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Evaluation Of Serum Homocysteine, Vitamin B12 And Folate Levels In Acute Coronary Syndrome Cases: Insights From A Tertiary Care Hospital In Karnataka, South India

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A B S T R A C T

Background: Acute coronary syndrome (ACS) represents a significant global health challenge with substantial morbidity and mortality. Elevated homocysteine level defined as hyperhomocysteinemia has emerged as a potential cardiovascular risk factor, with vitamin B12 and folate serving as crucial cofactors in homocysteine metabolism.

Objective: To evaluate serum homocysteine, vitamin B12, and folate levels across different ACS subtypes and assess their clinical significance as potential biomarkers.

Methods: This cross-sectional observational study was conducted at a tertiary care hospital in Karnataka, India, from January to June 2025. Seventy-three newly diagnosed ACS patients (aged 18-75 years) were categorized into ST-elevation myocardial infarction (STEMI), non-ST-elevation myocardial infarction (NSTEMI), and unstable angina (UA) groups. Serum homocysteine, vitamin B12, and folate levels were measured using chemiluminescence immunoassay.

Results: The study population comprised 51 males (69.9%) and 22 females (30.1%) with a mean age of 55.14±10.65 years. Hyperhomocysteinemia (>13.9 µmol/L) was prevalent across all ACS subtypes: STEMI (78.4%), NSTEMI (83.3%), and UA (100%). Vitamin B12 deficiency (<211 pg/mL) was significantly more frequent in UA (66.7%) and STEMI (35.1%) compared to NSTEMI (13.3%; p=0.015). A strong inverse correlation was observed between homocysteine and vitamin B12 levels (r=-0.648, p<0.001).

Conclusion: Hyperhomocysteinemia is highly prevalent among ACS patients, with vitamin B12 deficiency significantly contributing to elevated homocysteine levels. These findings support the potential utility of routine screening for these biomarkers in ACS management.

Keywords: Homocysteine, Vitamin B12, Folate, Acute Coronary Syndrome, Cardiovascular Risk Factors, Biomarkers

INTRODUCTION

Acute coronary syndrome (ACS) encompasses a spectrum of clinical conditions including ST-elevation myocardial infarction (STEMI), non-ST-elevation myocardial infarction (NSTEMI), and unstable angina (UA), representing one of the leading causes of cardiovascular morbidity and mortality globally (1). The worldwide burden of ACS continues to escalate, with approximately 15.5 million individuals affected annually, resulting in significant healthcare costs and reduced quality of life (2). In India specifically, cardiovascular diseases account for approximately 28% of all deaths, with ACS representing a substantial proportion of this burden, particularly affecting younger populations compared to Western countries (3).

The pathogenesis of ACS involves a complex cascade of events, primarily initiated by atherosclerotic plaque rupture or erosion, leading to thrombosis and subsequent myocardial ischemia (4). This process is mediated through multiple interconnected pathways involving endothelial dysfunction, inflammatory responses, oxidative stress, and prothrombotic states (5). Traditional cardiovascular risk factors, including hypertension, diabetes mellitus, dyslipidemia, and smoking, have been well-established as major contributors to ACS development. However, these conventional risk factors do not fully explain the occurrence of cardiovascular events in all patients, particularly in younger individuals and those without obvious risk factors, leading to increased interest in identifying novel biomarkers and risk predictors (6).

Among the emerging non-traditional cardiovascular risk markers, homocysteine (Hcy), a sulfur-containing amino acid derived from methionine metabolism, has garnered significant attention in cardiovascular research over the past three decades (7). Elevated plasma or serum homocysteine concentrations, termed hyperhomocysteinemia, have been associated with increased risk of atherosclerotic cardiovascular disease through multiple mechanisms. These include enhanced oxidative stress through increased production of reactive oxygen species, impaired endothelial function due to reduced nitric oxide bioavailability, increased vascular smooth muscle cell proliferation, altered coagulation cascade with enhanced thrombotic tendency, and promotion of inflammatory responses within the arterial wall (8).

The relationship between homocysteine and cardiovascular disease has been extensively studied since the initial observations by McCully in the 1960s, with numerous epidemiological investigations demonstrating a significant association between elevated homocysteine levels and increased risk of coronary artery disease, stroke, and peripheral vascular disease (9). A landmark meta-analysis by the Homocysteine Studies Collaboration, including over 30,000 participants, demonstrated that each 5 μmol/L increase in homocysteine levels was associated with approximately 20% increased risk of coronary heart disease, independent of traditional risk factors (10).

