

AIP AND CORONARY ARTERY DAMAGE AS ASSESSED BY INTRAVASCULAR ULTRASOUND IN ACUTE MYOCARDIAL INFARCTION PATIENTS

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ABSTRACT

Objectives: To investigate the relationship between the atherogenic index of plasma (AIP) and the severity of coronary artery disease (CAD) as assessed by intravascular ultrasound (IVUS) in patients with acute myocardial infarction (AMI).

Methods: A cross-sectional descriptive study was conducted on 45 patients with acute myocardial infarction (AMI) at Hue Central Hospital from June to December 2024. All patients underwent coronary angiography and intravascular ultrasound (IVUS). Blood lipid parameters were collected within the first 24 hours of admission. Clinical, laboratory, and IVUS imaging data were analyzed to assess the correlation between the atherogenic index of plasma (AIP) and the characteristics of coronary artery lesions.

Results: AIP was positively correlated with the number of diseased coronary branches ($r = 0.35$, $p = 0.02$) and hs-TnT levels ($r = 0.32$, $p = 0.03$). HDL-C showed a negative correlation with the number of diseased branches ($r = -0.42$, $p < 0.01$). Minimal lumen area (MLA) was inversely related to plaque burden ($r = -0.34$, $p = 0.02$). Coronary calcification was significantly associated with a history of atherosclerotic cardiovascular disease and diabetes mellitus ($p = 0.04$).

Conclusion: AIP is a useful biomarker for predicting the severity of coronary artery involvement in AMI patients. These findings support its potential role in risk stratification and guiding interventional strategies in clinical practice.

Keywords: AIP, intravascular ultrasound, acute myocardial infarction, atherosclerotic plaque.

I. INTRODUCTION

Coronary artery disease (CAD) is the leading cause of death and disability worldwide. Acute myocardial infarction (AMI), a severe clinical manifestation of CAD, constitutes a major portion of the cardiovascular disease burden, especially in countries with aging populations and high rates of metabolic disorders [1].

A study in South Korea reported that the total cost of AMI in 2012 reached over USD 1.17 billion, with 52% attributed to direct medical expenses and 42% to productivity losses from early mortality and disability [2]. In the United States, the annual economic burden of AMI between 2003 and 2014 was estimated at USD 84.9 billion, including USD

29.8 billion in direct medical costs and over USD 55 billion in productivity losses [3].

Beyond emergency treatment and reperfusion strategies, risk stratification and prognosis of coronary artery damage are key factors in long-term management. Intravascular ultrasound (IVUS) has proven to be an effective invasive imaging modality, allowing detailed assessment of plaque characteristics, minimal lumen area (MLA), plaque burden, and high-risk features such as thin-cap fibroatheromas.

In this context, the Atherogenic Index of Plasma (AIP), defined as $\log(\text{TG}/\text{HDL-C})$, has emerged as a potential biomarker reflecting atherosclerotic risk and coronary artery damage in recent studies. AIP

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not only indicates dyslipidemia but is also associated with chronic inflammation, atherosclerosis, and the formation of complex vascular lesions. A study involving 2,491 patients in China found that AIP was positively correlated with CAD severity assessed by the SYNTAX score ($r = 0.075$, $p < 0.001$), and it independently predicted severe coronary lesions (OR: 2.06; 95% CI: 1.38 - 3.07) [4].

However, data on the relationship between AIP and coronary lesion characteristics assessed via IVUS in high-risk AMI patients remain limited. Therefore, this study was conducted with the following aims: (1) to describe coronary lesion features as assessed by IVUS in patients with acute myocardial infarction; (2) to evaluate the association between AIP and coronary lesion parameters on IVUS, thereby determining the prognostic value of AIP in assessing the severity of coronary atherosclerosis and damage in clinical practice.

II. METHODS AND MATERIALS

2.1. Study design and population

This was a cross-sectional descriptive study conducted at the Department of Cardiovascular Emergency and Interventions, Hue Central Hospital, from June to December 2024. A total of 45 patients diagnosed with AMI and indicated for coronary intervention with IVUS during the study period were selected using a convenience sampling method.

