Original Article

Correlation of Atherogenic Index of Plasma with Angiographic Severity of Coronary Artery Disease in Patient with Acute ST Elevation Myocardial Infarction

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Abstract

Introduction: Recent research has unveiled the potential of the Atherogenic Index of Plasma (AIP) in forecasting cardiovascular disease risk and aiding in the stratification of cardiovascular disease risk. The purpose of this study was to determine the correlation of AIP with angiographic severity of coronary artery disease (CAD) in patient with ST-segment elevation myocardial infarction (STEMI).

Methods: This was an observational cross-sectional study, conducted in the department of cardiology, Chittagong Medical College Hospital (CMCH) from March 2023 to February 2024. AIP was calculated from the fasting lipid profile. AIP has been categorized in three categories as <0.11, >0.11-0.24, and >0.24. The severity of the CAD was calculated with the help of vessel score and Gensini score. Afterwards, correlation of AIP was done with the angiographic severity of CAD.

Results: The study comprised of 150 eligible patients with diagnosis of acute STEMI. The mean age of the participants was 51 years. Majority of the participants (76%) were male and found to be obese 46.6%. Most of the participants had dyslipidemia (77.3%) and 53.3% participants had diabetes mellitus, 37.3 % was hypertensive while only 4% participants had history of CAD among their family members. More than 49% of the participants had inferior acute STEMI and in most of the participants (48%) was single vessel involvement. The AIP score ranged from 0.02 to 0.88 with a mean score of 0.3. Most of the participants had AIP score >0.24 (56%). While the Gensini score ranged from 7.0 to 146.0 with a mean score of 47.2. It was found that there is statistically positive significant association with AIP score and Gensini score ($p<0.05$). In linear regression, it was found that for each unit increase of AIP score, Gensini score increases by 139 units. In this case, $R2=0.638$ suggests a strong relationship between AIP and Gensini score in the regression model. In logistic regression, AIP was found significant independent predictor of increasing Gensini score. i.e., AIP >0.11-0.24 were 8.424 times and AIP >0.24 were 22.662 times more risk than that of who had AIP <0.11.

Conclusion: AIP has significant positive correlation with angiographic severity of coronary artery disease in patients with acute STEMI.

Key words: STEMI, AIP, CAD severity, Gensini score.

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Introduction

Atherosclerosis stands as the primary cause of CAD, driven by various risk factors. Notably, plasma lipid profile plays a significant role in predicting and exacerbating CAD risk [1]. While reducing LDL-C levels has shown efficacy in reducing cardiovascular events a subset of individuals under statin therapy still faces residual risk [2].

The Atherogenic Index of Plasma (AIP) has emerged as a strong predictor of atherosclerosis and CAD risks, defined as the logarithmic conversion of the TG/HDL-C ratio [3]. AIP values stratify individuals into low, intermediate and high-risk categories offering insight into plasma atherogenicity and CAD risk [4]. AIP's association with obesity, hypertension, diabetes mellitus (DM) and other CAD risk factors underscores its predictive utility in epidemiological studies [5]. Recent research has solidified AIP's role as a superior predictor of cardiovascular events and CAD [6]. Different scoring systems are available for angiographic assessment of coronary vessel. The Gensini score has been established to quantify the severity and extent of CAD including stenosis severity in an anatomical location according to its functional relevance in the

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coronary circulation [7]. An important advantage of using Gensini score over others (e.g., SYNTEX score) is that it includes early alterations of atherosclerosis disease and mild stenosis.

Higher AIP levels were associated with more severe CAD among patients with non-ST segment elevation acute coronary syndrome (NSTE-ACS) [8]. AIP was independently associated with the presence and severity of STEMI among young patients, having gender-dependent effects [9]. In a study conducted among Mexican young adults aged 18-22 years, Huang et al. [10] confirmed AIP as a risk factor for CAD. Additionally, AIP was effective in the diagnosis of CAD with specificity of 61.8% and accuracy of 76.4% [11]. Considering these evidences presented, early assessment of AIP alongside CAD severity could improve patient and physician adherence to risk-reducing interventions and enhance clinical outcomes. Thus, the present study aimed to investigate the correlation between AIP and angiographic severity of CAD in patients with STEMI.