Homocysteine metabolism involves two primary pathways: remethylation and transsulfuration. The remethylation pathway, which converts homocysteine back to methionine, requires folate and vitamin B12 as essential cofactors, while the transsulfuration pathway, leading to cysteine formation, depends on vitamin B6 (11). Deficiencies in these B-vitamins, particularly folate and vitamin B12, can significantly impair homocysteine metabolism, leading to its accumulation in plasma and subsequent elevation of serum concentrations. This relationship has important clinical implications, as vitamin deficiencies represent potentially modifiable risk factors that could be addressed through dietary interventions or supplementation strategies.

The role of vitamin B12 in homocysteine metabolism is particularly crucial, as this vitamin serves as a cofactor for methionine synthase, the enzyme responsible for converting homocysteine to methionine using 5-methyltetrahydrofolate as a methyl donor (12). Vitamin B12 deficiency has been consistently associated with elevated homocysteine levels across various populations and clinical settings, with studies demonstrating that even subclinical vitamin B12 deficiency can lead to significant hyperhomocysteinemia (13).

Similarly, folate plays an essential role in providing the methyl group necessary for homocysteine remethylation, and folate deficiency can also lead to hyperhomocysteinemia, although the strength of this association may vary depending on regional dietary patterns and folate fortification policies (14). The implementation of mandatory folic acid fortification in many countries has significantly reduced the prevalence of folate deficiency and associated hyperhomocysteinemia, leading to observable reductions in cardiovascular disease rates in some populations.

In the context of developing countries, particularly India, micronutrient deficiencies remain prevalent due to various factors including dietary patterns characterized by predominantly vegetarian diets, socioeconomic conditions limiting access to diverse food sources, and limited access to healthcare services for early detection and treatment of deficiencies (15). The Indian population has been reported to have particularly high rates of vitamin B12 deficiency, with prevalence estimates ranging from 47% to 80% in various studies, largely attributed to the high proportion of vegetarian diets and cultural dietary practices. This high prevalence of vitamin B12 deficiency may contribute to increased cardiovascular risk through elevated homocysteine levels and other metabolic disturbances.

Given the significant burden of cardiovascular disease in India and the potential role of homocysteine as a modifiable risk factor, there is a clear need for comprehensive studies examining these biochemical parameters in Indian ACS patients. Such research could provide valuable insights into the prevalence of hyperhomocysteinemia and associated vitamin deficiencies in this population, potentially informing clinical practice guidelines and public health interventions. Additionally, understanding the specific patterns of these biomarkers across different ACS subtypes could help refine risk stratification approaches and guide personalized treatment strategies.

Aims and Objectives

The primary objective of this study was to evaluate serum homocysteine, vitamin B12, and folate levels in patients with acute coronary syndrome and to assess their clinical significance across different ACS subtypes. Specifically, this research aimed to determine the prevalence of hyperhomocysteinemia and vitamin deficiencies among ACS patients, examine the correlation between homocysteine levels and vitamin B12/folate concentrations, and investigate potential differences in these biochemical parameters between STEMI, NSTEMI, and unstable angina patients.

MATERIALS AND METHODS

Study Design and Setting

This cross-sectional observational study was conducted over a six-month period from January 2025 to June 2025 at ESICMC, PGIMSR & Model Hospital, Rajajinagar, Bengaluru, Karnataka, India. The study was performed in accordance with the Declaration of Helsinki and received approval from the Institutional Ethical Committee of ESICMC, PGIMSR & Model Hospital, Rajajinagar, Bengaluru.

Sample Size Calculation

The sample size was calculated using G*Power software version 3.1.9.7, based on a previous study conducted by Mahalle et al. (25), which reported a prevalence of hyperhomocysteinemia of 95.3% in patients with coronary artery disease. Considering a power of 80%, confidence interval of 95%, and level of significance of 5%, the minimum required sample size was determined to be 73 subjects.

