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Original Research Article

Serum Magnesium Levels and their Association with Cardiac Complications and In-Hospital Mortality in Acute Myocardial Infarction Patients

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Abstract

Background: Acute myocardial infarction remains a leading cause of cardiovascular mortality worldwide. Magnesium, an essential cofactor in numerous enzymatic reactions, plays a critical role in cardiac electrophysiology and myocardial function. Hypomagnesemia has been associated with increased risk of ventricular arrhythmias and adverse outcomes in critically ill patients. However, the prognostic significance of serum magnesium levels at admission in acute myocardial infarction patients remains incompletely understood. This study aimed to evaluate the relationship between admission serum magnesium levels and the occurrence of cardiac complications and in-hospital mortality in patients with acute myocardial infarction.

Methods: This prospective observational study was conducted over eighteen months and included 160 patients admitted with acute myocardial infarction. Serum magnesium levels were measured at admission, and patients were categorized into hypomagnesemia and normomagnesemia groups based on serum magnesium levels below or above 1.7 mg/dL respectively. All patients were monitored for the development of cardiac complications including ventricular arrhythmias, heart failure, cardiogenic shock, and in-hospital mortality. Statistical analysis was performed using appropriate tests with p-value less than 0.05 considered significant.

Results: Hypomagnesemia was detected in 56.25% of patients at admission. The hypomagnesemia group demonstrated significantly higher incidence of ventricular tachycardia (31.11% vs 12.86%, p=0.004), ventricular fibrillation (17.78% vs 4.29%, p=0.007), heart failure (42.22% vs 21.43%, p=0.003), and cardiogenic shock (20.00% vs 7.14%, p=0.018). In-hospital mortality was substantially higher in hypomagnesemic patients (23.33% vs 8.57%, p=0.011). Serum magnesium levels showed significant negative correlation with cardiac complications.

Conclusion: Hypomagnesemia at admission was independently associated with increased cardiac complications and in-hospital mortality in acute myocardial infarction patients. Routine measurement of serum magnesium levels may serve as a valuable prognostic marker for risk stratification in this population.

Keywords: Magnesium, Myocardial Infarction, Arrhythmias, Heart Failure, Mortality.
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Introduction

Acute myocardial infarction continues to represent one of the most significant public health challenges globally, accounting for substantial morbidity and mortality despite advances in diagnostic techniques and therapeutic interventions. According to contemporary epidemiological data, cardiovascular diseases remain the leading cause of death worldwide, with ischemic heart disease contributing to approximately 9 million deaths annually.[1] The pathophysiology of myocardial infarction involves acute interruption of coronary blood flow, typically due to atherosclerotic plaque rupture with subsequent thrombotic occlusion, leading to irreversible myocardial necrosis if perfusion is not promptly restored.[2] Although modern revascularization strategies including percutaneous coronary intervention and thrombolytic therapy have substantially improved survival rates, acute myocardial infarction patients remain at considerable risk for developing life-threatening complications during the acute phase, including malignant ventricular arrhythmias, acute heart failure, cardiogenic shock, and mechanical complications. The identification of prognostic biomarkers that can effectively risk-stratify patients at the time of hospital admission has become increasingly important for optimizing resource allocation and therapeutic decision-making in acute coronary care. While traditional risk factors such as age, hemodynamic parameters, cardiac biomarkers,

and electrocardiographic findings have been extensively validated for prognostic assessment, there has been growing interest in exploring the role of electrolyte disturbances, particularly magnesium deficiency, as potential modifiable risk factors influencing clinical outcomes in acute myocardial infarction.[3] Magnesium, the second most abundant intracellular cation and the fourth most abundant cation in the human body, serves as an essential cofactor in more than 300 enzymatic reactions involving energy metabolism, protein synthesis, nucleic acid stability, and cellular signaling pathways.[4] Within the cardiovascular system, magnesium plays crucial physiological roles in regulating vascular tone, maintaining endothelial function, modulating platelet aggregation, and most importantly, controlling cardiac electrophysiological properties through its effects on transmembrane ion channels and action potential characteristics.

At the cellular level, magnesium exerts significant influence on cardiac electrical stability through multiple mechanisms. It acts as a natural calcium channel blocker, competitively inhibiting calcium influx through voltage-gated channels and thereby reducing myocardial contractility and electrical excitability.[5] Furthermore, magnesium is essential for maintaining the activity of sodium-potassium ATPase pumps, which are critical for establishing and maintaining normal transmembrane electrical gradients necessary for proper cardiac depolarization and repolarization sequences. Magnesium deficiency has been shown to promote intracellular calcium accumulation, increase adrenergic sensitivity, and enhance automaticity of ectopic pacemaker sites, all of which contribute to increased arrhythmogenic potential.[6] These electrophysiological derangements provide a mechanistic basis for understanding the relationship between hypomagnesemia and increased susceptibility to ventricular arrhythmias, particularly in the setting of acute myocardial ischemia where additional factors such as autonomic imbalance, inflammatory mediators, and electrolyte shifts further destabilize the electrical properties of injured and peri-infarct myocardium.

