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Original Article

Association Between Cardiovascular Risk Factors and IVUS-Derived Coronary Calcium Score in the Indonesian Population

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Abstract

Background: Coronary artery calcification reflects the chronic burden of atherosclerosis and contributes to procedural complexity during Percutaneous Coronary Intervention (PCI). While coronary calcium has been extensively studied using Computed Tomography (CT), data on Intravascular Ultrasound (IVUS)-derived calcium characteristics in Southeast Asian populations remain limited. The Southeast Asian population, particularly Indonesians, may exhibit distinct patterns of atherosclerosis influenced by genetic, lifestyle, and metabolic factors. Therefore, we sought to investigate the association between cardiovascular risk factors and IVUS-derived total coronary calcium score in an Indonesian population.

Methods: This single-center, retrospective observational study included consecutive patients who underwent IVUS-guided PCI between January 2020 and December 2021. Data on patient demographics and cardiovascular risk factors were obtained from medical records. The IVUS calcium scores recorded in the database were independently reanalyzed and validated by an experienced interventional cardiologist to ensure consistency and accuracy. Associations between cardiovascular risk factors and total IVUS calcium score were assessed using Spearman's rank correlation and the Kruskal–Wallis test.

Results: A total of 111 patients were included in this study with a mean age of 61.3 ± 10.2 years; 72.1% were male. Hypertension, was present in 60.4%, type 2 Diabetes Mellitus (DM) in 45.0%, dyslipidemia in 38.7%, and active smoking in 40.5%. The mean IVUS total calcium score was 1.93 ± 1.41. Among individual risk factors, dyslipidemia ($\rho = 0.22$, $p = 0.021$) and smoking ($\rho = -0.24$, $p = 0.009$) were significantly associated with calcium score. Patients with ≥2 risk factors had higher mean calcium scores (2.15 ± 1.35) compared with those with ≤1 risk factor (1.15 ± 1.33; $p = 0.028$).

Conclusions: The total IVUS calcium score correlated significantly with the presence of dyslipidemia in this Indonesian population. A cumulative increase in cardiovascular risk factors was associated with greater coronary calcium burden, suggesting that multifactorial risk exposure plays an important role in coronary calcification in this population.

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Keywords: IVUS, coronary calcification, Indonesia, intravascular imaging.

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Introduction

Coronary artery calcification is a hallmark of advanced atherosclerosis and a key determinant of procedural complexity during Percutaneous Coronary Intervention (PCI). Intravascular Ultrasound (IVUS) allows direct in vivo quantification of coronary calcium distribution and burden. Greater coronary calcification has been shown to correlate with poorer procedural and long-term clinical outcomes, including reduced stent expansion, higher restenosis rates, and increased adverse cardiovascular events.[1-3]

While global studies have identified age, hypertension, diabetes, and dyslipidemia as major contributors to coronary calcification, ethnic and regional variations exist.[4] The Southeast Asian population, particularly Indonesians, may exhibit distinct patterns of atherosclerosis influenced by genetic, lifestyle, and metabolic factors.[5] However, studies using IVUS-derived calcium scoring in this population are scarce. Therefore, this study aims to explore the association between cardiovascular risk factors and IVUS-derived coronary calcium score among Indonesian patients undergoing PCI.

Methods

This retrospective, cross-sectional study included consecutive patients who underwent IVUS-guided PCI between January 2020 and December 2021. Eligible patients were aged ≥18 years and had adequate IVUS image quality for calcium quantification. Cardiovascular risk factors, including Hypertension, type 2 Diabetes Mellitus (DM), dyslipidemia, and current smoking, were recorded from medical records. The definition of risk factors was available in Supplementary Table 1.

Table 1. IVUS Calcium score.