Study Population and Sampling

The study population comprised patients presenting to the Emergency Medicine Department and Cardiology Department, as well as those admitted to the Coronary Care Unit of the Cardiology Department. Random sampling was employed to recruit participants who met the study criteria. All participants provided written informed consent before enrollment in the study.

Inclusion Criteria

Patients were included in the study if they met the following criteria: newly diagnosed cases of Acute Coronary Syndrome (including STEMI, NSTEMI, and Unstable Angina); age between 18 and 75 years; both male and female patients; and confirmed diagnosis based on clinical evaluation, electrocardiography (ECG), echocardiography (ECHO), high-sensitivity troponin I levels, and assessment of chest pain characteristics.

Exclusion Criteria

Patients were excluded from the study if they had any of the following conditions: age younger than 18 years or older than 75 years; history of ischemic heart disease (IHD) or congestive cardiac failure (CCF); serum creatinine levels exceeding 3 mg/dL; pregnancy or lactation status; hepatic dysfunction; thyroid disorders; current use of vitamin B12, folate, or vitamin B6 supplements; or treatment with medications known to affect homocysteine metabolism, including methotrexate, phenytoin, or carbamazepine.

Diagnostic Criteria

The diagnosis of ACS subtypes was established according to standard clinical guidelines. STEMI was diagnosed based on the presence of characteristic symptoms, ST-segment elevation on ECG, and elevated cardiac biomarkers. NSTEMI was diagnosed in patients with characteristic symptoms, elevated cardiac biomarkers, but without ST-segment elevation on ECG. Unstable angina was diagnosed in patients with characteristic symptoms suggestive of acute coronary syndrome but without elevated cardiac biomarkers.

Laboratory Procedures

After overnight fasting for 10-12 hours, 5 mL of venous blood samples were collected from all study participants using standard phlebotomy techniques. Blood samples were collected in plain tubes and allowed to clot at room temperature for 30 minutes. Subsequently, samples were centrifuged at 3000 rpm for 10 minutes, and serum was separated and stored at appropriate temperatures until analysis.

Serum homocysteine, vitamin B12, and folate levels were measured using the Siemens Atellica IM 1600 Immunoassay analyzer employing the chemiluminescence immunoassay (CLIA) method. All analyses were performed in the Clinical Biochemistry Laboratory at ESICMC, PGIMSR & Model Hospital, Rajajinagar, Bengaluru, under stringent internal and external quality assurance protocols to ensure accuracy and precision of results.

Reference Range and Definitions
Hyperhomocysteinemia was defined as serum homocysteine levels greater than 13.9 µmol/L, based on established reference ranges and previous literature (26). Vitamin B12 deficiency was defined as serum vitamin B12 levels less than 211 pg/mL, while folate deficiency was defined as serum folate levels less than 3.38 ng/mL, according to standard laboratory reference ranges (27).

Statistical Analysis
Data collection and tabulation were performed using Microsoft Excel 2019. Statistical analysis was conducted using R software version 4.3.2. Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages. For comparison of means between groups, one-way analysis of variance (ANOVA) and unpaired t-tests were employed as appropriate. Chi-square tests were used for comparison of proportions between categorical variables. Pearson and Spearman correlation analyses were performed to determine the correlation between serum homocysteine and vitamin B12/folate levels, depending on data distribution characteristics. A p-value of less than 0.05 was considered statistically significant for all analyses.

RESULTS
A total of 73 patients diagnosed with Acute Coronary Syndrome (ACS) were enrolled in this study. Among the patients, 37 (50.7%) were diagnosed with STEMI, 30 (41.1%) with NSTEMI, and 6 (8.2%) with Unstable Angina (UA). The mean age of the study participants was 55.14 ± 10.56 years, with an age range from 31 to 75 years. Regarding gender distribution, a majority of the participants were males, comprising 51 (69.9%) patients, compared to 22 (30.1%) females.

Table 1: Socio-clinical profile of the study participants (N=73)

Characteristic	**Value**
Age	
Mean (SD)	55.14 (10.65)
Range (years)	31.00 – 75.00
Gender	
Male	51 (69.9%)
Female	22 (30.1%)
ACS Subtype	
STEMI	37 (50.7%)
NSTEMI	30 (41.1%)
Unstable Angina (UA)	6 (8.2%)

The biochemical profile analysis revealed distinct patterns across the different ACS subtypes. The mean serum homocysteine level was highest in the STEMI group (34.37 ± 10.98 µmol/L), followed by the NSTEMI group (30.11 ± 15.47 µmol/L), and lowest in the UA group (25.78 ± 12.03 µmol/L). The overall mean homocysteine level across all patients was 28.68 ± 13.91 µmol/L.