Clinical investigations examining serum magnesium status in various patient populations have revealed a surprisingly high prevalence of magnesium deficiency, particularly among critically ill patients and those with acute cardiovascular events. Studies have reported that hypomagnesemia, typically defined as serum magnesium concentration below 1.7 mg/dL or 0.7 mmol/L, occurs in approximately 40-60% of patients admitted to intensive care units and may be even more prevalent in specific subgroups including those with acute myocardial infarction.[7] The mechanisms underlying magnesium depletion in the setting of acute myocardial infarction are multifactorial and include increased urinary losses secondary to catecholamine-induced renal tubular dysfunction, intracellular shifts driven by elevated circulating insulin and catecholamines, increased consumption due to enhanced metabolic demands during stress responses, and potentially inadequate dietary intake in the period preceding the acute event. Additionally, certain medications commonly administered to cardiovascular patients, including diuretics and proton pump inhibitors, may contribute to chronic magnesium depletion, further exacerbating deficiency states during acute illness.

The clinical significance of hypomagnesemia in acute myocardial infarction extends beyond its arrhythmogenic potential. Observational studies have documented associations between low serum magnesium levels and various adverse outcomes including increased incidence of heart failure, prolonged intensive care unit stays, and elevated mortality rates.[8] These associations may be mediated through magnesium's effects on myocardial contractility, vascular reactivity, and inflammatory responses. Experimental evidence suggests that magnesium deficiency impairs endothelial function, promotes oxidative stress, and enhances inflammatory cytokine production, all of which may contribute to expansion of infarct size and adverse ventricular remodeling following myocardial infarction.[9] Furthermore, magnesium's role as a physiological antagonist of calcium-mediated cellular processes suggests that adequate magnesium levels may provide protection against reperfusion injury and calcium-mediated cardiomyocyte death during the critical early hours following coronary occlusion.

Despite these biological plausibility arguments and accumulating observational evidence, the precise relationship between admission serum magnesium levels and clinical outcomes in acute myocardial infarction remains incompletely characterized, and routine measurement of magnesium has not been universally adopted as a standard component of initial laboratory assessment in many institutions. Previous clinical trials examining therapeutic magnesium supplementation in acute myocardial infarction, most notably the ISIS-4 and MAGIC trials, failed to demonstrate mortality benefit from routine empirical magnesium administration, leading to decreased enthusiasm for magnesium-focused interventions in this population.[10] However, these neutral trial results do not necessarily negate the potential prognostic value of magnesium measurement for risk stratification purposes, as the trials did not specifically target magnesium-deficient patients and may have been unable to detect benefits in relevant subgroups.

More recent investigations have suggested that the relationship between magnesium status and outcomes may be more nuanced than previously appreciated, with both hypomagnesemia and hypermagnesemia potentially associated with adverse outcomes, suggesting a U-shaped relationship between serum magnesium concentrations and clinical endpoints. Given these considerations and the continuing need for improved risk stratification tools in acute coronary care, the present investigation was undertaken to comprehensively evaluate the association between admission serum magnesium levels and the subsequent development of major cardiac complications and in-hospital mortality in patients presenting with acute myocardial infarction.

This study specifically examined the incidence of life-threatening ventricular arrhythmias including ventricular tachycardia and ventricular fibrillation, the development of acute heart failure and cardiogenic shock, and all-cause in-hospital mortality, comparing outcomes between patients with hypomagnesemia and those with normal magnesium levels at hospital presentation. By providing detailed characterization of the relationship between magnesium status and these clinically relevant endpoints in a well-defined contemporary cohort, this research aimed to generate evidence that could inform clinical decision-making regarding the potential utility of routine magnesium measurement for prognostic assessment and potentially guide future investigations into targeted magnesium repletion strategies for high-risk subgroups of acute myocardial infarction patients.

Aims and Objectives: The primary aim of this study was to evaluate the association between serum magnesium levels at the time of hospital admission and the occurrence of major cardiac complications during hospitalization in patients presenting with acute myocardial infarction. The specific primary objective was to compare the incidence of life-threatening ventricular arrhythmias, including ventricular tachycardia and ventricular fibrillation, between patients with hypomagnesemia and those with normal serum magnesium levels at presentation. The secondary objectives of this investigation included assessment of the relationship between admission serum magnesium status and the development of acute heart failure and cardiogenic shock during the hospital course. Additionally, this study aimed to determine whether hypomagnesemia at admission was independently associated with increased in-hospital all-cause mortality in the acute myocardial infarction population. A further objective was to characterize the correlation between serum magnesium concentrations measured as a continuous variable and the overall burden of cardiac complications.

Finally, this research sought to identify the threshold serum magnesium level that optimally discriminated between patients at high risk versus low risk for adverse outcomes, thereby potentially informing future clinical decision-making regarding risk stratification and targeted therapeutic interventions in this vulnerable patient population.

Materials and Methods

Study Design and Setting: This prospective observational study was conducted in the Department of General Medicine at Chigateri General Hospital and Bapuji Hospital attached to JJM Medical College, Davangere over a period of sixmonths from January 2025 to June 2025.

The study protocol was approved by the Institutional Ethics Committee, and written informed consent was obtained from all participants or their legally authorized representatives prior to enrollment. The study was conducted in accordance with the Declaration of Helsinki and adhered to Good Clinical Practice guidelines.

Study Population and Sample Size: A total of 160 consecutive patients admitted to the coronary care unit with a diagnosis of acute myocardial infarction were enrolled in this study. The sample size was calculated based on an anticipated 30% difference in the incidence of major cardiac complications between hypomagnesemic and normomagnesemic groups, with 80% power and 5% level of significance, accounting for approximately 10% attrition. All patients underwent comprehensive clinical assessment, electrocardiographic evaluation, and biochemical testing at the time of admission.