Materials and methods

This observational cross-sectional study was conducted in the Cardiology department of CMCH from March 2023 to February 2024. All patients admitted in coronary care unit (CCU) with the diagnosis of STEMI underwent screening for eligibility for participation in this study. Inclusion criteria were: i) Patient admitted to the hospital with a diagnosis of acute STEMI; ii) Participants aged more than 18 years; iii) Patients who gave informed written consent to participate in the study. Exclusion criteria were: i) Patients having history of percutaneous coronary intervention (PCI) and coronary artery bypass grafting (CABG); ii) Patients who have undergone cardiopulmonary resuscitation (CPR) prior to admission or experienced recent trauma; iii) History of congestive cardiac failure (CCF) or evident heart failure upon admission; iv) Presence of cardiogenic shock among the patients; v) Patients having any history of dyslipidemia treatment; vi) Patients with valvular heart disease; vii) patients with advanced renal disease serum creatinine levels ≥ 2mg/dl; viii) patients with advanced hepatic disease; ix) Patients with chronic obstructive pulmonary disease (COPD) and x) Known hypothyroidism or hyperthyroidism. Demographic data, risk factor profile, findings of clinical examination and investigation parameters were noted in the predesigned data collection sheet. Blood samples were sent for analysis within the onset of 24 hours of hospital admission. The investigation was included 12hrs fasting lipid profile, fasting blood sugar, hemoglobin, HbA1C and serum creatinine. AIP was calculated from the fasting lipid profile. Fasting serum triglyceride (TG) was measured by TGL (enzymatic) method. Fasting low density lipoprotein (LDL)-cholesterol was measured by ALDL method (using two reagents without need for sample pretreatment or specialized centrifugation step). Fasting high density lipoprotein (HDL)-cholesterol was measured by AHDL method (using two reagents without need for sample pretreatment or specialized centrifugation step). Fasting serum total cholesterol was measured by CHOL (enzymatic) method. AIP is defined as a logarithmically transformed ratio of TG to HDL-C. AIP=log10 (TG/HDL-C) [12]. AIP Level has been categorized as follows: Low risk score as: < 0.11; intermediate score as: 0.11-0.24 and high-risk score as: >0.24.

Coronary angiography was performed using either a percutaneous femoral or radial approach on the scheduled date, either during the hospital stay or within 4 weeks of discharge. Angiogram was performed by Shimadzu Bransist Alexa-c-12 (Ceiling mounted angiographic machine) manufactured by Japan. Angiogram of each coronary vessel was observed from at least two projections. Angiographic severity of coronary artery disease had been obtained with the help vessel score and Gensini score. Significant stenosis has been defined as ≥ 70% stenosis in any of the coronary artery other than left main artery, insignificant disease was considered < 70% stenosis or plaques in any coronary arteries. In case of left main artery ≥ 50% stenosis was considered significant [13]. As described by Gensini, the Coronary Artery Disease Scoring and Retrieval System (Card scores) had been designed in order to consider several factors: gradually escalating severity of the lesions, ranging from 25% to 100% in diameter reduction; the combined impact of the multiple lesions; the specific location of lesions within the coronary arteries; the influence of collateral circulation and the potential for grafting on the affected vessel [7]. After meticulous analysis of the coronary angiograms, all necessary data have been documented in case record forms. The ethical clearance for this study has been acquired from the Ethical Review Committee of CMCH. Informed written consent had been obtained from the eligible patients.

Statistical Analysis of the data was conducted on Microsoft Excel (office 2016) and SPSS version 25. Continuous variables were expressed as mean ± SD and categorical variables were expressed as frequency and percentages. Group comparisons were made by using student's t-test for continuous variables and Pearson's chi-square test for categorical variables. Correlation between AIP and coronary artery disease severity by Gensini score was done and plotted by scattered plot. Logistic regression was performed for association of AIP with Gensini score. Statistical significance and confidence interval were set at $p<0.05$ and 95% level respectively.

Result

A total of 150 STEMI patients were in included in this study. The mean age of the participants was 51.8 ±9.8 years, the minimum was 28 years and maximum was 70 years. Most of the patients were aged between 51-60 years (34.7%) followed by aged between 41-50 years (28%), aged between 61-70 years (21.3%) and aged between 28-40 years (16%).