Parameter	Definition	Score
Calcium arc >270° in ≥5 mm length	Presence of a superficial calcium arc exceeding 270° over a continuous segment of at least 5 mm in length.	Yes = 1, No = 0
360° circumferential calcium	Presence of complete 360° circular calcification involving the vessel wall.	Yes = 1, No = 0
Calcified nodule	Presence of a protruding, irregular surface composed of aggregated small calcium deposits on a calcified plate.	Yes = 1, No = 0
Vessel diameter <3.5 mm	Measured at the site of maximum calcium; defined as small vessel if <3.5 mm.	Yes = 1, No = 0

The IVUS Calcium Score is a composite index derived from four morphological parameters assessed on Intravascular Ultrasound (IVUS) imaging. Each criterion is scored as 1 if present and 0 if absent, giving a total score ranging from 0 to 4.

IVUS Acquisition and Analysis

All procedures were performed using 40-MHz or 60-MHz IVUS catheters (Boston Scientific, USA). The IVUS calcium scores recorded in the institutional database were independently re-analyzed and validated by an experienced interventional cardiologist to ensure consistency and accuracy. Re-evaluation of IVUS images was conducted using the Image Viewer application by an expert interventional cardiologist who was blinded to the pre-existing IVUS calcium score recorded in the database. In cases of discrepancy, a second independent reviewer provided adjudication.

Calcium was defined as a bright echo with posterior acoustic shadowing. If two separate calcium deposits were present in the same cross-section, only the largest was included; the total continuous length of superficial calcium was measured. The following parameters were assessed: maximum continuous superficial calcium angle, total continuous superficial calcium length, length of superficial calcium >270°, presence of calcified nodules (protruding irregular surface of aggregated small calcium deposits on a calcified plate), and vessel diameter at the site of maximum superficial calcium. The nearest frame with a visible vessel wall was used to determine

vessel diameter when shadowing prevented direct measurement at the maximum calcium site. Calcium burden was quantified using a composite Total IVUS Calcium Score (range 0–4), based on the presence of (1) calcium arc >270°, (2) calcium length ≥5 mm, (3) nodular calcification, and (4) full 360° circumferential calcium.

Statistical Analysis

All statistical analyses were performed using Python version 3.11 (Python Software Foundation, Wilmington, DE, USA) with the SciPy and Pandas libraries, which implement standard statistical algorithms equivalent to those used in SPSS and R. Continuous variables were summarized as mean ± Standard Deviation (SD) or median (Interquartile Range [IQR]) depending on data distribution, and categorical variables as frequencies and percentages.

Data normality was assessed visually and confirmed using the Shapiro–Wilk test, demonstrating a non-normal distribution for calcium scores. Therefore, nonparametric tests were applied. Associations between individual cardiovascular risk factors—hypertension, DM, dyslipidemia, and smoking—and the total IVUS calcium score were analyzed using Spearman's rank correlation coefficient (ρ). Comparisons of total IVUS calcium scores among groups defined by the number of risk factors (0–4) were evaluated using the Kruskal–Wallis test. A two-tailed p-value < 0.05 was considered statistically significant. A graphical visualization of the calcium score distribution and mean trend by risk factor count was created using the Matplotlib and seaborn packages in Python.