Inclusion and exclusion criteria

Inclusion criteria: Patients aged ≥ 18 years; Diagnosed with acute myocardial infarction (STEMI or NSTEMI) according to the 2023 ESC criteria; Underwent percutaneous coronary intervention (PCI) with IVUS imaging.

Exclusion criteria: History of coronary intervention or coronary artery bypass graft (CABG); Severe hepatic or renal failure ($GFR < 30$ ml/min); Ongoing acute infections or active malignancies; Missing lipid profile data at hospital admission.

2.2. Clinical and paraclinical data collection

Clinical data were extracted from medical records, including age, gender, cardiovascular risk factors (hypertension, diabetes, dyslipidemia, smoking), type of AMI, symptoms, and intervention-related information. Biochemical parameters-total cholesterol, triglycerides (TG), HDL-C, LDL-C, hs-TnT, NLR, PLR, LMR-were assessed within the

first 24 hours of admission, after patients had fasted for at least 10 hours.

Calculated indices included:

- Non-HDL-C = TC – HDL-C
- Atherogenic Index (AI) = $\frac{Non-HDL-C}{HDL-C}$
- $AIP = \log_{10} \frac{TG(mmol/l)}{HDL-C(mmol/l)}$
- $CRI-I = \frac{TC}{HDL-C}$

Lipid levels were classified as follows by the ESC/EAS 2019, NCEP ATP III 2001, and WHO 2007 guidelines [5-7].

Intravascular Ultrasound (IVUS)

All patients underwent IVUS using the Opticross HD 60Hz catheter following intracoronary nitroglycerin administration. The culprit lesion segment was examined with IVUS prior to stent deployment. IVUS images were independently analyzed by two experienced interventional cardiologists blinded to clinical and laboratory data.

Assessed parameters included: Minimal lumen area (MLA); Plaque burden ($[EEM - lumen]/EEM \times 100$); Plaque composition (fibrous, calcified, mixed); High-risk features (spotty calcification, thin-cap fibroatheroma [TCFA], positive remodeling)

2.3. Statistical Analysis

Quantitative data were presented as mean $\pm$ standard deviation (SD) or median (interquartile range), depending on distribution (assessed by Kolmogorov-Smirnov test). Comparisons between age groups (< 65 vs ≥ 65 years) were performed using independent t-tests or Mann-Whitney U tests for continuous variables, and chi-squared or Fisher's exact tests for categorical variables.

The correlation between AIP and coronary lesion characteristics (number of diseased branches, plaque burden, MLA, etc.) was assessed using Spearman correlation coefficients. A p-value of < 0.05 was considered statistically significant. Analyses were conducted using SPSS 25.0 software (IBM Corp., Armonk, NY, USA).

III. RESULTS

A total of 45 patients with acute myocardial infarction were included in the study, with a mean age of 68.89 ± 11.97 years. Males accounted for

62.22% of the population. The prevalence of diabetes mellitus was 25.56%, and 35.56% had a history of atherosclerotic cardiovascular disease. There were no statistically significant differences between age groups (< 65 vs. ≥ 65 years).

High-sensitivity troponin T (hsTnT) levels were significantly higher in the < 65 age group compared to the ≥ 65 group (median: 1.84 vs. 0.11; $p = 0.02$). Blood lipid parameters (total cholesterol, triglycerides, HDL-C, non-HDL-C) and inflammatory markers (NLR, PLR, LMR) showed no significant differences between age groups. The mean AIP of the overall group was

0.09 ± 0.35 , with no significant difference between age groups ($p = 0.41$).

Left ventricular function was assessed with a median ejection fraction (EF) of 51.00%. The <65 group had a higher rate of reduced systolic function, while the ≥65 group showed a higher rate of preserved systolic function, with a trend approaching statistical significance ($p = 0.055$, Likelihood Ratio test).

Treatment approach: Percutaneous coronary intervention (PCI) was performed in 95.56% of patients; only 4.44% received medical therapy alone (Table 1).

