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Assessment of serum magnesium levels in patients with Acute Coronary Syndrome presenting within 48 hours of onset of symptoms to the emergency department in a tertiary care hospital

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Abstract

Background: The aim of the study was to analyze serum magnesium (Mg) levels in patients with acute coronary syndrome (ACS) who presented within 48 hours of the onset of symptoms to the Emergency Department.

Methods: A total of 150 patients with ACS who presented within 48 hours of the onset of symptoms with chest pain and ECG changes suggestive of ACS were included. Serum Mg levels, along with sodium, potassium, calcium, and troponin levels, were measured.

Results: The majority of ACS cases occurred after the 6th decade of life (52.66%). Most patients in our study had non-ST-elevation myocardial infarction (NSTEMI) compared to ST-elevation myocardial infarction (STEMI) (48% vs 44%), and 8% of cases were of unstable angina. Recurrent myocardial infarction (MI) was observed in 34% of cases. Hypertension was present in 98 patients (65.33%), followed by diabetes (33.33%), and 54 patients (36%) had hyperlipidemia. Low serum Mg levels (< 1.8 mg%) were found in 54 patients (36%), 37 patients (24.66%) had serum Mg levels between 1.8 and 1.9 mg%, and 19.33% and 14% of cases had levels between 2 to 2.1 mg% and 2.2 to 2.3 mg%, respectively. Elevated serum Mg levels (≥ 2.4 mg%) were found in 6% of cases. Among the STEMI, NSTEMI, unstable angina, and recurrent MI cases, 33.33%, 40.27%, 25%, and 30.91%, respectively, had serum Mg levels < 1.8 mg%. The mean serum Mg levels among the low-risk, intermediate-risk, and high-risk ACS groups were 1.50 ± 0.71, 2.02 ± 0.32, and 1.72 ± 0.28, respectively ($p < 0.05$). The mean serum Mg level in the patients was 1.78 ± 0.32 on day 1 and 2.32 ± 0.44 on day 5. The mean serum Mg level was lower in recurrent MI patients than in those without recurrent MI (1.88 ± 0.34 vs 1.90 ± 0.31). Among the different types of STEMI, the mean serum Mg level was lowest in posterior wall MI (1.6). The mean serum Mg (mg%) levels in STEMI, NSTEMI, and unstable angina were 1.91 ± 0.28, 1.86 ± 0.32, and 1.97 ± 0.50, respectively. In recurrent MI patients, serum Mg was 1.88 ± 0.33. A significant positive correlation was found between serum sodium and serum Mg levels ($r = 0.23$, $p = 0.004$).

Conclusion: Low Mg levels were associated with higher disease severity. More studies are needed to determine whether serum Mg levels, along with other electrolyte levels, can be used as a complete electrolyte panel or as an adjuvant cardiac biomarker in the diagnosis and further management of ACS.

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Highlights

What is current knowledge?

- Mg is a crucial component of various biochemical reactions that require kinases (300 enzymes).
- Mg depletion is associated with multiple cardiovascular implications, including arrhythmogenesis, vasospasm, hypertension, and platelet activity.

What is new here?

- Significantly lower serum Mg levels were recorded in patients with chest pain presenting within 48 hours of the onset of symptoms.
- The role of hypomagnesemia as a marker of acute coronary syndrome has been clarified.

Introduction

Chest pain is one of the most common reasons for Emergency Department visits. Studies have shown that young Indians have ten times more risk of developing myocardial infarction (MI) compared to the Western population (1). Hence, acute coronary syndrome (ACS), especially in young Indians, is of particular concern.

Identifying ACS is very important, though prognosis depends on multiple factors, many of which are unexplained.

Magnesium (Mg) has been implicated in the pathogenesis of ACS and its complications, such as arrhythmias, especially in MI (2,3).

An adult's body contains approximately 24 grams of Mg, of which 50%-60% is present in the bones, while the remainder exists in soft tissues. Serum Mg levels represent less than 1% of the total body Mg (4).

Mg is a cofactor for 300 enzymatic reactions, including glycemic control, blood pressure regulation, and lipid peroxidation. The site of action of Mg involves platelets, smooth muscle, and myocardial cells. Mg deficiency can evoke hyperlipidemia and, subsequently, atherogenic deposits in coronary arteries, which leads to atherosclerosis (5). Hence, measuring Mg is crucial for cardiovascular health.