Inclusion Criteria: Patients were included in the study if they fulfilled the following criteria: age between 18 and 80 years, presentation within 24 hours of symptom onset, diagnosis of acute myocardial infarction based on contemporary universal definition criteria including characteristic chest pain lasting more than 20 minutes, electrocardiographic changes showing ST-segment elevation of at least 1 mm in two or more contiguous leads or new left bundle branch block or ST-segment depression with positive cardiac biomarkers, elevated cardiac troponin levels above the 99th percentile upper reference limit, and willingness to provide informed consent for study participation. Both ST-elevation myocardial infarction and non-ST-elevation myocardial infarction patients were included in the study cohort.

Exclusion Criteria: Patients were excluded from the study if they met any of the following criteria:

prior history of magnesium supplementation or magnesium-containing antacids within one week before admission, pre-existing chronic kidney disease with estimated glomerular filtration rate less than 30 mL/min/1.73m², known chronic liver disease or cirrhosis, documented electrolyte disorders requiring ongoing supplementation therapy, history of malabsorption syndromes or chronic diarrheal diseases, pregnancy or lactation, patients receiving dialysis treatment, documented malignancy under active treatment, inability to provide informed consent due to altered mental status without available legal representative, and patients who expired within 6 hours of admission before complete initial evaluation could be performed.

Clinical Assessment and Data Collection: Detailed clinical history was obtained from all patients including demographic information, cardiovascular risk factors, previous medical history, and current medications. Physical examination was performed with particular attention to vital signs including blood pressure, heart rate, respiratory rate, and oxygen saturation. Killip classification was determined based on clinical assessment of heart failure severity. A 12-lead electrocardiogram was obtained immediately upon admission and was interpreted by qualified cardiologists to determine the type and location of myocardial infarction. All patients underwent echocardiographic examination within 24 hours of admission to assess left ventricular systolic function, regional wall motion abnormalities, and any mechanical complications. Left ventricular ejection fraction was calculated using the modified Simpson's biplane method.

Laboratory Investigations: Blood samples were collected from all patients within 30 minutes of hospital admission through peripheral venipuncture using standard aseptic techniques. Samples were collected in appropriate vacutainer tubes and were processed immediately in the central laboratory. Serum magnesium levels were measured using colorimetric assay with calmagite as the chromogen on an automated biochemistry analyzer. The normal reference range for serum magnesium in the laboratory was 1.7 to 2.4 mg/dL. Hypomagnesemia was defined as serum magnesium level below 1.7 mg/dL, while normomagnesemia was defined as serum magnesium level of 1.7 mg/dL or above. Additional laboratory parameters measured at admission included complete blood count, serum electrolytes including sodium and potassium, renal function tests including serum creatinine and blood urea nitrogen, random blood glucose, lipid profile including total cholesterol, triglycerides, high-density lipoprotein cholesterol and low-density lipoprotein cholesterol, and cardiac biomarkers including cardiac troponin-I and creatine kinase-MB isoenzyme. Serial cardiac biomarker measurements were performed at 6-hour and 12-hour intervals to document peak levels.

Patient Management and Monitoring: All patients received standard medical management for acute myocardial infarction according to current clinical practice guidelines. This included antiplatelet therapy with loading doses of aspirin and P2Y12 inhibitors, anticoagulation with unfractionated heparin or low molecular weight heparin, beta-blockers unless contraindicated, angiotensin-converting enzyme inhibitors or angiotensin receptor blockers, and statins. ST-elevation myocardial infarction patients underwent primary percutaneous coronary intervention when available within appropriate time windows, or received thrombolytic therapy with streptokinase or tenecteplase when primary percutaneous coronary intervention was not feasible. Non-ST-elevation myocardial infarction patients were managed according to risk stratification with either early invasive strategy or initial conservative management. Importantly, no therapeutic magnesium supplementation was administered to any patient during the initial 48 hours of hospitalization to avoid confounding the relationship between admission magnesium status and outcomes. All patients were continuously monitored with telemetry in the coronary care unit for detection of arrhythmias and hemodynamic instability.

Outcome Assessment and Follow-up Protocol: All patients were prospectively followed throughout their hospital stay until discharge or death. The primary outcome was the occurrence of major ventricular arrhythmias, specifically sustained ventricular tachycardia defined as ventricular tachycardia lasting more than 30 seconds or requiring termination due to hemodynamic compromise, and ventricular fibrillation requiring defibrillation. Secondary outcomes included development of acute heart failure defined according to Killip class II or higher with clinical and radiological evidence of pulmonary congestion, cardiogenic shock defined as sustained hypotension with systolic blood pressure less than 90 mmHg for more than 30 minutes despite adequate volume status with evidence of tissue hypoperfusion and requirement for inotropic support, and all-cause in-hospital mortality. All arrhythmic events were documented through continuous telemetry monitoring and were confirmed by review of rhythm strips by two independent cardiologists. Heart failure was diagnosed based on clinical criteria including dyspnea, pulmonary rales, elevated jugular venous pressure, and chest radiograph findings, supplemented by echocardiographic assessment

when necessary. All outcome events were recorded using standardized case report forms, and data were verified through review of medical records by investigators blinded to the magnesium status of individual patients.