Majority of the participants (76%) were male, while 24% were female. The overall body mass index (BMI) of the participants ranged from 19.4 kg/m2 to 33.4 kg/m2 with a mean BMI of 25.2 kg/m2. In addition, majority of the participants were found to be obese (46.6%). The baseline characteristics of the study population were outlined in Table 1. Most of the participants had dyslipidemia (77.3%), 53.3% had diabetes mellitus, 69.3% had smoking history but only 4% participants had family history of CAD.

Table 1: Baseline characteristics of the participants (n=150)

Variables	Frequency	Percentage
Age group		
28-40	24	16.0
41-50	42	28.0
51-60	52	34.7
61-70	32	21.3
Gender		
Male	114	76.0
Female	36	24.0
Risk factors		
Dyslipidemia	116	77.3
Smoking	104	69.3
Diabetes	80	53.3
Hypertension	56	37.3
Obesity	70	46.6
Family history of CAD	06	4.0

CAD: coronary artery disease.

Around 49% of the participants had inferior myocardial infarction (MI), 24% had anterior MI, 14.7% had antero-septal MI, 9.3% participants had extensive anterior MI, 1.3% had posterior MI and 1.3% had high lateral MI. In this study, 60% of the participants received thrombolytic therapy. Most of the participants had single vessel involvement (48%), 33.3% had double vessel diseases and 19% had triple vessel disease.

The AIP score ranged from 0.2 to 0.88 with a mean score of 0.3 (Table 2 & Figure 1) and the Gensini score ranged from 7.0 to 146.0 with a mean score of 47.2 (Table 2 & Figure 2).

Table 2: AIP and Gensini score of the participants (n=150)

Variables	Minimum	Maximum	Mean	Std. Deviation
AIP	0.02	0.88	0.30	0.176
Gensini	7.0	146.0	47.2	30.7

AIP: atherogenic index of plasma.

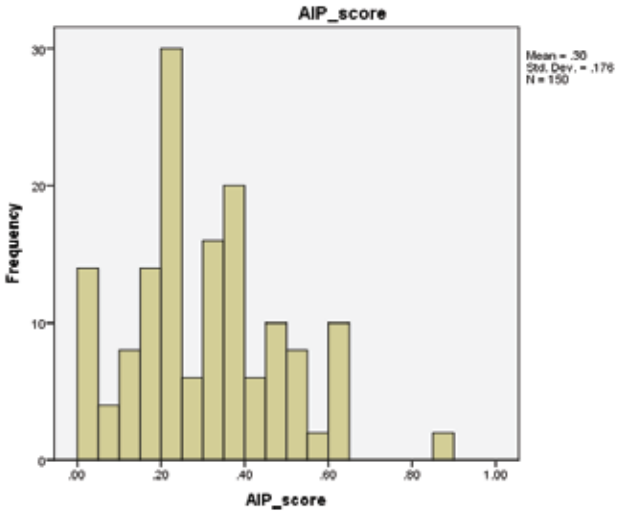


Figure 1: Distribution of Atherogenic Index of Plasma (AIP) score of the participants

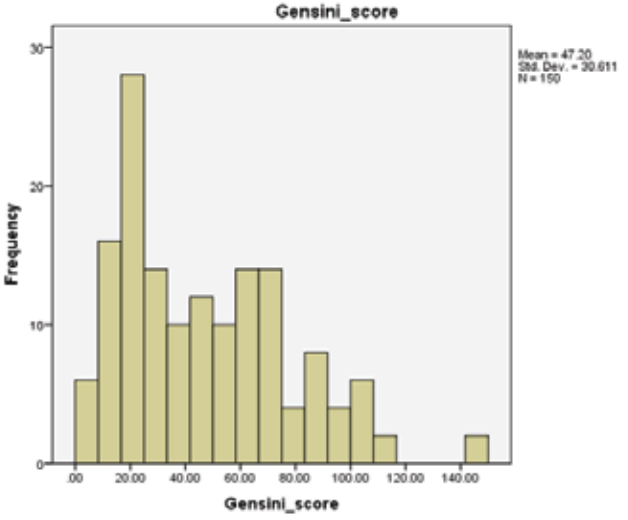


Figure 2: Distribution of the Gensini score of the participants.

