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Association Between Hemoglobin Levels and Clinical Outcomes in Patients With Acute Myocardial Infarction: A Retrospective Study

Sidra Tul Muntaha [1, 2], Tayyaba Shabbir [3, 4], Sheikh Ammar Mukhtar Vohra [5], Muhammad Uzair Khalid [3, 6], Abdullah Khan [7], Aqsa Rubab [8], Somia Bibi [9], Saad Binliaquat [3, 4]

1. Medicine and Surgery, Punjab Rangers Teaching Hospital, Lahore, PAK 2. Internal Medicine, District Headquarters Khanewal Hospital, Khanewal, PAK 3. Internal Medicine, Jinnah Hospital Lahore, Lahore, PAK 4. Internal Medicine, Royal Derby Hospital, Derby, GBR 5. Internal Medicine, Akhtar Saeed Medical and Dental College, Lahore, PAK 6. Surgery, Spire Cardiff Hospital, Cardiff, GBR 7. Internal Medicine, Gujranwala Medical College, Lahore, PAK 8. Internal Medicine, Fatima Memorial Hospital College of Medicine and Dentistry, Lahore, PAK 9. Internal Medicine, Rawalpindi Medical University, Rawalpindi, PAK

Corresponding author: Sheikh Ammar Mukhtar Vohra, ammarvohra125@gmail.com

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Abstract

Background

Anemia is common in acute myocardial infarction (AMI) and has been associated with worse outcomes. Local data from Pakistan, where anemia is highly prevalent, remain limited. This study evaluated the association between admission hemoglobin and in-hospital outcomes in patients with AMI.

Methods

This retrospective cohort study included all eligible patients (n=285) with AMI admitted consecutively to a tertiary care hospital in Rawalpindi, Pakistan, between July 2023 and July 2025, according to predefined inclusion and exclusion criteria. Patients were categorized into low-hemoglobin (anemia) and normal-hemoglobin groups according to World Health Organization (WHO) criteria. Data were recorded from medical records using a structured proforma. The primary outcome was in-hospital mortality; secondary outcomes included reinfarction, major bleeding, acute kidney injury (AKI), heart failure, cardiogenic shock, stroke, and arrhythmia. Groups were compared using the independent t-test and chi-square test. Logistic regression, adjusted for age, sex, and left ventricular ejection fraction (LVEF), was used to assess the association between low hemoglobin and outcomes. $p<0.05$ was considered statistically significant.

Results

Of the 285 patients, 149 (52.28%) had anemia, and 136 (47.72%) had normal hemoglobin. Patients with low hemoglobin were significantly older, were more often female, and had lower LVEF and longer hospital stay ($p<0.05$). In-hospital mortality, reinfarction, and major bleeding were significantly higher in patients with low hemoglobin on unadjusted analysis ($p<0.05$). After adjustment for age, sex, and LVEF, low hemoglobin remained associated with in-hospital mortality (adjusted odds ratio (aOR): 4.59, 95% confidence interval (CI): 1.49-14.13; $p=0.008$), but not with reinfarction or major bleeding.

Conclusions

Low admission hemoglobin was associated with lower LVEF, longer hospital stay, and higher in-hospital mortality among patients with AMI, and the association with mortality persisted after adjustment for age, sex, and LVEF. Prospective multicenter studies are needed to confirm these findings and establish their clinical implications.

Categories: Cardiology, Emergency Medicine, Internal Medicine
Keywords: anemia, association, hemoglobin, left ventricular ejection fraction, mortality, myocardial infarction, outcomes

Introduction

Hemoglobin is a heme-containing protein inside erythrocytes that mediates oxygen transport from the lungs to peripheral tissues. As per the World Health Organization, the normal hemoglobin cutoff is ⩾13 g/dL in adult males and ⩾12 g/dL in adult females, with concentrations below these thresholds defined as anemia. Data from Global Burden of Disease (GBD) 2021 demonstrated that anemia involved 1.9 billion persons (24% of the total world population) in 2021 and constituted one of the three major causes of years lived with disability worldwide [1,2]. It remains the most common hematological disorder worldwide, with a disproportionately higher burden in developing countries, including Pakistan, due to nutritional deficiencies, chronic blood loss, and chronic disease conditions [3].