Statistical Analysis: Statistical analysis was performed using SPSS software version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation and were tested for normal distribution using the Kolmogorov-Smirnov test. Categorical variables were expressed as frequencies and percentages. Comparison of continuous variables between hypomagnesemia and normomagnesemia groups was performed using independent samples t-test for normally distributed variables and Mann-Whitney U test for non-normally distributed variables. Categorical variables were compared using chi-square test or Fisher's exact test as appropriate depending on expected cell frequencies. Pearson correlation coefficient was calculated to assess the relationship between serum magnesium levels and continuous outcome variables.

Receiver operating characteristic curve analysis was performed to determine the optimal cutoff value of serum magnesium for predicting major cardiac complications, with calculation of area under the curve, sensitivity, and specificity. Multivariate logistic regression analysis was performed to identify independent predictors of adverse outcomes after adjusting for potential confounding variables including age, gender, diabetes mellitus, hypertension, smoking status, anterior wall myocardial infarction, and left ventricular ejection fraction. Results were expressed as odds ratios with 95% confidence intervals. A two-tailed p-value of less than 0.05 was considered statistically significant for all analyses.

Results

Baseline Characteristics: The study enrolled 160 patients with acute myocardial infarction, comprising 112 males (70.00%) and 48 females (30.00%). The mean age of the study population was 58.34 ± 11.26 years. Based on admission serum magnesium levels, patients were categorized into two groups: hypomagnesemia group (serum magnesium <1.7 mg/dL) consisting of 90 patients (56.25%) and normomagnesemia group (serum magnesium ≥1.7 mg/dL) consisting of 70 patients (43.75%). The mean serum magnesium level in the hypomagnesemia group was 1.42 ± 0.18 mg/dL compared to 2.03 ± 0.24 mg/dL in the normomagnesemia group, demonstrating a statistically significant difference ($p<0.001$).

The baseline demographic and clinical characteristics of both groups are presented in Table 1. The two groups were comparable with respect to age, gender distribution, and prevalence of cardiovascular risk factors including hypertension, diabetes mellitus, smoking status, and dyslipidemia, with no statistically significant differences observed. The proportion of ST-elevation myocardial infarction versus non-ST-elevation myocardial infarction was similar between groups. However, the hypomagnesemia group demonstrated a higher proportion of anterior wall myocardial infarction compared to the normomagnesemia group (48.89% vs 34.29%, $p=0.048$). The mean time from symptom onset to hospital presentation was comparable between groups (4.82 ± 2.14 hours vs 4.56 ± 2.08 hours, $p=0.453$).

Laboratory and Echocardiographic Parameters: Table 2 summarizes the laboratory and echocardiographic parameters of the study population. The mean serum potassium level was significantly lower in the hypomagnesemia group compared to the normomagnesemia group (3.76 ± 0.52 mmol/L vs 4.12 ± 0.48 mmol/L, $p<0.001$), suggesting an association between magnesium and potassium homeostasis. Serum creatinine levels were similar between groups (1.08 ± 0.32 mg/dL vs 1.04 ± 0.28 mg/dL, $p=0.421$).

Peak cardiac troponin-I levels were significantly higher in the hypomagnesemia group (42.68 ± 18.42 ng/mL vs 34.52 ± 16.28 ng/mL, $p=0.004$), suggesting larger infarct size in magnesium-deficient patients. Similarly, peak creatine kinase-MB levels were elevated in the hypomagnesemia group (186.34 ± 72.56 IU/L vs 152.78 ± 64.32 IU/L, $p=0.002$). Left ventricular ejection fraction assessed by echocardiography was significantly lower in patients with hypomagnesemia (42.28 ± 8.64% vs 46.82 ± 7.92%, $p=0.001$), indicating more severe left ventricular systolic dysfunction in this group.

Cardiac Arrhythmic Complications: The incidence of ventricular arrhythmic complications showed marked differences between the two groups, as detailed in Table 3. Sustained ventricular tachycardia occurred in 28 patients (31.11%) in the hypomagnesemia group compared to only 9 patients (12.86%) in the normomagnesemia group, demonstrating a statistically significant difference ($p=0.004$). The relative risk for ventricular tachycardia in hypomagnesemic patients was 2.42 (95% confidence interval: 1.23-4.76). Ventricular fibrillation requiring electrical defibrillation was documented in 16 patients (17.78%) with hypomagnesemia compared to 3 patients (4.29%) with normal magnesium levels ($p=0.007$), yielding a relative risk of 4.15 (95% confidence interval: 1.25-13.74). The combined incidence of any major ventricular arrhythmia (ventricular tachycardia or ventricular fibrillation) was significantly higher in the hypomagnesemia group (42.22% vs 15.71%,

p<0.001). Additionally, frequent premature ventricular contractions defined as more than 30 per hour were observed more commonly in hypomagnesemic patients (52.22% vs 30.00%, p=0.004). Atrial fibrillation developed in 22 patients (24.44%) with hypomagnesemia compared to 11 patients (15.71%) with normal magnesium levels, though this difference did not reach statistical significance (p=0.162).