AIP has been categorized in three categories as <0.11, >0.11-0.24, and >0.24 (Table 3). Most of the participants had AIP score >0.24 (56%)

Table 3: Distribution of the participants according to the categories of AIP (n=150)

AIP	Frequency (n)	Percentage (%)
<0.11	26	17.3%
>0.11-0.24	40	26.7%
>0.24	84	56.0%
Mean ±SD	3.0 ±.176	
Minimum-Maximum	0.02-.88	

AIP: atherogenic index of plasma.

Table 4 showed the association of AIP with vessel involvement of the participants of the study (p<0.05).

Table 4: Association of AIP with vessel involvement (n=150)

Variables	AIP			*p value
	<0.11 (n=26)	>0.11-0.24 (n=40)	>0.24 (n=84)	
Single	22 (30.6%)	20 (27.8%)	30 (41.7%)	0.017
Double	04 (8.0%)	16 (32.0%)	30 (60.0%)	0.007
Triple	-	4 (14.3%)	24 (85.7%)	0.001

AIP: atherogenic index of plasma.*Pearson Chi-Square.

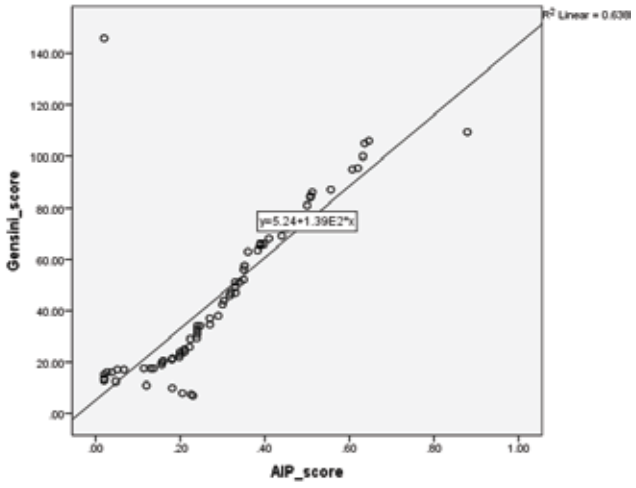


Figure 3: Scattered plot of linear regression.

The most significant findings of the study, AIP has positive correlation with Gensini score as seen in the scattered plot of linear regression (Figure 3). Here, the expression "y = 5.24 + 1.39E2*x" represents a mathematical equation in the form of a linear regression model, where:

- 'y' is the dependent variable or the response variable which is Gensini score.
- 'x' is the independent variable or the predictor variable, which is AIP score.
- '5.9' is the y-intercept, which is the value of 'y' when 'x' is zero.
- '1.39E2' represents the coefficient of 'x'. This means that for every unit increase in 'x', 'y' increases by 1.39 times 10 raised to the power of 2 (which is 100). So, it's equivalent to 139.

In simpler terms, the equation "y = 5.24 + 1.39E2*x" describes a straight line where 'y' increases by 139 units for every unit increase in 'x', starting from an initial value of 5.24 when 'x' is zero. The 'E' notation is commonly used in scientific and engineering calculations to represent numbers in exponential form. So, for each unit increase of AIP score, Gensini score increases by 139 units.

An R2 value of 0.638 indicates the coefficient of determination in a regression model.The interpretation is that 63.8% of the variability in the dependent variable y can be explained by the independent variable(s) included in the regression model. A higher R2 value closer to 1 indicates a stronger relationship between the independent and dependent variables. In this case, R2=0.638 suggests a moderately strong relationship between the variables in the model between the independent and dependent variables in the regression model, with approximately 63.8% of the variance in the dependent variable explained by the independent variable(s).

For logistic regression, Gensini score was divided into tertiles. So, the tertiles for the Gensini score are approximately 7 to 53 for first tertile, 54 to 99 for second tertile and 100 to 146 for third tertile. As there was a positive statistically significant relationship between AIP and Gensini score, the third tertile of Gensini scored was considered as severe.