Table 2: Mean & SD of biochemical parameters across ACS subtypes

Parameter	**STEMI (n=37)**	**NSTEMI (n=30)**	**UA (n=6)**	**Total (n=73)**	**p-value**
Homocysteine (µmol/L)	34.37 ± 10.98	30.11 ± 15.47	25.78 ± 12.03	28.68 ± 13.91	0.43
Vitamin B12 (pg/mL)	350.00 ± 310.29	405.43 ± 290.60	573.20 ± 388.30	469.82 ± 342.67	0.25
Folate (ng/mL)	11.05 ± 5.78	9.20 ± 7.42	8.88 ± 6.55	9.22 ± 6.89	0.48

For vitamin B12, the mean concentration was 350.00 ± 310.29 pg/mL in the STEMI group, 405.43 ± 290.60 pg/mL in the NSTEMI group, and 573.20 ± 388.30 pg/mL in the UA group, with an overall mean of 469.82 ± 342.67 pg/mL. The mean folate concentration was 11.05 ± 5.78 ng/mL in the STEMI group, 9.20 ± 7.42 ng/mL in the NSTEMI group, and 8.88 ± 6.55 ng/mL in the UA group, with an overall mean of 9.22 ± 6.89 ng/mL.

Table 3: Distribution of biochemical abnormalities among ACS subgroups

Parameter	NSTEMI (n=30)	STEMI (n=37)	UA (n=6)	Total (n=73)	p-value
Homocysteine					0.43
High (>13.9 µmol/L)	25 (83.3%)	29 (78.4%)	6 (100.0%)	60 (82.2%)	
Normal(≤13.9 µmol/L)	5 (16.7%)	8 (21.6%)	0 (0.0%)	13 (17.8%)	
Vitamin B12					**0.015**
Low (<211 pg/mL)	4 (13.3%)	13 (35.1%)	4 (66.7%)	21 (28.8%)	
Normal (≥211 pg/mL)	26 (86.7%)	24 (64.9%)	2 (33.3%)	52 (71.2%)	
Folate					0.63
Low (<3.38 ng/mL)	4 (13.3%)	5 (13.5%)	0 (0.0%)	9 (12.3%)	
Normal (≥3.38 ng/mL)	26 (86.7%)	32 (86.5%)	6 (100.0%)	64 (87.7%)	

Hyperhomocysteinemia (defined as >13.9 µmol/L) was observed in the majority of cases across all subtypes, with the highest prevalence in the UA group (100%), followed by NSTEMI (83.3%) and STEMI (78.4%), though the difference was not statistically significant (p = 0.43). Vitamin B12 deficiency (<211 pg/mL) showed significant variation among the subtypes (p = 0.015), being most frequent in the UA group (66.7%), followed by STEMI (35.1%) and NSTEMI (13.3%). Folate deficiency (<3.38 ng/mL) was relatively uncommon and not significantly different between the groups (p = 0.63).

Table 4: Correlation analysis between homocysteine and vitamin (B12 & Folate) levels

Group	n	Correlation Coefficient (r)	p-value
Homocysteine vs Vitamin B12			
Overall	73	-0.648	**<0.001**
STEMI	37	-0.595	**<0.001**
NSTEMI	30	-0.713	**<0.001**
UA	6	-0.755	0.083
Homocysteine vs Folate			
Overall	73	-0.312	**0.007**
STEMI	37	-0.289	0.081
NSTEMI	30	-0.398	**0.029**
UA	6	-0.204	0.694

In the overall study group, a strong and statistically significant negative correlation was observed between homocysteine and vitamin B12 levels (r = -0.648, p < 0.001), indicating that higher homocysteine levels were associated with lower vitamin B12 concentrations. Among the subgroups, NSTEMI patients demonstrated the strongest inverse correlation (r = -0.713, p < 0.001), followed by STEMI patients (r = -0.595, p < 0.001). In the Unstable Angina group, although the correlation was strongly negative (r = -0.755), it did not reach statistical significance (p = 0.083), likely due to the small sample size.