Table 1: Clinical and Paraclinical Characteristics by Age Group

Characteristic	Total (n=45)	Age < 65	Age ≥ 65	p
Age (years)	68.89 ± 11.97			
Male (%)	28 (62.22%)	9 (64.28%)	19 (61.29%)	1.00
Diabetes mellitus	7 (25.56%)	2 (14.28%)	5 (16.13%)	1.00
History of ASCVD	16 (35.56%)	4 (28.56%)	12 (38.71%)	0.74
hsTnT (ng/ml)	0.31 (0.003 - 7.26)	1.84 (0.003 - 0.45)	0.11 (0.003 - 7.26)	0.02
Total cholesterol (mmol/l)	4.85 ± 1.41	4.99 ± 1.46	4.79 ± 1.40	0.75
Triglyceride (mmol/l)	1.37 (0.53 - 6.67)	1.31 (0.60 - 6.67)	1.40 (0.53 - 5.25)	0.77
HDL-C (mmol/l)	1.20 (0.66 - 5.64)	1.08 (0.69 - 1.62)	1.26 (0.66 - 5.64)	0.27
non-HDL-C (mmol/l)	3.53 ± 1.35	3.86 ± 1.49	3.38 ± 1.28	0.29
NLR	2.39 (0.36 - 9.40)	2.58 (1.17 - 5.92)	2.39 (0.36 - 9.40)	0.89
PLR	149.04 ± 67.36	119.80 (46.55 - 280.00)	136.99 (52.39 - 308.18)	0.56
LMR	4.17 ± 4.52	3.27 (1.63 - 22.00)	2.80 (0.91 - 24.76)	0.84
AI	3.05 ± 1.42	3.63 ± 1.71	2.78 ± 1.20	0.16
AIP	0.09 ± 0.35	0.15 ± 0.34	0.07 ± 0.35	0.41
CRI-I	4.05 ± 1.41	4.63 ± 1.72	3.78 ± 1.19	0.16
Regional wall motion abnormality	28 (62.22%)	8 (57.14%)	20 (64.52%)	0.74

Characteristic		Total (n=45)	Age < 65	Age ≥ 65	p
Left ventricular systolic function	Normal	17 (37.78%)	6 (42.86%)	11 (35.48%)	0.055 ^a
	Preserved	7 (15.56%)	0 (0%)	7 (22.58%)	
	Reduced	21 (46.67%)	8 (57.14%)	13 (41.94%)	

ASCVD: Atherosclerotic cardiovascular disease; hsTnT: high-sensitivity Troponin T; HDL-C: high-density lipoprotein cholesterol; Non-HDL-C: non-HDL cholesterol; NLR: neutrophil-to-lymphocyte ratio; PLR: platelet-to-lymphocyte ratio; LMR: lymphocyte-to-monocyte ratio; AI: atherogenic index; AIP: atherogenic index of plasma; CRI-I: Castelli risk index I.

Multivessel disease was observed in 62.22% of patients, with a balanced distribution across age groups. Left main (LM) coronary artery involvement was seen in 11.11%, predominantly in the ≥65 group, though not statistically significant. Average plaque burden ($71.31 \pm 7.04\%$), MLA ($2.86 \pm 0.79 \text{ mm}^2$), and number of diseased branches were similar across age groups.

Mixed atherosclerotic plaques were the most prevalent type (93.33%), while purely fibrous and calcified plaques were rare. High-risk plaques were detected in 77.78% of patients using IVUS. Spotty calcification was present in 46.67%, and a calcification arc $\geq 180^\circ$ was found in 13.3%, with no significant difference between age groups (Table 2).

Table 2: Coronary Lesion and Calcification Characteristics Assessed by Coronary Angiography and IVUS