Table 5 showed the logistic regression analysis of predictors of increasing Gensini score. The model was statistically significant. In this model, AIP was found significant independent predictor of severe Gensini score. i.e., AIP >0.11-0.24 were 8.424 times and AIP >0.24 were 22.662 times more risk than that of who had AIP <0.11.

Table 5: Logistic Regression Analysis of predictors of increasing Gensini score

Variables	B	p value	Odds Ratio	95% C.I. for Odds Ratio	
				Lower	Upper
AIP <0.11(reference)					
AIP >0.11-0.24	1.670	0.036	8.424	1.017	37.289
AIP >0.24	2.595	0.001	22.662	3.910	167.817

AIP: atherogenic index of plasma; CI: confidence interval.

Discussion

The correlation between the AIP and the angiographic severity of CAD in patients with STEMI has been investigated in this study. In this study, a positive significant association was found.

In the present study, it was found that the mean age of the participants was 51 years, with a mean BMI of 25.2 kg/m2. Majority of the participants (76%) were male, while 46.6% of the participants were found to be obese. Most of the participants had dyslipidemia (53.3%), while only 4% participants had history of CAD among their family members. More than 49% of the participants had inferior acute STEMI and in most of the participants, there was single vessel involvement (48%). Although this distribution varies in different studies according to the study population, there was a consistency in the findings in studies conducted in India and other countries of South Asia where Acet et al. [14] found that the mean age was 53 years and the male were more (60%). Khazaal [15] in his study in India found that less than 5% participants had history of CAD.

The AIP score ranged from 0.02 to 0.88 with a mean score of 0.3, while the Gensini score ranged from 7.0 to 146.0 with a mean score of 47.2 in our study. A similar range of AIP and Gensini score was found in different review articles including systematic reviews where Niroumand et al. [16] in their study showed that the AIP score ranged from 0.2 to 0.92. Mohanty et al. [17] in their study found that the AIP score ranged from 0.03 to 0.89 with a mean score of 0.7, while the Gensini score ranged from 7.2 to 142.0 with a mean score of 46.4. These findings are consistent with the findings of the present study.

Studies conducted in Asia, Europe and America by Cai et al. [6], Dobiasova. [4] and Daniels et al. [6], respectively have explored the relationship between AIP and CAD severity in different patient populations, including those with stable coronary artery disease, acute coronary syndrome, and STEMI. By comparing and contrasting findings from these studies, a more comprehensive understanding of the potential role of AIP in predicting CAD severity in STEMI patients can be achieved.

A study by Li et al. [18] investigated the association between AIP and CAD severity in patients with stable coronary artery disease. They found a significant positive correlation between AIP levels and the extent of coronary artery stenosis as determined by angiography. This finding gives the suggestion that AIP may serve as a useful biomarker in the prediction of CAD severity not only in acute settings but also in stable CAD patients.

Research by Kurklu et al. [19] examined the relationship between AIP and CAD severity in patients presenting with acute coronary syndrome. They observed a similar positive correlation between AIP levels and the severity of coronary artery lesions, supporting the notion that AIP is associated with the extent of atherosclerosis in ACS patients. In a study done by Zhou et al. [20] specifically focusing on STEMI patients, they reported a significant correlation between elevated AIP levels and the severity of CAD as assessed by angiography. Their findings align with those of previous studies in ACS and stable CAD populations. In addition, Kurklu et al. [19] and Zhou et al. [20] in their study have also investigated the prognostic value of AIP in STEMI patients, suggesting that higher AIP levels may be associated with worse clinical outcomes, including increased risk of major adverse cardiac events and mortality.

While the studies conducted by Feng et al. [11] in China, Elyamani et al. [21] in Italy and Islam et al. [22] in Bangladesh collectively support the association between AIP and CAD severity across different patient cohorts, variations in study design, patient characteristics, and analytical methods may influence the strength and consistency of the observed correlations. For example, differences in the definition of CAD severity, methods of AIP calculation and adjustment for confounding variables may contribute to heterogeneity in study findings.