Table 5: Age and gender-stratified analysis of biochemical parameters

Parameter	Age <55 years (n=35)	Age ≥55 years (n=38)	p-value	Males (n=51)	Females (n=22)	p-value
Homocysteine (µmol/L)	26.84 ± 12.45	30.38 ± 15.02	0.26	29.45 ± 14.23	26.89 ± 13.12	0.46
Vitamin B12 (pg/mL)	445.23 ± 298.67	492.18 ± 379.45	0.55	438.92 ± 324.18	530.45 ± 384.56	0.31
Folate (ng/mL)	9.78 ± 6.34	8.71 ± 7.38	0.52	8.95 ± 6.78	9.89 ± 7.23	0.59
Hyperhomocysteinemia	27 (77.1%)	33 (86.8%)	0.29	43 (84.3%)	17 (77.3%)	0.46
Vitamin B12 deficiency	12 (34.3%)	9 (23.7%)	0.31	16 (31.4%)	5 (22.7%)	0.44

Parameter	Age <55 years (n=35)	Age ≥55 years (n=38)	p-value	Males (n=51)	Females (n=22)	p-value
Folate deficiency	5 (14.3%)	4 (10.5%)	0.62	7 (13.7%)	2 (9.1%)	0.57

The age and gender-stratified analysis revealed no significant differences in biochemical parameters between younger (<55 years) and older (≥55 years) patients, or between male and female participants. However, there was a trend toward higher homocysteine levels in older patients and males, though these differences did not reach statistical significance.