Anemia is a well-recognized prognostic indicator in cardiovascular disease. Diminished hemoglobin lowers arterial oxygen content and provokes a compensatory rise in heart rate, stroke volume, and cardiac output to preserve systemic oxygen delivery, thereby augmenting myocardial oxygen demand and decreasing coronary flow reserve, especially when fixed coronary lesions are present. Persistent anemia promotes left ventricular hypertrophy, unfavorable remodeling, and hemostatic dysfunction, whereas hemodilution, inflammatory activation, and neurohormonal stimulation further exacerbate cardiovascular compromise [4-6].

Acute myocardial infarction (AMI) is myocardial necrosis due to prolonged ischemia documented by rise/fall of cardiac troponin with ischemic evidence, classified as ST-elevation MI (STEMI) and non-ST-elevation MI (NSTEMI) on electrocardiogram (ECG). Myocardial infarction (MI) is a leading cause of death worldwide. In Pakistan, coronary artery disease affects 18.9% of the population, and MI occurs at a younger age, highlighting a major public health burden and need for early recognition and emergency care [7-9].

Despite the availability of reperfusion therapies such as thrombolysis and primary percutaneous coronary intervention (PCI), in-hospital mortality and major adverse cardiac events (MACE) after MI remain considerably high, particularly in patients with comorbidities. MACE, which includes all-cause death, recurrent infarction, cardiogenic shock, malignant arrhythmias, and stroke, prolongs hospitalization, raises healthcare expenditure, and predisposes to long-term heart failure. Therefore, early risk stratification with simple, routinely available parameters is essential for triage and outcome improvement [10-12].

Admission hemoglobin is one such inexpensive and readily accessible prognostic marker. Multiple international studies have shown that low hemoglobin on admission in patients with MI predicts higher in-hospital mortality, MACE, reduced left ventricular ejection fraction (LVEF), and longer hospital stay. In a landmark analysis of >39,000 patients with acute coronary syndrome (ACS), Sabatine et al. reported a reverse J-shaped association between baseline hemoglobin and adverse cardiovascular events [5]. Similarly, anemia on admission has been linked with lower LVEF on echocardiography owing to exacerbated myocardial oxygen supply-demand imbalance and larger infarct size [5,13-16].

Despite substantial international evidence linking low admission hemoglobin to adverse outcomes after myocardial infarction, most available data originate from other countries [5,13,15,16]. Differences in anemia prevalence and etiology, age at MI presentation, and access to timely reperfusion may limit the applicability of these findings to our setting. In Pakistan, anemia is highly prevalent, largely due to nutritional deficiencies and chronic disease [3]. However, local evidence regarding the frequency of anemia and its association with in-hospital outcomes following AMI remains scarce. Evaluating this association in our population may provide locally relevant evidence to inform clinical practice. Accordingly, the primary objective of this study was to assess the association between low admission hemoglobin and in-hospital mortality after adjustment for age, sex, and left ventricular ejection fraction (LVEF). Secondary objectives were to compare other in-hospital outcomes, including reinfarction, major bleeding, acute kidney injury (AKI), heart failure, cardiogenic shock, stroke, and life-threatening arrhythmias, as well as baseline characteristics between patients with low and normal hemoglobin levels.

Materials And Methods

Study design and study population

This retrospective cohort study was conducted at Benazir Bhutto Hospital, Rawalpindi, Pakistan, using the medical records of patients admitted between July 2023 and July 2025. All eligible patients (n=285) with acute myocardial infarction (AMI) during this period were included through consecutive sampling according to predefined inclusion and exclusion criteria. Ethical approval was granted by the hospital's Ethical Review Board (reference number: BBH.ERB.258/294) on September 15, 2025, after which the retrospective review of medical records commenced. Patient confidentiality was maintained throughout the study.