Variable	Total (n=45)	Age < 65	Age ≥ 65	p
Left main lesion	5 (11.11%)	0 (0%)	5 (16.13%)	0.30
Single-vessel disease	17 (37.78%)	5 (35.71%)	12 (38.71%)	1.00
Multivessel disease	28 (62.22%)	9 (64.29%)	19 (61.29%)	1.00
Chronic total occlusion	5 (11.11%)	3 (21.43%)	2 (6.45%)	0.17
Number of diseased vessels	1.93 ± 0.84	2.00 ± 0.88	1.90 ± 0.83	0.73
MLA (mm^2)	2.86 ± 0.79	$2.79 (1.92 - 4.81)$	$2.64 (1.43 - 4.93)$	0.72
Plaque burden (%)	71.31 ± 7.04	72.43 ± 6.71	70.81 ± 7.22	0.55
Mixed atherosclerotic plaque	42 (93.33%)	14 (100%)	28 (90.32%)	0.54
Calcified plaque	1 (2.22%)	0 (0.00%)	1 (3.23%)	1.00
Fibrous plaque	2 (4.44%)	0 (0.00%)	2 (6.26%)	1.00
Vulnerable plaque	35 (77.78%)	10 (71.43%)	25 (80.65%)	0.70
Spotty calcification	21 (46.67%)	5 (35.71%)	16 (51.61%)	0.36
Calcification arc	25 (55.56%)	8 (57.14%)	17 (54.84%)	1.00
Thrombus	8 (17.78%)	4 (28.57%)	4 (12.90%)	0.23
Calcification arc $\geq 180^\circ$	6 (13.33%)	1 (7.14%)	5 (16.13%)	0.65
Number of treated vessels	1.29 ± 0.63	1.14 ± 0.55	1.35 ± 0.66	0.35

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Key findings by age group quartiles. Inflammatory and lipid markers: The < 65 group showed higher medians for hsTnT, triglycerides, non-HDL-C, AI, CRI-I, and AIP, indicating more severe myocardial damage and atherosclerosis. In contrast, the ≥ 65 group had higher Q2 for HDL-C (1.26 vs. 1.08), suggesting better protective lipid profiles.

Systemic inflammation. The < 65 group had higher PLR and NLR values, while the ≥ 65 group had a higher Q3 for LMR (4.79 vs. 4.14), indicating different inflammatory responses. MLA and plaque burden: Similar between the two age groups.

Left ventricular function: The median EF in the ≥ 65 group was 55%, higher than 47.5% in the < 65 group, consistent with more severe myocardial injury in younger patients.

Correlation between lipid markers and coronary lesion characteristics. hsTnT was positively associated with AI ($r = 0.32$; $p = 0.03$) and CRI-I ($r = 0.32$; $p = 0.03$). AIP was positively correlated with the number of diseased coronary branches ($r = 0.35$; $p = 0.02$). HDL-C was negatively correlated with the number of diseased branches ($r = -0.42$; $p < 0.01$). MLA was inversely related to plaque burden ($r = -0.34$; $p = 0.02$). A negative correlation was also observed between AIP and PLR, suggesting that elevated AIP can occur even when PLR is low, indicating a complex interplay between lipid metabolism and inflammation (Table 3).

Table 3: Correlations between inflammatory markers and coronary artery lesion characteristics

Correlation Between Variables		r	p
hsTnT	AI	0.32	0.03
	CRI-I	0.32	0.03
Triglyceride	PLR	- 0.40	0.01
PLR	AIP	- 0.31	0.04
MLA	Plaque Burden	- 0.34	0.02
Number of diseased coronary branches	HDL-C	- 0.42	< 0.01
	AI	0.31	0.04
	AIP	0.35	0.02
	CRI-I	0.31	0.04
	Number of Intervened Branches	0.51	< 0.01

Association between coronary calcification and risk factors. Among patients with calcification, the prevalence of diabetes was significantly higher (28.57%) compared to those without calcification (4.17%). 85.71% of diabetics had vascular calcification, compared to only 39.47% of non-diabetics, with a statistically significant association ($p = 0.04$).

Similarly, a history of atherosclerotic cardiovascular disease was more common among patients with coronary calcification (52.38%) than in those without (20.83%), also statistically significant ($p = 0.04$) (Tables 4 and 5).

Table 4: Association between diabetes mellitus and coronary artery calcification

		Coronary Artery Calcification Status		Total
		Absent	Present	
Diabetes	Absent	23	15	38
	% within diabetes group	60.53%	39.47%	
	% within calcification group	95.83%	71.43%	
	Present	1	6	7
	% within diabetes group	14.29%	85.71%	
	% within calcification group	4.17%	28.57%	
Total		24	21	45

Calcification nodules are indicative of vascular calcification, detected via intravascular ultrasound (IVUS).