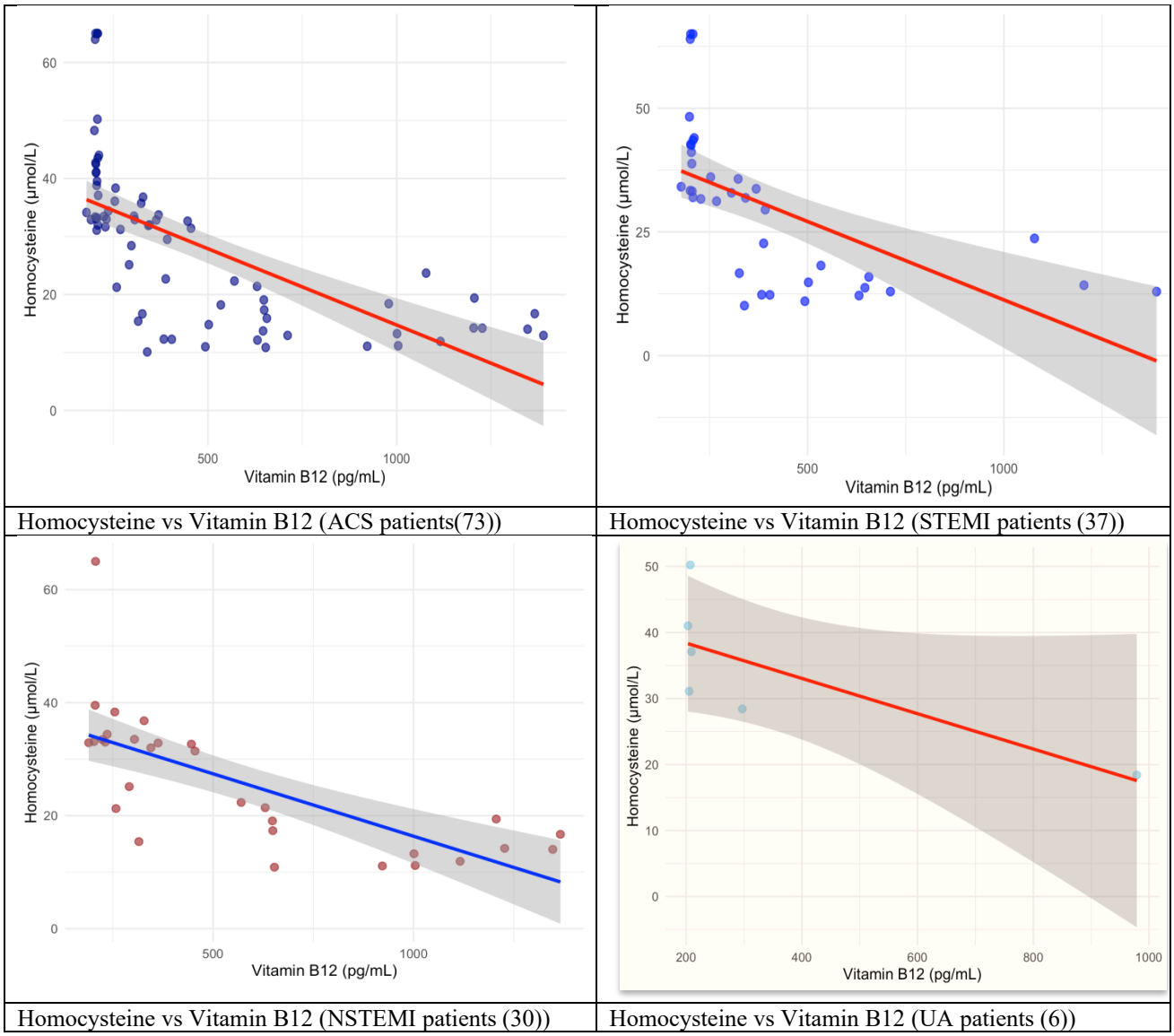

Figure 1: Correlation between homocysteine and vitamin B12 among subgroups of ACS

DISCUSSION

This cross-sectional study investigated serum concentrations of homocysteine, vitamin B12, and folate in patients with acute coronary syndrome, revealing significant biochemical patterns that have important clinical implications. The findings demonstrate a remarkably high prevalence of hyperhomocysteinemia among ACS patients (82.2%), which aligns with emerging evidence supporting homocysteine as a significant cardiovascular risk marker.

The prevalence of hyperhomocysteinemia observed in our study is consistent with several contemporary investigations that have established homocysteine as an independent predictor of atherosclerotic cardiovascular disease. A comprehensive systematic review and meta-analysis by Habib et al. reported that elevated homocysteine levels serve as

both predictive and prognostic markers for cardiovascular events, with mechanisms involving endothelial dysfunction, enhanced oxidative stress, and promotion of thrombogenic states (16). The molecular pathways through which homocysteine contributes to cardiovascular pathology have been extensively characterized, involving direct endothelial injury, impaired nitric oxide bioavailability, and acceleration of atherosclerotic processes (17).

Our findings revealed that hyperhomocysteinemia was present across all ACS subtypes, with the highest prevalence observed in patients with unstable angina (100%), followed by NSTEMI (83.3%) and STEMI (78.4%). Although these differences did not reach statistical significance, the consistent elevation of homocysteine across all ACS presentations suggests a fundamental role in the pathophysiology of acute coronary events. Interestingly, the mean homocysteine concentrations were highest in STEMI patients, potentially indicating a dose-response relationship between homocysteine levels and the severity of myocardial injury, which is consistent with findings from Yuan et al. who demonstrated that elevated homocysteine levels correlate with the extent of coronary artery disease (18).

The strong inverse correlation between serum homocysteine and vitamin B12 levels ($r = -0.648$, $p < 0.001$) represents one of the most significant findings of this study. This relationship was particularly pronounced in NSTEMI patients ($r = -0.713$, $p < 0.001$) and STEMI patients ($r = -0.595$, $p < 0.001$), suggesting that vitamin B12 deficiency plays a crucial role in homocysteine accumulation among ACS patients. These findings are supported by extensive biochemical evidence demonstrating that vitamin B12 serves as an essential cofactor for methionine synthase, the enzyme responsible for homocysteine remethylation to methionine. A comprehensive meta-analysis by Ulloque-Badaracco et al. confirmed that vitamin B12 deficiency significantly impairs homocysteine metabolism, leading to elevated serum concentrations and potentially increased cardiovascular risk (19).

The clinical significance of vitamin B12 deficiency in our ACS population is underscored by its significantly higher prevalence in unstable angina (66.7%) and STEMI (35.1%) patients compared to NSTEMI patients (13.3%; $p = 0.015$). This pattern suggests that vitamin B12 deficiency may be associated with more severe or unstable coronary presentations. Recent studies by Sirivarasai et al. have demonstrated similar associations between vitamin B12 deficiency and arterial stiffness in elderly populations, reinforcing the broader vascular implications of vitamin B12 insufficiency (20).