Inclusion and exclusion criteria

Patients aged ⩾18 years, irrespective of gender, with a confirmed diagnosis of AMI according to the Fourth Universal Definition of MI, and with available admission hemoglobin, echocardiography findings, and complete medical records were included. Patients were excluded if they had unstable angina, active bleeding at presentation, blood transfusion within the preceding 30 days, chronic liver or renal disease, a hematological disorder or active malignancy, or major surgery or trauma within the preceding 30 days, or if they left against medical advice or were transferred within 24 hours of admission. Figure *1* presents the study flow diagram, detailing the patient screening and selection process and the application of inclusion and exclusion criteria to enhance transparency in participant selection and study reporting.

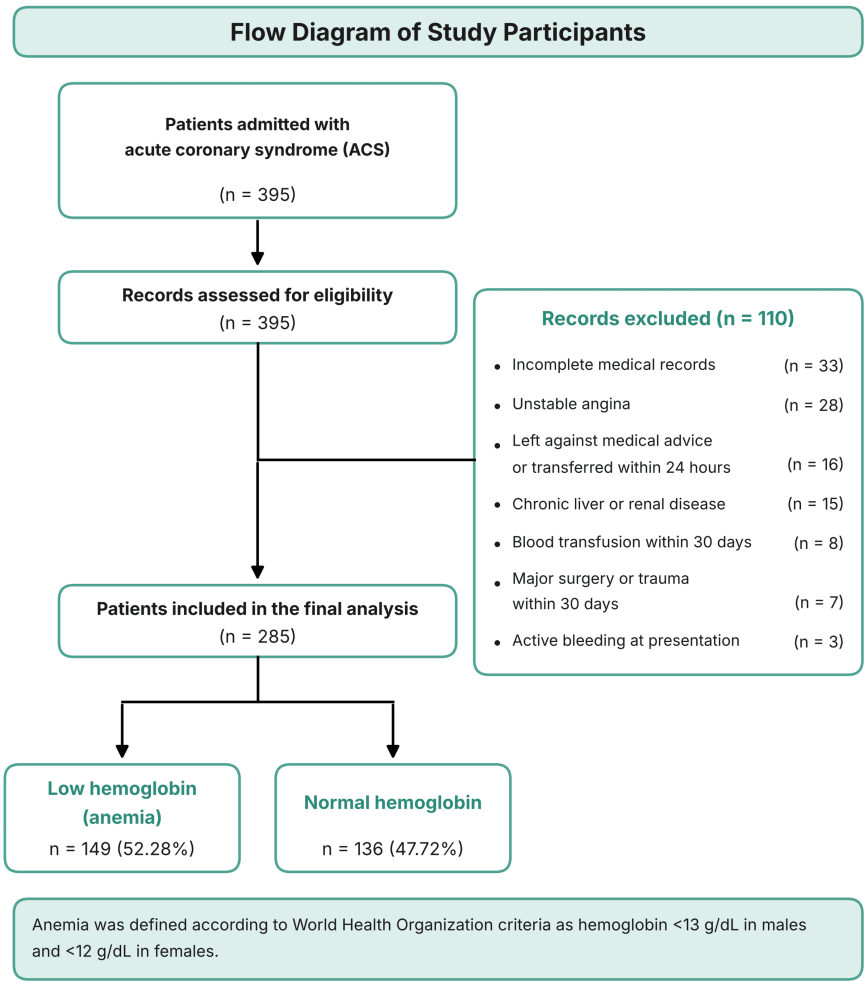


FIGURE 1: Flow Diagram of Patient Screening, Eligibility Assessment, Exclusions, and Final Study Inclusion

Primary and secondary objectives

The primary objective was to assess the association between low admission hemoglobin and in-hospital all-cause mortality in patients with AMI after adjustment for age, sex, and left ventricular ejection fraction. The secondary objectives were to compare the incidence of reinfarction, major bleeding, acute kidney injury, heart failure, cardiogenic shock, stroke, and life-threatening arrhythmia between patients with low and normal hemoglobin, and to compare baseline demographic and clinical characteristics, including LVEF and length of hospital stay, between the two groups.