Heart Failure and Cardiogenic Shock

The development of acute heart failure during hospitalization demonstrated a strong association with admission magnesium status, as shown in Table 4. Clinical evidence of heart failure with Killip class II or higher occurred in 38 patients (42.22%) in the hypomagnesemia group compared to 15 patients (21.43%) in the normomagnesemia group (p=0.003). When stratified by Killip classification, Killip class II heart failure was present in 24 patients (26.67%) with hypomagnesemia versus 12 patients (17.14%) with normal magnesium (p=0.134), while Killip class III heart failure occurred in 10 patients (11.11%) versus 3 patients (4.29%) respectively (p=0.104). Cardiogenic shock, representing the most severe hemodynamic complication, developed in 18 patients (20.00%) with hypomagnesemia compared to 5 patients (7.14%) with normomagnesemia (p=0.018), corresponding to a relative risk of 2.80 (95% confidence interval: 1.08-7.26). Patients who developed cardiogenic shock required vasopressor and inotropic support, with mean duration of inotrope therapy being 4.64 ± 2.18 days in the hypomagnesemia group compared to 3.20 ± 1.48 days in the normomagnesemia group (p=0.042). The requirement for mechanical ventilation was also higher in hypomagnesemic patients who developed cardiogenic shock (13 out of 18 patients, 72.22%) compared to normomagnesemic patients with shock (2 out of 5 patients, 40.00%), though the small numbers limited statistical interpretation (p=0.170).

Mortality Outcomes: In-hospital mortality represented the most critical endpoint of this investigation. As demonstrated in Table 5, all-cause mortality during hospitalization was significantly higher in the hypomagnesemia group, with 21 deaths (23.33%) compared to 6 deaths (8.57%) in the normomagnesemia group (p=0.011). The relative risk of in-hospital death associated with hypomagnesemia was 2.72 (95% confidence interval: 1.16-6.39). Analysis of the causes of death revealed that fatal ventricular arrhythmias accounted for 9 deaths (42.86%) in the hypomagnesemia group and 2 deaths (33.33%) in the normomagnesemia group.

Progressive cardiogenic shock with multi-organ failure was responsible for 8 deaths (38.10%) in hypomagnesemic patients compared to 3 deaths (50.00%) in normomagnesemic patients. Other causes including cardiac rupture, reinfarction, and stroke accounted for the remaining deaths in both groups. The mean time to death from admission was 4.82 ± 3.26 days in the hypomagnesemia group compared to 5.67 ± 2.94 days in the normomagnesemia group (p=0.521). Among patients who died, the mean serum magnesium level was 1.38 ± 0.24 mg/dL compared to 1.74 ± 0.38 mg/dL in survivors (p<0.001).

Correlation Analysis and Predictive Value: Pearson correlation analysis revealed significant inverse relationships between serum magnesium levels and various adverse outcomes, as presented in Table 6. Serum magnesium demonstrated a significant negative correlation with the occurrence of ventricular tachycardia (r = -0.286, p<0.001), ventricular fibrillation (r = -0.242, p=0.002), development of heart failure (r = -0.268, p=0.001), cardiogenic shock (r = -0.223, p=0.004), and in-hospital mortality (r = -0.238, p=0.002). Additionally, serum magnesium levels showed positive correlation with left ventricular ejection fraction (r = 0.312, p<0.001) and negative correlation with peak troponin-I levels (r = -0.276, p<0.001).

Receiver operating characteristic curve analysis identified an optimal serum magnesium cutoff value of 1.58 mg/dL for predicting the composite outcome of major cardiac complications or death, with an area under the curve of 0.736 (95% confidence interval: 0.658-0.814, p<0.001), sensitivity of 68.75%, and specificity of 71.43%. Multivariate logistic regression analysis adjusting for age, diabetes mellitus, anterior myocardial infarction, and left ventricular ejection fraction demonstrated that hypomagnesemia remained an independent predictor of in-hospital mortality with an adjusted odds ratio of 3.42 (95% confidence interval: 1.28-9.16, p=0.014).

Table 1: Baseline Demographic and Clinical Characteristics

Parameter	Hypomagnesemia (n=90)	Normomagnesemia (n=70)	p-value
Age (years), mean ± SD	59.12 ± 11.84	57.34 ± 10.48	0.324
Male gender, n (%)	64 (71.11)	48 (68.57)	0.719
Hypertension, n (%)	52 (57.78)	38 (54.29)	0.651
Diabetes mellitus, n (%)	38 (42.22)	26 (37.14)	0.511
Current smoking, n (%)	46 (51.11)	34 (48.57)	0.747
Dyslipidemia, n (%)	42 (46.67)	30 (42.86)	0.627

Family history of CAD, n (%)	24 (26.67)	18 (25.71)	0.893
Previous MI, n (%)	12 (13.33)	8 (11.43)	0.717
STEMI, n (%)	62 (68.89)	46 (65.71)	0.673
Anterior wall MI, n (%)	44 (48.89)	24 (34.29)	0.048
Time to presentation (hours), mean ± SD	4.82 ± 2.14	4.56 ± 2.08	0.453
Systolic BP (mmHg), mean ± SD	128.64 ± 24.32	132.18 ± 22.86	0.354
Heart rate (bpm), mean ± SD	84.26 ± 16.42	80.52 ± 14.68	0.139
Serum magnesium (mg/dL), mean ± SD	1.42 ± 0.18	2.03 ± 0.24	<0.001

CAD = Coronary artery disease; MI = Myocardial infarction; STEMI = ST-elevation myocardial infarction; BP = Blood pressure; SD = Standard deviation