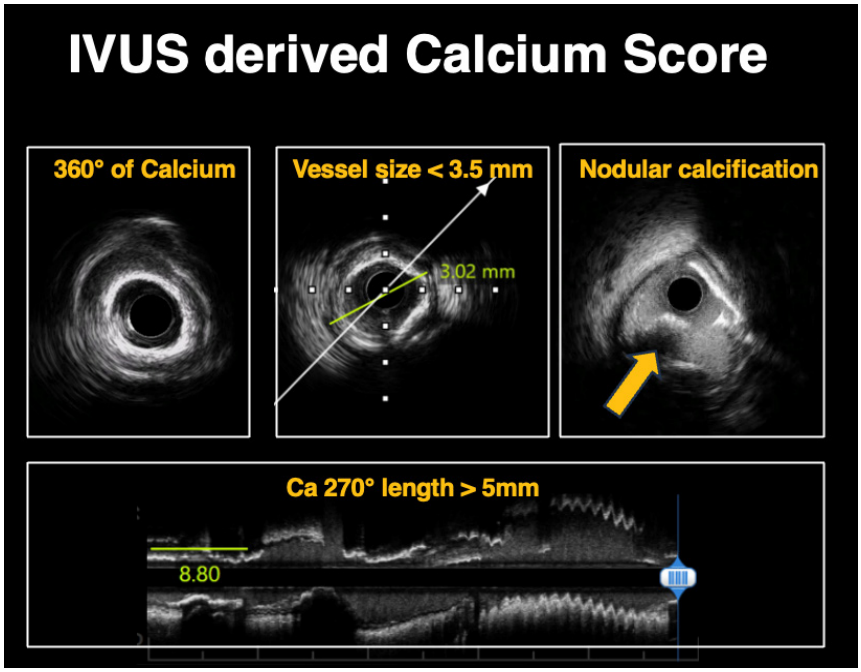

Figure 1. IVUS-derived calcium score components.
Representative intravascular ultrasound (IVUS) images illustrating the four parameters used to calculate the IVUS-derived calcium score. The score is based on the presence of: 360° of calcium indicating circumferential calcification (top left panel), vessel size <3.5 mm measured at the site of maximum calcium (top middle panel), nodular calcification characterized by a protruding, irregular calcium surface (yellow arrow, top right panel), and calcium arc >270° extending ≥5 mm in length (bottom panel). Each component is assigned a value of 1 if present and 0 if absent, yielding a total score ranging from 0 to 4.

Results

A total of 111 patients who underwent IVUS-guided PCI were included in this analysis (Table 2). The mean age was 61.3 ± 10.2 years, and the majority were male (72.1%). The mean Body Mass Index (BMI) was 25.4 ± 3.8 kg/m², reflecting a predominantly overweight cohort. Hypertension was present in 60.4%, DM in 45.0%, dyslipidemia in 38.7%, and current smoking in 40.5% of patients. Clinical presentation consisted of Acute Coronary Syndrome (ACS) in 32.4% and Chronic Coronary Syndrome (CCS) in 67.6% of the study population. The left anterior descending artery was the most frequently treated vessel (49.5%), followed by the right coronary artery (34.2%) and left circumflex artery (16.2%). The median IVUS total calcium score was 2 (IQR, 1–3), with a range of 0-4, indicating that moderate calcification was commonly observed

The correlation between cardiovascular risk fac-

Table 2. Baseline demographic and clinical characteristics (n = 111).

Variable	Mean ± SD or / Median (IQR)
Age (years)	61.3 ± 10.2
Male (sex), n (%)	80 (72.1)
Body Mass Index (kg/m²), n (%)	25.4 ± 3.8
Hypertension, n (%)	67 (60.4)
Diabetes mellitus, n (%)	50 (45.0)
Dyslipidemia, n (%)	43 (38.7)
Current smoker, n (%)	45 (40.5)
Clinical presentation, n (%)	
ACS (*)	36 (32.4)
CCS	75 (67.6)
Vessel Location, n (%)	
LM	4 (3.6)
LAD	60 (54.1)
LCx	10 (9)
RCA	37 (33.3)
IVUS total calcium score, median (IQR)	2 (1–3)

Abbreviations: SD = Standard Deviation, IQR = Interquartile Range, ACS = Acute Coronary Syndrome, CCS: Chronic Coronary Syndrome, LM: Left Main, LAD: Left Anterior Descending, LCx: Left Circumflex, RCA: Right Coronary Artery, IVUS = Intravascular Ultrasound. *ACS include Unstable angina pectoris, Non ST – Elevation Myocardial Infarction, and ST Elevation Myocardial Infarction.

Table 3. Correlation between cardiovascular risk factors and IVUS total calcium score.

Risk Factor	Spearman ρ	P-value
Hypertension	0.15	0.107
Diabetes Mellitus	0.15	0.104
Smoking	−0.24	0.0098
Dyslipidemia	+0.22	0.0214

Table 4. IVUS total calcium score by number of risk factors.