Mg acts as a cardioprotective element due to its β-adrenoreceptor-blocking, antiplatelet effects, and inhibitory action on the cardiac conduction system (6). It is considered essential for maintaining the functional integrity of the myocardium. Mg also plays a significant role in other cardiovascular diseases. It has been found that myocardial Mg concentration is very low in patients who experience sudden death due to ischemia. In addition, the ion-stabilizing effect of Mg helps maintain stable intra- and extracellular concentrations of other electrolytes. Various studies have documented significant alterations in Mg and other electrolytes in patients with acute myocardial infarction (AMI).

There is a close association between intracellular Mg status and the cellular ionic balance of sodium, potassium, and calcium. Although Mg deficiency can potentiate oxidative injuries in the post-ischemic myocardium, routine checks of serum electrolytes, especially serum Mg in ACS patients, along with cardiac troponins, are not commonly performed, even in private hospitals. The correlation between serum Mg and other electrolytes in ACS, or the change in serum Mg levels in different types of ACS or with cardiac biomarkers, has not been widely researched to date, despite numerous reports on the use of Mg as an adjuvant therapy in MI.

Hence, the present study was conducted to assess the level of serum Mg and other electrolytes in ACS patients.

Primary objectives:

1. To assess the alteration in serum Mg levels in patients with ACS who present within 48 hours of symptom onset.
2. To assess the difference in serum Mg levels across various types of ACS (ST-elevation myocardial infarction (STEMI), non-ST-elevation myocardial infarction (NSTEMI), unstable angina, and recurrent MI).

Methods

Study population:

All patients with ACS who presented to the Emergency Medicine Department of

Sree Gokulam Medical College and Research Foundation, a tertiary care hospital in rural Kerala, within 48 hours of symptom onset during the study period.

Study setting:

The study was conducted in the Emergency Medicine Department of Sree Gokulam Medical College and Research Foundation, Trivandrum, Kerala.

Study period:

18 months (September 2019 to March 2021).

Inclusion criteria:

All patients meeting the criteria for ACS who presented within 48 hours of symptom onset during the study period in the Department of Emergency Medicine with two of the following features:

1. Characteristic chest pain,
2. ECG changes suggestive of ACS,
3. Elevated cardiac enzymes (Troponin T).

Exclusion criteria:

- Patients with renal failure (Both ARF and CRF),
- Patients with acute and chronic liver failure,
- Patients with acute gastroenteritis,
- Patients with malignancy or features suggestive of sepsis,
- Already diagnosed cases of myocarditis, pericarditis, and rheumatic fever.

Study design:

Hospital-based cross-sectional study.

Sampling technique:

Consecutive sampling.

Sample size estimation:

Reference article: Lal L, Murmu H (7). Serum Mg in Patients with AMI. Required sample size (n),

Sample size calculation:

$$n = \frac{Z_{1}-\alpha/2 \quad S^2}{d^2}$$

$\bar{x}$ = 1.01(Of Serum Mg level in mg %)
SD=0.94
α (Type 1 error) = 5%
Z1 –α/2=1.96
d=15% of $\bar{x}$, Therefore, n = 150

Data collection methods:

Data was collected from the sample population using data collection forms to evaluate the association between Mg and ACS.

Study variables:

Serum Mg levels in NSTEMI, STEMI, unstable angina, and re-infarction.

Confounding variables:

Serum levels of sodium, potassium, and calcium; smoking; diabetes; hypertension; dyslipidemia.

Background variables:

Age, sex, S/P CABG or S/P angioplasty, past history of CAD, or other known comorbidities.

Data collection forms

Study Tool/Instrument: Serum electrolytes and serum troponin levels were measured using the Siemens Dimension RxL Max fully automatic biochemistry analyser. Serum Mg levels were measured using the photometric method, while the other electrolytes and troponin were measured using integrated multisensor technology.

Methodology of data collection:

Informed written consent was obtained from the patient or legal relatives. Participants enrolled in the study completed a questionnaire, and a proforma was filled out by the researcher based on their data, along with laboratory test reports of serum electrolytes and troponin T values. Information was collected from case sheets, investigation reports, and previous medical records. Baseline serum creatinine levels and previous medical history were reviewed to determine acute or chronic renal failure and meet the inclusion criteria. A 4 ml blood sample was drawn into a plain bottle, and serum separated by centrifuge was used to estimate Mg, troponin T, and other electrolyte levels. Approved commercial reagent kits adapted to the analyser were used, and samples were analysed by the Siemens Dimension RxL Max Fully Automatic Biochemistry Analyser. The overall workflow is detailed in Figure 1.