Table 2: Laboratory and Echocardiographic Parameters

Parameter	Hypomagnesemia (n=90)	Normomagnesemia (n=70)	p-value
Serum potassium (mmol/L), mean ± SD	3.76 ± 0.52	4.12 ± 0.48	<0.001
Serum sodium (mmol/L), mean ± SD	138.42 ± 4.26	139.18 ± 3.84	0.248
Serum creatinine (mg/dL), mean ± SD	1.08 ± 0.32	1.04 ± 0.28	0.421
Random blood glucose (mg/dL), mean ± SD	162.34 ± 52.68	154.26 ± 48.32	0.327
Total cholesterol (mg/dL), mean ± SD	186.42 ± 42.36	182.64 ± 38.52	0.566
LDL cholesterol (mg/dL), mean ± SD	118.26 ± 36.48	114.82 ± 34.26	0.543
HDL cholesterol (mg/dL), mean ± SD	38.64 ± 8.42	40.12 ± 9.26	0.304
Triglycerides (mg/dL), mean ± SD	152.48 ± 62.34	146.82 ± 58.26	0.562
Peak troponin-I (ng/mL), mean ± SD	42.68 ± 18.42	34.52 ± 16.28	0.004
Peak CK-MB (IU/L), mean ± SD	186.34 ± 72.56	152.78 ± 64.32	0.002
Hemoglobin (g/dL), mean ± SD	13.42 ± 1.86	13.68 ± 1.74	0.378
Total leucocyte count (×10³/μL), mean ± SD	11.84 ± 3.26	11.32 ± 2.94	0.304
LVEF (%), mean ± SD	42.28 ± 8.64	46.82 ± 7.92	0.001

LDL = Low-density lipoprotein; HDL = High-density lipoprotein; CK-MB = Creatine kinase-MB; LVEF = Left ventricular ejection fraction; SD = Standard deviation

Table 3: Cardiac Arrhythmic Complications

Arrhythmia	Hypomagnesemia (n=90)	Normomagnesemia (n=70)	p-value	Relative Risk (95% CI)
Ventricular tachycardia, n (%)	28 (31.11)	9 (12.86)	0.004	2.42 (1.23-4.76)
Ventricular fibrillation, n (%)	16 (17.78)	3 (4.29)	0.007	4.15 (1.25-13.74)
Any major VT/VF, n (%)	38 (42.22)	11 (15.71)	<0.001	2.69 (1.50-4.81)
Frequent PVCs, n (%)	47 (52.22)	21 (30.00)	0.004	1.74 (1.16-2.62)
Atrial fibrillation, n (%)	22 (24.44)	11 (15.71)	0.162	1.56 (0.82-2.95)
Complete heart block, n (%)	8 (8.89)	4 (5.71)	0.442	1.56 (0.49-4.94)

VT = Ventricular tachycardia; VF = Ventricular fibrillation; PVCs = Premature ventricular contractions; CI = Confidence interval

Table 4: Heart Failure and Hemodynamic Complications

Complication	Hypomagnesemia (n=90)	Normomagnesemia (n=70)	p-value	Relative Risk (95% CI)
Any heart failure (Killip ≥II), n (%)	38 (42.22)	15 (21.43)	0.003	1.97 (1.18-3.29)
Killip class II, n (%)	24 (26.67)	12 (17.14)	0.134	1.56 (0.85-2.85)
Killip class III, n (%)	10 (11.11)	3 (4.29)	0.104	2.59 (0.75-8.99)
Killip class IV, n (%)	4 (4.44)	0 (0.00)	0.093	-
Cardiogenic shock, n (%)	18 (20.00)	5 (7.14)	0.018	2.80 (1.08-7.26)
Inotrope requirement, n (%)	32 (35.56)	14 (20.00)	0.025	1.78 (1.04-3.04)
Duration of inotropes (days), mean ± SD	4.64 ± 2.18	3.20 ± 1.48	0.042	-
Mechanical ventilation, n (%)	22 (24.44)	9 (12.86)	0.054	1.90 (0.94-3.84)

CI = Confidence interval; SD = Standard deviation

Table 5: Mortality Outcomes

Outcome	Hypomagnesemia (n=90)	Normomagnesemia (n=70)	p-value	Relative Risk (95% CI)
In-hospital mortality, n (%)	21 (23.33)	6 (8.57)	0.011	2.72 (1.16-6.39)
Cause of death:				
Fatal arrhythmias, n (% of deaths)	9 (42.86)	2 (33.33)	0.684	-
Cardiogenic shock, n (% of deaths)	8 (38.10)	3 (50.00)	0.623	-
Cardiac rupture, n (% of deaths)	2 (9.52)	0 (0.00)	0.512	-
Reinfarction, n (% of deaths)	1 (4.76)	1 (16.67)	0.351	-
Stroke, n (% of deaths)	1 (4.76)	0 (0.00)	0.612	-
Time to death (days), mean ± SD	4.82 ± 3.26	5.67 ± 2.94	0.521	-
Serum Mg in deaths (mg/dL), mean ±SD	1.38 ± 0.24	1.68 ± 0.18	0.006	-

CI = Confidence interval; SD = Standard deviation; Mg = Magnesium.

Table 6: Correlation Analysis Between Serum Magnesium and Clinical Outcomes

Variable	Pearson Correlation Coefficient (r)	p-value
Ventricular tachycardia	-0.286	<0.001
Ventricular fibrillation	-0.242	0.002
Heart failure (any)	-0.268	0.001
Cardiogenic shock	-0.223	0.004
In-hospital mortality	-0.238	0.002
Left ventricular ejection fraction	0.312	<0.001
Peak troponin-I	-0.276	<0.001
Peak CK-MB	-0.264	0.001
Hospital length of stay	-0.186	0.018

ROC Curve Analysis for Composite Outcome (Major Complications or Death)

- Optimal serum magnesium cutoff: 1.58 mg/dL
- Area under curve: 0.736 (95% CI: 0.658-0.814)
- Sensitivity: 68.75%
- Specificity: 71.43%
- p-value: <0.001

CK-MB = Creatine kinase-MB; CI = Confidence interval; ROC = Receiver operating characteristic.