Table 5: Association between history of atherosclerotic cardiovascular disease and coronary artery calcification

		Coronary artery calcification status		Total
		Absent	Present	
History of ASCVD	Absent	19	10	29
	% within ASCVD history group	65.52%	34.48%	
	% within calcification group	79.17%	47.61%	
	Present	5	11	16
	% within ASCVD history group	31.25%	68.15%	
	% within calcification group	20.83%	52.38%	
Total		24	21	45

Relationship Between Left Ventricular Systolic Function and Coronary Calcification. Among patients with calcification, 61.90% had reduced systolic function, compared to 50.00% with normal function in the non-calcified group. Although Pearson and Likelihood Ratio tests did not yield statistically significant differences ($p > 0.05$), the Linear-by-Linear Association test was significant ($p = 0.048$), suggesting a linear trend: the more severe the calcification, the greater the likelihood of impaired systolic function (Chart 6).

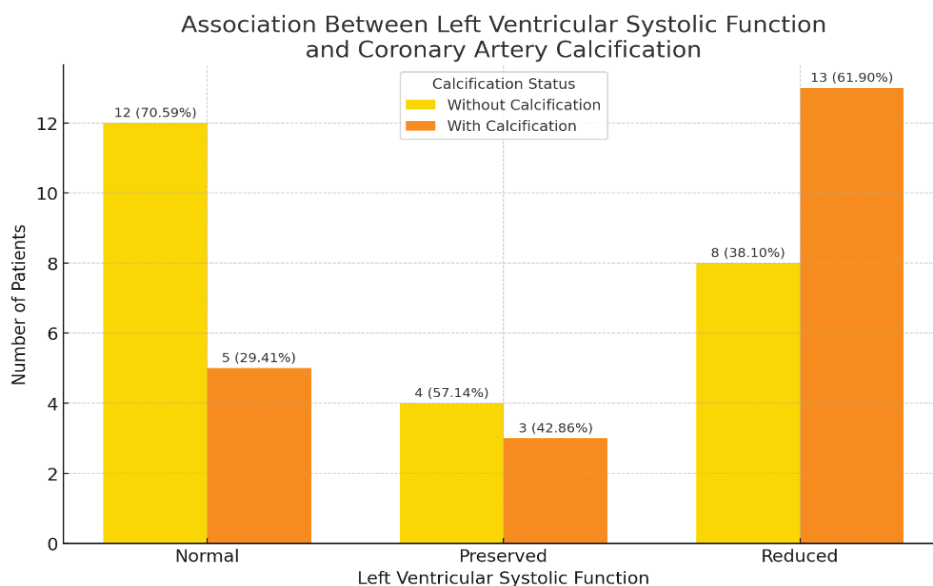


Chart 1: Association Between Left Ventricular Systolic Function and Coronary Artery Calcification

IV. DISCUSSION

This study explored the association between the Atherogenic Index of Plasma (AIP) and the severity of coronary artery disease (CAD) in acute myocardial infarction (AMI) patients using intravascular ultrasound (IVUS). The findings showed a statistically significant positive correlation between AIP and the number of diseased coronary branches ($r = 0.35$; $p = 0.02$), as well as with hsTnT levels ($r = 0.32$; $p = 0.03$). Conversely, HDL-C was negatively associated with the number of diseased branches ($r = -0.42$; $p < 0.01$), highlighting the interplay between dyslipidemia, inflammation, and atherosclerotic burden in AMI.

These findings are consistent with Li et al. [4], who reported a significant correlation between AIP and coronary artery disease severity assessed by the SYNTAX score. Their study demonstrated that AIP independently predicted high-risk CAD (OR = 2.06; 95% CI: 1.38-3.07; $p < 0.001$). Our results also support the meta-analysis by Ulloque-Badaracco et al. [8], which concluded that an increase in AIP more than doubled the risk of CAD (OR = 2.11; 95% CI: 1.65-2.69). These consistent associations across diverse populations emphasize the utility of AIP as a practical biomarker in cardiovascular risk stratification.

Furthermore, our study complements the findings by Guo and Ma [8], who underscored the anti-inflammatory and endothelial-protective functions of HDL-C. The observed negative correlation between HDL-C and diseased coronary branches in our cohort reinforces the role of HDL-C in vascular protection. Low HDL-C not only reflects dyslipidemia but also signals enhanced vascular inflammation and plaque vulnerability, which are critical in CAD pathophysiology.