Reference values (2-4,6,7):

Sodium = 136-145 mmol/L, Potassium = 3.5-5.1 mmol/L, Calcium = 8.5-10.1 mg%, Mg = 1.8-2.4 mg%, and Troponin T = <0.010 is considered negative.

Statistical analysis:

Data collected was entered in Microsoft Excel, and statistical analysis was performed using SPSS software. Quantitative variables are expressed as mean and standard deviation, while study population characteristics are expressed as percentages. To compare serum Mg levels across different groups of ACS, the Chi-square test was used. The relationship between serum Mg levels and other electrolytes in ACS was analysed using Pearson's correlation.

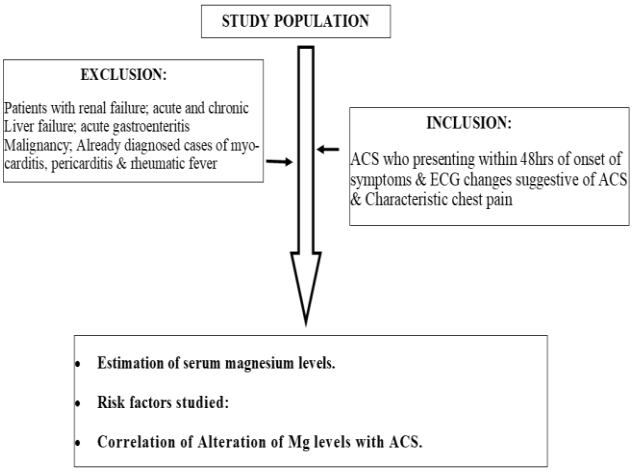

Figure 1. Flow chart of study plan

Definitions:

ECG changes suggestive of ACS:

STEMI is characterized by ST-segment elevation in two or more contiguous leads or a new left bundle branch block. Threshold values for ST-segment elevation consistent with STEMI are J-point elevation greater than 2 mm (0.2 mV) in leads V2 and V3 and 1 mm or more in all other leads, or by new or presumed new right bundle branch block (8).

NSTEMI is characterized by ST-segment depression of 0.5 mm (0.05 mV) or greater, or dynamic T-wave inversion with pain or discomfort. Non-persistent or transient ST elevation of 0.5 mm or greater for less than 20 minutes is also included in this category (9).

The other types of ACS are characterized by normal or non-diagnostic changes in the ST segment or T wave that are inconclusive and require risk stratification.

Results

Among the types, 66 patients (44%) had STEMI, while 72 patients (48%) had NSTEMI, and only 8% had unstable angina. Out of 150 cases, 34% had recurrent MI. Hence, the majority of the patients in our study had NSTEMI rather than STEMI. Of those, 45.5% of STEMI patients, 58.3% of NSTEMI patients, and 50% of unstable angina patients were over 65 years of age. There was no significant association between ACS and age ($p = 0.3$). A total of 105 were males and 45 were females, resulting in a male-to-female ratio of 2.3:1.

Basic characteristics:

Among STEMI, NSTEMI, and unstable angina patients, 45.5%, 58.3%, and 50% were under 65 years of age, respectively. In addition, 7% of STEMI patients, 69.4% of NSTEMI patients, and 58.3% of unstable angina patients were male. In this study, no significant association was found between age, gender, smoking, hypertension, diabetes, and different types of ACS ($p > 0.05$). A previous history of CAD was observed in 44% of NSTEMI cases, compared to 21% of STEMI cases and 42% of unstable angina cases. Furthermore, 14% of NSTEMI patients and 25% of unstable angina patients had undergone CABG previously. Additionally, 31% of NSTEMI patients, 33% of unstable angina patients, and 12% of STEMI patients had other comorbidities. All these findings were statistically significant.

Among the risk factors, 95 patients were hypertensive (63%), which is a major risk factor for the development of ACS, followed by diabetes (50%). Fifty-two patients (35%) were found to have hyperlipidemia, and 34 patients (23%) had other comorbidities such as hypothyroidism, CVA, seizure disorder, and rheumatoid arthritis. Fifty-one patients (34%) had a previous history of CAD. Forty-eight patients (32%) were known or ex-smokers, and they were all male.