Assessment of study variables

Anemia was defined according to World Health Organization (WHO) criteria as hemoglobin <13 g/dL in males and <12 g/dL in females, and patients were categorized into anemic (low-hemoglobin) and non-anemic (normal-hemoglobin) groups. Anemia severity was further graded according to WHO criteria as mild (11.0-12.9 g/dL in males and 11.0-11.9 g/dL in females), moderate (8.0-10.9 g/dL), or severe (<8.0 g/dL) [1]. Admission hemoglobin was defined as the first value recorded at hospital presentation. MI was diagnosed according to the Fourth Universal Definition of Myocardial Infarction [17]. Transthoracic echocardiography was performed by qualified cardiologists during the initial in-hospital evaluation, and LVEF was measured using the modified Simpson's biplane method. In-hospital outcomes were recorded as diagnosed and documented by the treating clinical teams in the medical records during the index admission; standardized diagnostic criteria were not reapplied retrospectively to reclassify these events.

Data collection

Data were extracted from medical records using a structured proforma. The first section recorded demographic and clinical data, including age, gender, history of ischemic heart disease, diabetes mellitus,

hypertension, dyslipidemia, and smoking. The second section recorded admission hemoglobin, LVEF, length of hospital stay, and in-hospital outcomes (mortality, reinfarction, major bleeding, acute kidney injury, heart failure, cardiogenic shock, stroke, and life-threatening arrhythmia).

Data analysis

Data were analyzed using SPSS version 25.0 (IBM Corp., Armonk, NY). Categorical variables were presented as frequencies and percentages, and continuous variables as mean ± standard deviation (SD). Normality was assessed using the Shapiro-Wilk test. Baseline characteristics, clinical outcomes, and hospital stay were compared between the low- and normal-hemoglobin groups using the independent-samples t-test and chi-square test, as appropriate; all expected cell counts were ⩾5, so the chi-square test was valid for all categorical comparisons. As all consecutive eligible patients during the study period were included, no a priori sample size calculation was performed. The dataset was reviewed for missing values, and no missing data were identified among the analyzed variables in the 285 included patients; therefore, no imputation was required. Binary logistic regression was performed to estimate unadjusted and adjusted odds ratios (aORs) with 95% confidence intervals (CIs) for the association between low hemoglobin and in-hospital outcomes. In-hospital mortality was the primary endpoint. The adjusted model included age (continuous), sex, and LVEF (continuous), selected on the basis of established prognostic relevance and baseline differences between groups; no automated variable selection was performed. Given the 29 observed deaths, the number of covariates was restricted to minimize the risk of overfitting. Secondary outcomes showing significant univariate associations (reinfarction and major bleeding) were examined using the same adjusted model. All tests were two-sided, and $p<0.05$ was considered statistically significant.

Results

Out of 285 patients, 149 (52.28%) had low hemoglobin levels, while 136 (47.72%) had normal hemoglobin levels. Among the 149 patients with anemia, anemia was mild in 98 (65.77%), moderate in 41 (27.51%), and severe in 10 (6.72%) patients.

Table *1* summarizes the baseline characteristics of 285 patients with myocardial infarction. Patients with low hemoglobin were significantly older, were predominantly female, had lower LVEF, and had a longer hospital stay ($p<0.05$). No significant differences were observed in the history of ischemic heart disease, diabetes, hypertension, dyslipidemia, or smoking ($p>0.05$).

Variables	Overall (N=285)	Low hemoglobin (n=149)	Normal hemoglobin (n=136)	p-value
Age, years (mean±SD)	66.14±12.49	68.47±12.50	63.60±12.03	0.001
Gender, number (%)				
Male	175 (61.4)	63 (42.3)	112 (82.4)	<0.001
Female	110 (38.6)	86 (57.7)	24 (17.6)	
Hemoglobin, g/dL (mean±SD)	12.44±2.01	10.75±0.96	14.30±0.91	<0.001
Left ventricular ejection fraction, % (mean±SD)	52.49±5.82	50.04±5.56	55.18±4.86	<0.001
Hospital stay, days (mean±SD)	4.91±2.43	5.96±2.21	3.76±2.13	<0.001
History of ischemic heart disease, number (%)	37 (13.0)	22 (14.8)	15 (11.0)	0.446
Diabetes mellitus, number (%)	72 (25.3)	43 (28.9)	29 (21.3)	0.184
Hypertension, number (%)	89 (31.2)	43 (28.9)	46 (33.8)	0.438
Dyslipidemia, number (%)	49 (17.2)	28 (18.8)	21 (15.4)	0.554
Smoking, number (%)	66 (23.2)	39 (26.2)	27 (19.9)	0.261

