence of significant stenosis.

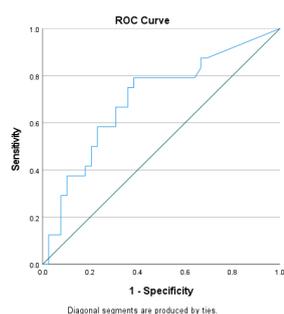


Figure 1. ROC curve for CACS – RCA stenosis

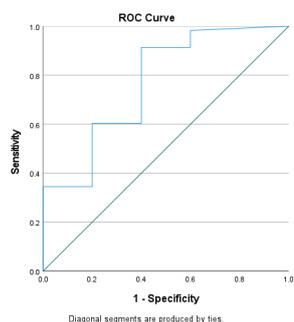


Figure 2. ROC curve for CACS – LAD stenosis

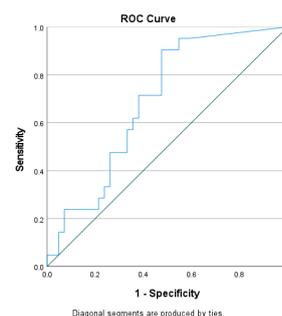


Figure 3. ROC curve for CACS – LCX stenosis

Discussion

This study demonstrated that the coronary artery calcium score (CACS) showed moderate-to-good diagnostic accuracy in identifying significant coronary artery stenosis, particularly in the right coronary artery (RCA) and left anterior descending (LAD) segments. Positive correlations were observed between CACS and angiographic stenosis for RCA ($\rho = 0.338$, $p = 0.007$), LAD ($\rho = 0.492$, $p = 0.001$), and LCX ($\rho = 0.314$, $p = 0.012$), whereas no significant stenosis was identified in the left main (LM) segment. These findings are consistent with the results of Liaquat et al. (2022), who demonstrated a progressive association between increasing CACS and the likelihood of $\geq 50\%$ stenosis, confirming the diagnostic reliability of calcium scoring for anatomical coronary narrowing (Liaquat et al., 2022).

The moderate strength of the observed correlations reflects the variable relationship between plaque calcification and luminal stenosis across coronary territories. RCA and LCX segments frequently develop predominantly calcified plaques, which enhance diagnostic correspondence between CACS and angiographic stenosis, while LAD lesions often contain mixed or non-calcified components that lower correlation values. Chen et al. (2023) emphasized that zero calcium scores may coexist with hemodynamically significant stenoses,

particularly in younger individuals with lipid-rich plaques, underscoring that CACS reflects total atherosclerotic burden rather than direct luminal obstruction (C. Chen et al., 2024).

Anatomical and biomechanical factors further influence the diagnostic variability of calcium scoring. Proximal LAD regions experience higher shear stress and endothelial injury, promoting early atherogenesis before calcification becomes detectable (Jiang et al., 2023). In contrast, RCA and LCX arteries tend to exhibit earlier calcification due to less turbulent flow and different wall stress patterns, explaining stronger regional correlations between calcium burden and stenosis. Moradi et al. (2017) highlighted that positive vascular remodeling may mask lumen narrowing despite high calcium density, whereas negative remodeling produces significant stenosis with minimal calcification, complicating the interpretation of CACS in segmental analyses (Moradi et al., 2017).

Compared with other imaging modalities, CACS offers moderate diagnostic performance but substantial clinical practicality. Blaha et al. (2020) reported that calcium scores between 100–400 Agatston units are predictive of multivessel disease and triple the risk of major adverse cardiovascular events. Although intravascular ultrasound (IVUS) and coronary CT angiography (CCTA) demonstrate higher sensitivity in detecting non-calcified plaques, CACS remains a low-cost, non-invasive, and widely accessible risk-stratification method. Tummala et al. (2022) supported this approach by demonstrating that regional calcium scoring maintains diagnostic validity across diverse plaque morphologies, particularly when integrated with segmental angiographic assessment (Blaha et al., 2020; Tummala et al., 2022).

Clinically, these findings support the role of CACS as a preliminary screening tool to stratify patients for invasive

angiographic evaluation. Establishing standardized thresholds, such as ≥ 50 for RCA and ≥ 10 for LAD or LCX, may enhance the efficiency of diagnostic algorithms and reduce unnecessary invasive procedures in low-risk patients. Ferencik et al. (2022) and Wysocki et al. (2024) emphasized that combining CACS with conventional risk scoring models could improve coronary artery disease (CAD) detection, particularly in resource-limited settings such as Indonesia, where structured imaging-based triage is increasingly essential (Ferencik et al., 2022; Wysocki et al., 2024).

Several methodological constraints must be acknowledged in interpreting the findings. The relatively small sample size and retrospective design limit generalizability and statistical power. The absence of interobserver validation for quantitative coronary angiography (QCA) introduces potential bias, and the lack of significant LM stenosis prevented a complete multisegment analysis. Walli-Attai et al. (2020) and Liaquat et al. (2022) highlighted similar challenges in single-center studies and recommended larger multicenter, prospective designs incorporating CAD-RADS and fractional flow reserve CT (FFR-CT) correlations to enhance reproducibility and clinical translation (Walli-Attai et al., 2020; Liaquat et al., 2022).

Conclusion

Coronary artery calcium scoring (CACS) demonstrated significant correlation and good diagnostic accuracy for detecting stenosis in the right coronary artery (RCA) and left circumflex artery (LCX). The AUC values ranging from 0.72 to 0.78 confirm the potential of CACS as a reliable non-invasive screening modality for coronary artery disease. Integrating CACS with invasive coronary angiography may enhance patient risk stratification, allowing early identification of clinically significant

stenosis and guiding more precise
diagnostic and therapeutic decision-making

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