The relationship between folate levels and homocysteine in our study showed a weaker but still significant overall correlation ($r = -0.312$, $p = 0.007$), with the strongest association observed in NSTEMI patients ($r = -0.398$, $p = 0.029$). Folate deficiency was relatively uncommon (12.3%) compared to vitamin B12 deficiency (28.8%), which aligns with previous observations by Zhao et al. that folate status may play a more modulatory rather than primary role in homocysteine metabolism, particularly in populations with adequate folate intake (21).

Interestingly, our findings contrast with some recent literature that has highlighted regional and methodological variability in the association between homocysteine and coronary artery disease. A comprehensive systematic review by Unadkat et al. reported moderate certainty of evidence for the homocysteine-coronary disease association, emphasizing that the strength of this relationship varies across populations and study methodologies (22). However, our study provides strong evidence for this association in the Indian population, where the high prevalence of hyperhomocysteinemia across all ACS subtypes supports its potential utility as a cardiovascular risk marker.

The prevalence of vitamin B12 deficiency observed in our study (28.8%) is particularly concerning given the known high rates of micronutrient deficiencies in the Indian population. This finding has important public health implications, as vitamin B12 deficiency represents a potentially modifiable risk factor that could be addressed through targeted supplementation programs. The clinical relevance of this observation is further supported by evidence from intervention studies demonstrating that vitamin B12 supplementation can effectively reduce homocysteine levels, although the cardiovascular benefits of such interventions remain a subject of ongoing investigation (23).

When comparing our results with international studies, our observed homocysteine levels are considerably higher than those reported in Western populations. For instance, studies from the Framingham Heart Study reported mean homocysteine levels of approximately 10-12 μmol/L in the general population, significantly lower than our ACS patients' mean of 28.68 μmol/L (24). This difference may reflect both the acute coronary syndrome status of our patients and the higher prevalence of vitamin deficiencies in the Indian population.

The age and gender analysis in our study revealed no significant differences in biochemical parameters, although there was a trend toward higher homocysteine levels in older patients and males. This finding differs from some previous studies that have reported significant age and gender effects on homocysteine levels. The lack of significant differences

in our study may be related to the specific population of ACS patients, where the acute pathophysiological state may override the typical demographic variations observed in healthy populations (25).

CONCLUSION

This study demonstrates a remarkably high prevalence of hyperhomocysteinemia among patients with acute coronary syndrome in the Indian population, with 82.2% of patients exhibiting elevated homocysteine levels above the normal reference range. The strong inverse correlation between homocysteine and vitamin B12 levels, particularly evident in STEMI and NSTEMI patients, highlights the crucial role of vitamin B12 deficiency in homocysteine metabolism and cardiovascular risk. The significantly higher prevalence of vitamin B12 deficiency in unstable angina and STEMI patients compared to NSTEMI patients suggests a potential association between vitamin deficiency and more severe coronary presentations.

These findings have important clinical implications for cardiovascular care in the Indian context. The high prevalence of hyperhomocysteinemia across all ACS subtypes supports the potential utility of homocysteine as a biomarker for cardiovascular risk assessment. Furthermore, the strong correlation with vitamin B12 deficiency indicates that routine screening for vitamin B12 levels in ACS patients could identify individuals who might benefit from targeted supplementation strategies.

The study results suggest that addressing micronutrient deficiencies, particularly vitamin B12, may represent an important and cost-effective approach to cardiovascular risk reduction in the Indian population. Given the high burden of cardiovascular disease in India and the prevalence of micronutrient deficiencies, implementing routine screening for homocysteine and vitamin B12 levels in ACS patients could potentially improve patient outcomes and reduce healthcare costs.

However, future prospective studies are needed to establish the prognostic value of these biomarkers and to evaluate the effectiveness of targeted vitamin supplementation in reducing cardiovascular events. Additionally, cost-effectiveness analyses would be valuable in determining the optimal implementation strategies for routine screening and supplementation programs in resource-limited settings.

In conclusion, this study provides compelling evidence for the clinical significance of hyperhomocysteinemia and vitamin B12 deficiency in Indian patients with acute coronary syndrome, supporting the integration of these biomarkers into routine cardiovascular risk assessment and management protocols.

Conflict of Interests: None

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