Discussion

The present prospective observational study demonstrated a significant association between hypomagnesemia at hospital admission and increased incidence of major cardiac complications as well as in-hospital mortality in patients with acute myocardial infarction. The prevalence of hypomagnesemia in this cohort was 56.25%, which was consistent with previous reports suggesting that magnesium deficiency affects approximately 40 to 65 percent of patients admitted with acute coronary syndromes.[11] The findings of this investigation provided several important insights into the prognostic significance of serum magnesium status in the acute myocardial infarction population, and the results suggested that routine measurement of admission magnesium levels might serve as a valuable adjunct to existing risk stratification tools in coronary care units.

The most striking finding of this study was the substantially elevated incidence of life-threatening ventricular arrhythmias in patients with hypomagnesemia. Ventricular tachycardia occurred in 31.11% of hypomagnesemic patients compared to 12.86% of those with normal magnesium levels, while ventricular fibrillation was observed in 17.78% versus 4.29% respectively. These findings were concordant with the results reported by Goyal et al. who found that hypomagnesemia was associated with a 2.8-fold increased risk of ventricular arrhythmias in acute myocardial infarction patients.[12] Similarly, Bashir et al. reported that patients with serum magnesium levels below 1.6 mg/dL had significantly higher rates of ventricular tachycardia and ventricular fibrillation compared to those with higher magnesium concentrations.[13] The mechanistic basis for the arrhythmogenic effects of magnesium deficiency has been elucidated through multiple experimental studies demonstrating that hypomagnesemia enhances automaticity of ectopic pacemaker sites, prolongs action potential duration through effects on potassium channel function, and increases intracellular calcium accumulation which promotes triggered activity and afterdepolarizations.[14] In the setting of acute myocardial ischemia, these electrophysiological derangements are further amplified by autonomic imbalance, metabolic acidosis, and regional heterogeneity of repolarization, creating a substrate highly susceptible to reentrant arrhythmias.

The association between hypomagnesemia and development of acute heart failure observed in this study was also noteworthy, with 42.22% of

magnesium-deficient patients developing clinical heart failure compared to 21.43% of those with normal magnesium status. This finding was consistent with the report by Alshaarawy et al. who identified low serum magnesium as an independent predictor of heart failure development in acute myocardial infarction patients.[15] The mechanisms underlying this association likely involve magnesium's role in myocardial energy metabolism and contractile function. Magnesium serves as an essential cofactor for adenosine triphosphate synthesis and utilization, and deficiency states impair the efficiency of oxidative phosphorylation, thereby compromising myocardial contractile reserve during periods of increased metabolic demand such as the acute phase of myocardial infarction.[16] Additionally, magnesium deficiency has been shown to promote myocardial inflammation and oxidative stress, processes that contribute to infarct expansion and adverse left ventricular remodeling. The observation in this study that left ventricular ejection fraction was significantly lower in hypomagnesemic patients provided additional support for the detrimental effects of magnesium deficiency on myocardial systolic function.

Cardiogenic shock, representing the most severe hemodynamic complication of acute myocardial infarction, occurred in 20.00% of hypomagnesemic patients compared to only 7.14% of those with normal magnesium levels in this study. This finding paralleled the results of Ahmed et al. who reported that hypomagnesemia was associated with increased risk of cardiogenic shock in their cohort of anterior wall myocardial infarction patients.[17] The relationship between magnesium status and cardiogenic shock development may be multifactorial, involving not only the direct effects of magnesium on myocardial contractility but also its influence on systemic vascular resistance and coronary microvascular function. Magnesium acts as a physiological vasodilator through multiple mechanisms including calcium channel blockade and enhancement of endothelial nitric oxide production, and deficiency states may therefore contribute to increased afterload and impaired coronary perfusion, factors that can precipitate or exacerbate cardiogenic shock in the setting of extensive myocardial damage.[18] The most clinically significant finding of this investigation was the substantially elevated in-hospital mortality rate among hypomagnesemic patients, with 23.33% mortality in the magnesium-deficient group compared to 8.57% in those with normal magnesium levels. This represented a nearly three-fold increase in mortality risk associated with hypomagnesemia, which persisted even after adjustment for traditional risk factors in multivariate analysis. These results were remarkably similar to those reported by Kafkas et al. who found that low serum magnesium was an independent predictor of 30-day mortality in acute myocardial infarction patients with an adjusted odds ratio of 3.1.[19] However, it should be noted that some studies have reported conflicting results regarding the prognostic significance of magnesium status. Specifically, the meta-analysis by Shiga et al. suggested that while hypomagnesemia was associated with increased arrhythmia risk, the relationship with mortality was less consistent across studies.[20] These discrepancies may be attributable to differences in study populations, timing of magnesium measurement, definitions of hypomagnesemia, and adjustment for confounding variables. The present study attempted to minimize these limitations through prospective enrollment, standardized outcome definitions, and comprehensive adjustment for potential confounders in statistical analyses.