TABLE 1: Demographic and Clinical Characteristics of Patients According to Hemoglobin Status

SD: standard deviation

Table *2* presents the in-hospital outcomes of patients with myocardial infarction. Patients with low hemoglobin had significantly higher rates of in-hospital mortality, reinfarction, and major bleeding ($p<0.05$). No significant differences were observed in acute kidney injury, heart failure, cardiogenic shock, stroke, or arrhythmia ($p>0.05$).

Clinical outcomes	Overall (N=285)	Low hemoglobin (n=149)	Normal hemoglobin (n=136)	Test statistic (χ^2-value for chi-square test)	p-value
In-hospital mortality, number (%)	29 (10.2)	24 (16.1)	5 (3.7)	10.70	0.001
Reinfarction, number (%)	32 (11.2)	23 (15.4)	9 (6.6)	4.70	0.030
Major bleeding, number (%)	18 (6.3)	14 (9.4)	4 (2.9)	3.98	0.046
Acute kidney injury, number (%)	17 (6.0)	12 (8.1)	5 (3.7)	1.71	0.191
Heart failure, number (%)	26 (9.1)	14 (9.4)	12 (8.8)	0.00	1.000
Cardiogenic shock, number (%)	25 (8.8)	14 (9.4)	11 (8.1)	0.03	0.857
Stroke, number (%)	30 (10.5)	19 (12.8)	11 (8.1)	1.18	0.277
Life-threatening arrhythmia, number (%)	20 (7.0)	13 (8.7)	7 (5.1)	0.90	0.343

TABLE 2: In-Hospital Outcomes According to Hemoglobin Levels

χ^2 value is the test statistic for the chi-square test.

Table *3* shows the unadjusted and adjusted associations between low hemoglobin and in-hospital outcomes. In the unadjusted analysis, low hemoglobin was significantly associated with higher odds of in-hospital mortality, reinfarction, and major bleeding ($p<0.05$). After adjustment for age, sex, and LVEF, low hemoglobin remained associated with in-hospital mortality ($p<0.05$), while the associations with reinfarction and major bleeding were no longer statistically significant ($p>0.05$).

Clinical outcome	Unadjusted OR (95% CI)	Unadjusted p-value	Adjusted OR (95% CI)	Adjusted p-value
In-hospital mortality	5.03 (1.86-13.59)	0.001	4.59 (1.49-14.13)	0.008
Reinfarction	2.58 (1.15-5.78)	0.022	1.63 (0.64-4.20)	0.307
Major bleeding	3.42 (1.10-10.67)	0.034	2.48 (0.68-9.07)	0.170

TABLE 3: Unadjusted and Adjusted Associations Between Anemia and In-Hospital Outcomes

OR: odds ratio, CI: confidence interval

Binary logistic regression

Reference category: normal hemoglobin

Adjusted for age (continuous), sex, and left ventricular ejection fraction (continuous)

Discussion

In this retrospective study, low admission hemoglobin was associated with higher in-hospital mortality in patients with acute myocardial infarction. Patients with low hemoglobin were older, were more often female, and had lower LVEF and longer hospital stay than those with normal hemoglobin. On unadjusted analysis, in-hospital mortality, reinfarction, and major bleeding were more frequent in the low-hemoglobin group. After adjustment for age, sex, and LVEF, the association with in-hospital mortality persisted, whereas the associations with reinfarction and major bleeding were no longer statistically significant.

The prevalence of low hemoglobin in the present MI cohort (52.28%) was higher than that reported by Jomaa et al. (36.60%) [4] and Aboul-Enein et al. (24.80%) [10] in populations from Tunisia and Saudi Arabia, respectively. However, this is consistent with the high background burden of anemia in Pakistan, where a tertiary hospital study from Peshawar reported anemia in 66.80% of general patients, even after excluding

pregnant women and infants. This high baseline prevalence, largely driven by nutritional deficiency and chronic disease, likely contributes to our findings and underscores the importance of routine hemoglobin assessment in patients with AMI in our setting [18].