From a clinical standpoint, the integration of AIP with IVUS findings revealed a high prevalence of high-risk plaques (77.78%), spotty calcification (46.67%), and an average minimal lumen area (MLA) of 2.86 mm². These imaging features are consistent with those reported in the CLIMA study [9], which found that plaques with high-risk morphology (MLA < 3.5 mm², lipid arc > 180°, fibrous cap thickness < 75 μm, and macrophage infiltration) were associated with a 7.5-fold increase in major adverse cardiovascular events (MACE). Although IVUS does not visualize fibrous cap thickness or macrophage infiltration like OCT, it remains a reliable modality for assessing plaque burden and morphology.

The correlation between MLA and plaque burden in our study ($r = -0.34$; $p = 0.02$) aligns with findings from the VIVA study [10], which

showed that MLA $<4.0 \text{ mm}^2$ and plaque burden $\geq 70\%$ were strong predictors of adverse outcomes. These imaging markers, when combined with biochemical indices like AIP, may enhance early identification of high-risk patients and guide more aggressive intervention strategies.

Interestingly, patients under 65 years had higher AIP and hsTnT levels, suggesting more intense inflammatory activity and myocardial damage despite younger age—an observation consistent with the findings of Taha Okan et al. [11]. This supports the idea that younger patients with high AIP are not necessarily at lower risk and may benefit from early intervention. Similar trends were reported by Tian et al. [12], who noted that dyslipidemia, insulin resistance, and inflammation contribute to early-onset cardiovascular disease.

In line with the ESC/EAS 2019 guidelines [5] and ESC 2021 [13], our study reinforces the value of AIP as a risk modifier. These guidelines recommend supplementing traditional lipid markers (e.g., LDL-C) with additional indices such as AIP, non-HDL-C, and ApoB to enhance risk stratification, especially in metabolic syndrome or diabetes. The NCEP ATP III report [7] also recognizes low HDL-C and high triglycerides as independent risk factors, and our results further validate these recommendations.

Regarding coronary calcification, our findings showed a significant association with diabetes and prior atherosclerotic cardiovascular disease (ASCVD) ($p = 0.04$). This supports the view that chronic metabolic conditions contribute to vascular calcification, a marker of advanced atherosclerosis. These findings are consistent with the work of Assempoor et al. [14], who reported that high AIP is associated not only with CAD ($OR = 2.79$) but also with vascular calcification ($OR = 2.28$) and MACE ($HR = 1.59$).

The PROSPECT study [15] highlighted the importance of non-culprit lesions, which, despite being angiographically mild, accounted for a substantial proportion of cardiovascular events. Features such as plaque burden $\geq 70\%$ and MLA $\leq 4.0 \text{ mm}^2$ were predictive of MACE. Our cohort exhibited similar characteristics, suggesting a high atherosclerotic burden even in lesions that may not appear critical on angiography.

Additionally, the observed inverse correlation between AIP and PLR ($r = -0.31$; $p = 0.04$) suggests that AIP may reflect systemic inflammation independently of traditional inflammatory indices. The integration of AIP with inflammatory and imaging biomarkers offers a comprehensive approach to CAD risk assessment.

Finally, our findings align with those of Mahdavi-Roshan et al. [16], who demonstrated that AIP remains predictive of CAD risk even after adjusting for traditional risk factors. This further strengthens the clinical relevance of AIP, especially in populations with complex metabolic profiles. Unlike their study which used community-level data, our use of IVUS adds morphological context to biochemical associations, enhancing clinical applicability.

V. CONCLUSION

This study demonstrates that AIP is significantly associated with coronary artery damage as assessed by IVUS in AMI patients. It reflects both dyslipidemia and atherosclerotic burden, supporting its role as a non-invasive, cost-effective biomarker in cardiovascular risk stratification. Integrating AIP with advanced imaging techniques like IVUS may improve early detection and individualized treatment planning. Future studies with larger sample sizes and longitudinal follow-up are warranted to validate these findings and establish optimal AIP thresholds for clinical decision-making.

Conflict of Interest Statement

The authors declare that there are no conflicts of interest regarding the research, authorship, or publication of this article.

Ethical Approval Statement

This study was approved by the Institutional Review Board of the Hue University of Medicine and Pharmacy, Vietnam, under approval number H2024/419, dated August 5, 2024.

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