Number of Risk Factors	n	Mean ± SD	Median	Range
0	5	2.20 ± 1.30	2.0	1–4
1	33	1.15 ± 1.33	1.0	0–4
2	46	2.15 ± 1.35	2.5	0–4
3	24	1.79 ± 1.47	1.5	0–4
4	3	2.33 ± 1.53	2.0	1–4

SD: Standard Deviation; Kruskal–Wallis H = 10.85, p = 0.028.

tors and the IVUS total calcium score is shown in Table 3. Spearman correlation analysis revealed that dyslipidemia was significantly positively associated with total IVUS calcium score ($\rho = 0.22$, $p = 0.021$), whereas current smoking was significantly negatively associated ($\rho = -0.24$, $p = 0.009$). Hypertension and DM were not significantly correlated with calcium score ($p > 0.05$).

When categorized by the total number of risk factors, patients with two or more risk factors had markedly higher calcium scores than those with one or no risk factors (Kruskal–Wallis H = 10.85, p = 0.028) (Table 4). Patients with a greater number of cardiovascular risk factors demonstrated higher total calcium scores. The overall distribution pattern showed that calcium burden increased progressively with the number of risk factors (Figure 2).

Discussion

In this study, we found that the total IVUS-derived calcium score correlated significantly with dyslipidemia and the cumulative number of cardiovascular risk factors. In contrast, hypertension and DM were not independently associated with calcium burden. These findings suggest that lipid-related metabolic disturbances may play a more prominent role in coronary calcification than blood pressure or glycemic control. The graded increase in IVUS calcium score with increasing numbers of risk factors further supports the hypothesis that cumulative metabolic stress accelerates vascular calcification.

The positive association between dyslipidemia and coronary calcium score is consistent with prior studies showing that lipid deposition and oxidation trigger osteogenic transformation of vascular smooth muscle cells, leading to microcalcification within the intima and media.[6] Elevated Low-Density Lipoprotein Cholesterol (LDL-C) and oxidized lipids stimulate inflammation and apoptosis, promoting calcium deposition as a late manifestation of chronic atherosclerotic activity.[7] These mechanisms have been supported by both histopathologic and imaging studies using IVUS and Optical Coherence Tomography (OCT), demonstrating that lipid-rich plaques often evolve into heavily calcified lesions over time.[7-8]

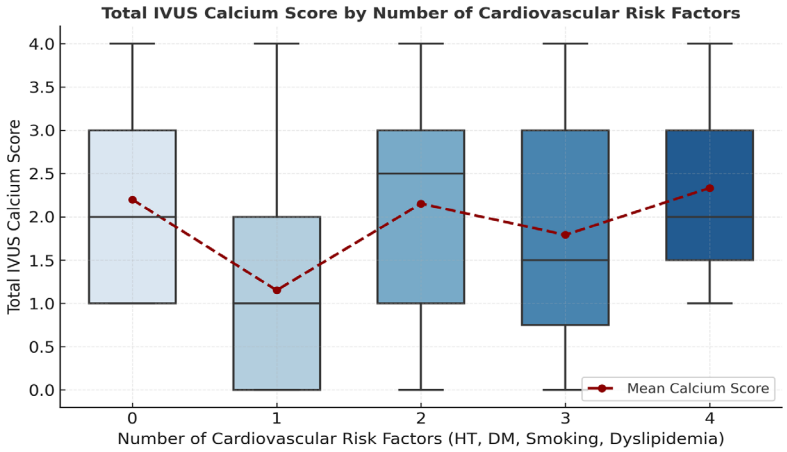

Figure 2. IVUS calcium score by number of risk factors.
The red dashed line represents the trend of mean values.