Regarding the demographic characteristics, the strong association of low hemoglobin with advanced age and female gender is well documented. These findings have been consistently supported by previous studies in the literature. Sabatine et al. [5], in a pooled analysis of 39,922 patients with ACS, showed that anemia was significantly more prevalent in elderly and female patients [4]. This may be explained by lower baseline iron stores, menstrual blood loss, poor nutritional intake, and higher prevalence of chronic disease and frailty, particularly in developing countries. In our cohort, other than hypertension, all comorbidities, including prior ischemic heart disease, diabetes, dyslipidemia, and smoking, were numerically more frequent in patients with low hemoglobin, but the difference was not statistically significant, although a similar trend has been noted in previous literature [10,13].

In this study, patients with low hemoglobin had a lower mean LVEF than those with normal hemoglobin, which reflects underlying pathophysiology: reduced oxygen-carrying capacity impairs myocardial oxygen supply, while compensatory tachycardia and increased stroke volume raise oxygen demand. This supply-demand mismatch promotes larger infarct size, adverse remodeling, and depressed contractility. This is supported by Dutsch et al., who demonstrated a correlation between admission anemia and lower LVEF [14]. Similarly, prolonged hospitalization in the low-hemoglobin group in the present study is consistent with prior studies. Recent data from patients with ACS admitted to the intensive care unit (ICU) showed that pre-existing anemia was significantly associated with longer ICU stay and greater intensive care requirements. This may reflect a more complicated course, hemodynamic instability, higher incidence of heart failure, need for transfusions, and delayed recovery due to impaired oxygen delivery [10,19].

In-hospital mortality was significantly higher in patients with low hemoglobin than in those with normal hemoglobin. This finding aligns with previous studies linking anemia to increased mortality after AMI. Tanaka et al. reported increased in-hospital mortality among anemic patients [16], while Sabatine et al. described a reverse J-shaped relationship between hemoglobin levels and cardiovascular mortality [5]. Moghaddam et al. also reported higher mortality in anemic patients with ST-elevation myocardial infarction undergoing primary PCI. Reduced oxygen delivery to ischemic myocardium and increased cardiac workload may partly explain this association [13].

Reinfarction and major bleeding were more frequent in patients with low hemoglobin on unadjusted analysis, but these associations were no longer statistically significant after adjustment for age, sex, and LVEF. Because data on antithrombotic therapy, invasive procedures, and vascular access site were unavailable, these outcomes cannot be interpreted as independent effects of anemia. Conversely, the non-significant adjusted results do not exclude an association, as the confidence intervals were wide and the study may have been underpowered for these outcomes. Previous studies have reported associations between anemia and these outcomes [10,20]. Although the frequencies of acute kidney injury (AKI), heart failure, cardiogenic shock, stroke, and life-threatening arrhythmias were higher in patients with low hemoglobin levels, no significant differences were seen between the two groups in the current study. Likewise, results have been reported by several studies around the world [4,11-16].

These findings have practical and potential policy implications for our setting. Hemoglobin is routinely measured at hospital admission at little additional cost, and documenting anemia status in patients with AMI may help clinicians identify individuals who warrant closer in-hospital monitoring and further evaluation of the underlying cause. At the health system level, the high prevalence of anemia observed in this cohort supports incorporating hemoglobin levels and anemia status into local MI registries and quality improvement initiatives, as well as considering anemia assessment within existing cardiac care pathways in public sector hospitals. Given the substantial national burden of nutritional anemia, these findings also highlight the potential relevance of broader anemia prevention strategies to cardiovascular care [3,18]. Nevertheless, the retrospective observational design precludes causal inference, and these implications should be considered hypothesis-generating rather than a basis for immediate policy changes. Prospective multicenter studies are needed to validate these findings and establish whether systematic anemia assessment can improve clinical outcomes.