In the present study, AIP has been categorized in three categories as <0.11, >0.11-0.24, and >0.24. Most of the participants had AIP score >0.24 (56%). Association was seen among the different risk factors of CAD by the different categories of AIP. It was found that, having dyslipidemia has statistically significant association with AIP ($p<0.05$). AIP was statistically significantly all the participants with single, double or triple vessel involvement. The correlation between the AIP and the angiographic severity of CAD in patients with STEMI can be assessed using the Gensini score. The Gensini score is a method of quantifying the severity of CAD based on coronary angiography findings.

A study by Acet et al. [14] found a significant positive correlation between elevated AIP levels and higher Gensini scores, indicating more severe CAD in STEMI patients. Similarly, another study by Elyamani et al. [21] reported similar findings, with higher AIP values correlating with increased Gensini scores and more extensive coronary artery lesions.

The most significant finding of the present study was the association of Gensini score with categories of AIP among the participants. It was found that there is statistically significant association with AIP score and Gensini score. There is a positive significance which means AIP is positively significant with Gensini score. It was found that total cholesterol, HDL, LDL, triglycerides and creatinine all have statistically positive significant association with AIP. Studies investigating this correlation have yielded intriguing findings. For example, a study by Zencirci et al. [23] conducted on a cohort of STEMI patients demonstrated a statistically significant positive correlation between AIP levels and the Gensini score ($r = 0.65$, $P< 0.001$). This indicates that as AIP levels increase, there's a corresponding increase in the severity of CAD as assessed by the Gensini score. Furthermore, another study by Alshlbh et al. [24] corroborated these findings, showing a similar strong positive correlation between AIP and the Gensini score among STEMI patients ($r = 0.72$, $p<0.001$). Notably, this study also included subgroup analyses stratified by traditional risk factors, revealing that the correlation between AIP and CAD severity remained robust across different patient profiles.

In linear regression of the present study, it was found that for each unit increase of AIP score, Gensini score increases by 139 units. In this case, R2=0.638 suggests a moderately strong relationship between the variables in the model between the independent and dependent variables in the regression model, with approximately 63.8% of the variance in the dependent variable explained by the independent variable(s). In logistic regression, AIP was found significant independent predictor of severe Gensini score. i.e., AIP >0.11-0.24 were 8.424 times and AIP >0.24 were 22.662 times more risk than that of who had AIP <0.11.

In a multicenter study done by Bekler et al. [25], AIP has been found to be independently associated with the extent and complexity of coronary artery lesions assessed by the Gensini score, even after adjusting for potential confounders such as sex, age, and other comorbidities. Specifically, each one-unit increase in AIP was associated with a 1.5-point increase in the Gensini score (95% CI: 1.2–1.9, $p < 0.001$).

Studies conducted by Acet et al. [14] in European population, Bekler et al. [25] in Scandinavian population, and Bhuvana [26] in South Asian population have collectively highlight the potential utility of AIP as a predictive biomarker for CAD severity in STEMI patients, as assessed using the Gensini score. By incorporating AIP measurements into clinical risk stratification algorithms, clinicians may enhance their ability to identify high-risk patients which may in turn benefit for more aggressive treatment related strategies, ultimately improving patient outcomes.

However, despite of these findings, it is essential to acknowledge potential limitations, such as the retrospective nature of some studies and the need for validation in larger prospective cohorts. Nevertheless, the consistent positive correlation observed between AIP and the Gensini score across multiple studies underscores the clinical relevance and potential of AIP as a valuable tool in the management of STEMI patients.

This study has several limitations: i) Samples of the study were taken from a single tertiary hospital in the port city of Bangladesh, so the results may not be representative of entire country; ii) The cross-sectional design of the study limits its ability to establish causality or determine the temporal relationship between AIP levels and severity of CAD and iii) Presence of some unmeasured confounding variables, such as comorbidities, medication use, or lifestyle factors, could influence the observed association between AIP and severity of CAD.

Conclusion

A strong positive correlation between AIP and the Gensini score as found in the study suggests that elevated AIP levels may serve as a predictor of more severe CAD. Establishing a correlation between AIP and angiographic severity of coronary artery disease in STEMI patients may have significant clinical implications. AIP can potentially serve as a readily available biomarker for risk stratification and prognostication in STEMI patients, aiding in treatment decision-making and follow-up care. Further large scale, multicenter studies are recommended to validate this finding and clarify the clinical utility of AIP in the context of acute myocardial infarction.

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