The correlation analysis performed in this study revealed significant inverse relationships between serum magnesium levels and various adverse outcomes, suggesting that the association between magnesium status and complications may be continuous rather than strictly threshold-dependent. This finding was consistent with the concept that even mild degrees of magnesium deficiency may have clinically relevant effects, and supported the potential value of viewing magnesium as a continuous prognostic variable rather than simply categorizing patients as hypomagnesemic or normomagnesemic. The receiver operating characteristic curve analysis identified an optimal cutoff value of 1.58 mg/dL for predicting the composite outcome of major complications or death, which was slightly lower than the conventional laboratory threshold of 1.7 mg/dL typically used to define hypomagnesemia. This observation suggested that the relationship between magnesium levels and outcomes may begin at concentrations still considered within the lower normal range by standard laboratory criteria, and raised questions about whether current reference ranges for serum magnesium are optimally calibrated for cardiovascular risk assessment.

An important consideration in interpreting the findings of this study relates to the potential mechanisms underlying magnesium deficiency in acute myocardial infarction patients. Several pathophysiological processes operative during acute coronary events may contribute to acute magnesium depletion, including catecholamine surge-induced renal losses, insulin-mediated intracellular shifts, and increased cellular consumption during stress responses.[21] Additionally, chronic magnesium deficiency may represent a pre-existing risk factor that contributes to atherosclerosis development and acute coronary

events, rather than simply being a consequence of the acute illness. This bidirectional relationship between magnesium status and cardiovascular disease complicates efforts to establish causality and raises important questions about whether magnesium deficiency should be viewed primarily as a modifiable risk factor amenable to intervention or predominantly as a prognostic marker reflecting disease severity and baseline risk. The neutral results of large randomized trials examining prophylactic magnesium supplementation in unselected acute myocardial infarction patients, such as the ISIS-4 and MAGIC trials, suggested that empirical magnesium administration to all patients was not beneficial.[22] However, these trials did not specifically target patients with documented hypomagnesemia, and it remains possible that selective magnesium repletion in deficient patients might improve outcomes, a hypothesis that warrants investigation in future targeted clinical trials.

Several limitations of this study deserve consideration. First, serum magnesium concentration may not accurately reflect total body magnesium stores, as the vast majority of body magnesium is intracellular or bound in bone, with less than 1% present in extracellular fluid. Ionized magnesium, which represents the physiologically active fraction, was not measured in this study due to technical limitations, and some investigators have suggested that ionized magnesium measurement might provide superior prognostic information compared to total serum magnesium.[23] Second, magnesium levels were measured only at admission, and serial measurements during hospitalization might have provided additional insights into the dynamics of magnesium homeostasis and the potential impact of medical therapies on magnesium status. Third, the observational nature of this study precludes definitive conclusions regarding causality, and unmeasured confounding variables may have influenced the observed associations between magnesium status and outcomes. Fourth, the sample size, while adequate for detecting differences in major outcomes, may have been insufficient for certain subgroup analyses or for detecting smaller effect sizes in secondary endpoints. Finally, this study was conducted at a single center with a specific patient population, and generalizability to other settings and populations requires confirmation through multicenter investigations with diverse patient cohorts.

Despite these limitations, this study provided robust evidence supporting the prognostic significance of admission serum magnesium levels in acute myocardial infarction patients. The findings suggested that incorporation of magnesium measurement into routine initial laboratory assessment might enhance risk stratification and could potentially identify patients who might benefit from closer monitoring or more aggressive interventions. Future research directions should include prospective randomized controlled trials specifically examining whether targeted magnesium supplementation in patients with documented hypomagnesemia at the time of acute myocardial infarction can reduce the incidence of arrhythmic complications and improve survival outcomes. Additionally, investigation of optimal magnesium repletion protocols, including timing, dosing, and route of administration, would be valuable for informing clinical practice. Research examining the potential mechanisms linking magnesium deficiency to adverse outcomes at the molecular and cellular levels could also provide insights that might identify novel therapeutic targets beyond simple magnesium replacement. Finally, cost-effectiveness analyses evaluating the clinical and economic implications of routine magnesium screening in acute coronary care would help inform healthcare policy decisions regarding implementation of magnesium assessment in standard protocols for acute myocardial infarction management.

Conclusion

This prospective observational study demonstrated that hypomagnesemia at hospital admission was significantly associated with increased incidence of major cardiac complications and in-hospital mortality in patients with acute myocardial infarction.

Specifically, magnesium-deficient patients experienced substantially higher rates of life-threatening ventricular arrhythmias including ventricular tachycardia and ventricular fibrillation, more frequent development of acute heart failure and cardiogenic shock, and nearly three-fold elevation in in-hospital mortality compared to patients with normal admission magnesium levels. These associations persisted after adjustment for traditional cardiovascular risk factors and markers of disease severity, suggesting that hypomagnesemia may represent an independent prognostic indicator in this population.

The findings indicated that routine measurement of serum magnesium at the time of hospital presentation for acute myocardial infarction may provide valuable prognostic information that could enhance risk stratification and guide clinical decision-making regarding intensity of monitoring and therapeutic interventions. While these observational data cannot establish causality or prove that magnesium replacement would improve outcomes, they provide a strong rationale for future randomized controlled trials examining whether targeted magnesium supplementation in deficient

patients might reduce complications and improve survival in acute myocardial infarction. Until such evidence becomes available, heightened awareness of magnesium status and consideration of this readily measurable parameter in prognostic assessment appears warranted in the management of patients with acute coronary syndromes.

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