The strengths of this study include consecutive enrollment, WHO-based anemia classification, assessment of multiple in-hospital outcomes, and reporting of both unadjusted and adjusted estimates in a setting with limited local evidence. However, several limitations should be acknowledged. First, the retrospective, single-center design limits generalizability, and the modest sample size limits precision. Requiring echocardiography and complete medical records may have introduced selection bias, including potential survivor bias, as patients who died early or were more severely ill may have been excluded. Second, the small number of deaths (n=29) restricted the number of predictors in the adjusted model, resulting in relatively wide confidence intervals. Hemoglobin was analyzed as a dichotomous variable, precluding assessment of a graded or nonlinear relationship with outcomes. Furthermore, examining eight outcomes without adjustment for multiple comparisons increases the possibility of chance findings. Third, the groups differed in age, sex, and LVEF, while important clinical variables (infarct type, Killip class, risk scores, cardiac biomarkers, admission renal function, and presentation delay), laboratory variables (iron indices, mean

corpuscular volume (MCV), and serial hemoglobin measurements), and treatment-related factors (antithrombotic therapy, vascular access site, and revascularization strategy) were not consistently available. This may have resulted in residual confounding; consequently, the observed associations with reinfarction and major bleeding cannot be attributed to anemia alone, and the etiology and chronicity of anemia could not be confirmed. Moreover, adjustment for LVEF, which may lie on the causal pathway, could have attenuated the observed association. Additionally, outcomes were based on clinician-documented diagnoses without independent adjudication using standardized diagnostic criteria, particularly for major bleeding. Finally, the observational design precludes causal inference. Future multicenter prospective studies incorporating comprehensive clinical, hematological, and treatment-related variables, together with standardized outcome definitions, are warranted to validate these findings.

Conclusions

Low admission hemoglobin was common among patients with acute myocardial infarction in our population and was associated with older age, female sex, lower left ventricular ejection fraction, and longer hospital stay. Patients with low hemoglobin had higher in-hospital mortality, and this association persisted after adjustment for age, sex, and LVEF. Reinfarction and major bleeding were also more frequent in the low-hemoglobin group; however, these associations were not statistically significant after adjustment. Given the retrospective, single-center design, limited number of mortality events, and lack of data on infarct severity and treatment-related factors, these findings should be interpreted as associations rather than evidence of causation. Prospective multicenter studies incorporating comprehensive clinical and treatment-related variables are needed to determine whether admission hemoglobin adds prognostic value to established risk scores.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Sheikh Ammar Mukhtar Vohra, Somia Bibi, Sidra Tul Muntaha, Tayyaba Shabbir, Muhammad Uzair Khalid, Abdullah Khan, Aqsa Rubab, Saad Binliaquat

Acquisition, analysis, or interpretation of data: Sheikh Ammar Mukhtar Vohra, Somia Bibi, Sidra Tul Muntaha, Tayyaba Shabbir, Muhammad Uzair Khalid, Abdullah Khan, Aqsa Rubab, Saad Binliaquat

Drafting of the manuscript: Sheikh Ammar Mukhtar Vohra, Somia Bibi, Sidra Tul Muntaha, Tayyaba Shabbir, Muhammad Uzair Khalid, Abdullah Khan, Aqsa Rubab, Saad Binliaquat

Critical review of the manuscript for important intellectual content: Sheikh Ammar Mukhtar Vohra, Somia Bibi, Sidra Tul Muntaha, Tayyaba Shabbir, Muhammad Uzair Khalid, Abdullah Khan, Aqsa Rubab, Saad Binliaquat

Supervision: Sheikh Ammar Mukhtar Vohra, Sidra Tul Muntaha, Tayyaba Shabbir

Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. The Ethical Review Board (ERB) of Benazir Bhutto Hospital issued approval BBH.ERB.258/294. Ethical approval was obtained before the start of the study. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **AI use statement:** The authors used ChatGPT free version as follows: language polishing, structure or formatting in Introduction and discussion. The AI-generated content was carefully reviewed and verified by the all authors. Any necessary corrections were made by the authors, who take full responsibility for the accuracy, integrity, and final content of the manuscript. The authors confirm that they have reviewed and verified all AI-assisted content and take full responsibility for the work. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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