Another potential explanation for the observed association between dyslipidemia and higher calcium burden lies in the effect of statin therapy. Statins, while effectively reducing lipid content and stabilizing plaques, have been shown to increase calcified plaque volume through mechanisms of plaque healing and stabilization. This "paradoxical" increase in calcification represents plaque stabilization rather than disease progression, as statins promote the transformation of vulnerable, lipid-rich plaques into more stable, fibrotic, and calcified forms.[9]

Interestingly, our data showed an inverse correlation between current smoking and calcium score. This apparent paradox has also been reported in several imaging studies, which have revealed that smokers tend to have lipid-rich, necrotic plaques that are less calcified. Smoking is associated with increased inflammation and plaque instability, promoting rupture rather than stable calcification. Therefore, the lower calcium score in smokers does not indicate a reduced atherosclerotic burden, but rather a predominance of softer, non-calcified lesions that carry a higher short-term risk of acute coronary events.[10]

The overall calcium burden in our cohort (median IVUS calcium score 2 [IQR 1–3]) appears comparable to that reported in other Asian populations, but generally lower than values observed in Western cohorts. This difference may reflect ethnic, dietary, or lifestyle factors that influence atherogenesis and plaque maturation. Studies such as MESA (Multi-Ethnic Study of Atherosclerosis) have shown that Asian individuals often exhibit lower coronary calcium scores at similar risk factor levels compared with Western populations. Genetic factors affecting lipid metabolism and calcium regulation, as well as lower average dietary intake of saturated fat, may contribute to these findings.[11-12]

Our findings emphasize the importance of comprehensive lipid control and multifactorial risk management in preventing the progression

of coronary calcification. The stepwise increase in calcium burden with the accumulation of multiple risk factors highlights the cumulative effect of metabolic and inflammatory stress on atherosclerosis progression. Clinically, these results suggest that patients presenting for coronary intervention who harbor several risk factors should be approached with heightened awareness, as they are more likely to have heavily calcified and technically demanding lesions.

Limitations

This study has several limitations. The retrospective design may introduce selection bias, and the sample size was modest. All patients were treated at a single center, limiting generalizability. Quantitative calcium scoring by IVUS, while reproducible, remains semi-quantitative and may differ slightly between operators. Finally, the study did not evaluate longitudinal outcomes, so the prognostic impact of the IVUS calcium score could not be assessed.

Conclusion

In summary, this study demonstrates that dyslipidemia and cumulative cardiovascular risk factors are significantly associated with increased coronary calcification as quantified by the IVUS-derived calcium score in an Indonesian population. These results reinforce the central role of lipid metabolism and multifactorial risk exposure in driving coronary atherosclerosis and calcification.

List of Abbreviations

ACS	Acute Coronary Syndrome
BMI	Body Mass Index
CAD	Coronary Artery Disease
CCS	Chronic Coronary Syndrome
CT	Computed Tomography
DM	type 2 Diabetes Mellitus
IQR	Interquartile Range
IVUS	Intravascular Ultrasound
LAD	Left Anterior Coronary
LCx	Left Circumflex
LDL-C	Low-Density Lipoprotein Cholesterol
LM	Left Main
OCT	Optical Coherence Tomography
PCI	Percutaneous Coronary Intervention
MESA	Multi-Ethnic Study of Atherosclerosis
RCA	Right Coronary Artery
SD	Standard Deviation

Ethical Clearance

This study was conducted in accordance with the ethical standards of the institutional and/or national research committee and with the Declaration of Helsinki. Ethical approval was obtained from the Dr. Hasan Sadikin General Hospital ethics committee.

Publication Approval

All authors consent to the publication of this manuscript.

Authors Contributions

All authors have made a significant intellectual contribution to the manuscript according to the criteria formulated by the International Committee of Medical Journal Editors.

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Conflict of Interest

The authors declare that no conflict of interest occurs for this work.

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Generative AI and AI-Assisted Technologies in the Writing Process

Authors acknowledge that Artificial Intelligence (AI) tools were only used to assist in language editing and did not generate or alter the scientific content, analyses, or conclusions presented in this manuscript .

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