Among the 51 patients with a previous history of CAD, 13 patients had undergone CABG, and 25 patients had undergone percutaneous coronary intervention (PCI), while the rest were on medical management. Out of 150 ACS patients, 8.7% and 16.7% had undergone CABG and PCI previously (Table 1).

Patients who did not have ST-elevation MI were risk stratified using the HEART score. Of these, 2.4% belonged to the low-risk ACS group, 53.6% belonged to the intermediate-risk ACS group, and 44% belonged to the high-risk ACS group. Among these, 1%, 38%, and 33% of the low-risk, intermediate-risk, and high-risk patients had NSTEMI, while the remaining 12% had unstable angina (Table 2).

Table 1. Association between different types of acute coronary syndrome and various factors

Age	ACS						Total		P-value
	STEMI		NSTEMI		Unstable angina				
	n	%	n	%	n	%	n	%	
> 65	30	45.5	42	58.3	6	50	78	52	0.3
45-65	32	48.5	29	40.3	6	50	67	44.7	
< 45	4	6.1	1	1.4	0	0	5	3.3	
Gender									
Male	48	72.7	50	69.4	7	58.3	105	70	0.6
Female	18	27.3	22	30.6	5	41.7	45	30	
Smoking									
No	45	68.2	50	69.4	7	58.3	102	68	0.7
Yes	21	31.8	22	30.6	5	41.7	48	32	
Hypertension									
No	28	42.4	22	30.6	5	41.7	55	36.7	0.3
Yes	38	57.6	50	69.4	7	58.3	95	63.3	
diabetes									
No	33	50	34	47.2	8	66.7	75	50	0.45
Yes	33	50	38	52.8	4	33.3	75	50	
Dyslipidaemia									
No	50	75.8	41	56.9	7	58.3	98	65.3	0.05
Yes	16	24.2	31	43.1	5	41.7	52	34.7	
Previous history of CAD									
No	52	78.8	40	55.6	7	58.3	99	66	0.01
Yes	14	21.2	32	44.4	5	41.7	51	34	
Coronary artery bypass grafting (CABG)									
No	66	100	62	86.1	9	75	137	91.3	0.002
Yes	0	0	10	13.9	3	25	13	8.7	
PCI									
No	56	84.8	59	81.9	10	83.3	125	83.3	0.9
Yes	10	15.2	13	18.1	2	16.7	25	16.7	

Table 2. Distribution of ST-elevation myocardial infarction in acute coronary syndrome patients

HEART score	ACS			
	NSTEMI		Unstable angina	
	n	%	n	%
Low risk	1	1.4	1	8.3
Intermediate risk	38	52.8	7	58.3
High risk	33	45.8	4	33.3
Total	72	100.0	12	100.0

The majority of the cases that had STEMI were classified as anterior or inferior wall MI. Out of 66 patients with STEMI, 26 patients (39%) had anterior wall MI, and 28 patients (42%) had inferior wall MI. In addition, 6% of the cases had inferior plus posterior wall MI, while another 6% had lateral wall MI. Posterior wall MI alone and anterolateral wall MI were less than 5%.

Out of 150 ACS cases, 51 patients (34%) were found to have low serum Mg levels (< 1.8 mg%), while 40 patients (27%) had serum Mg levels on the lower side, i.e., 1.8 to 1.9 mg%. Additionally, 19% and 15% had serum Mg levels between 2 to <2.2 and 2.2 to 2.4 mg%, respectively. Only 5.3% had elevated serum Mg levels (>2.4 mg%). Out of 150 ACS cases, 32% of STEMI patients, 38% of NSTEMI patients, 25% of unstable angina cases, and 29% of recurrent MI cases had serum Mg levels <1.8 mg%. In contrast, only 6%, 4%, 8%, and 6% of STEMI, NSTEMI, unstable angina, and recurrent MI patients had serum Mg levels ≥ 2.4 mg%. The majority of cases had hypomagnesemia (p = 0.9).

Majority (61%) of the ACS cases had normal serum sodium levels. Fifty-seven patients (38%) were found to have serum sodium levels < 135 mmol/L, and 0.7% had serum sodium levels > 145 mmol/L. Out of the 150 ACS cases, 32% of STEMI cases, 43% of NSTEMI cases, 42% of unstable angina cases, and 45% of recurrent MI cases had serum sodium levels <135 mmol/L. Furthermore, 67% of STEMI cases, 57% of NSTEMI cases, 58% of unstable angina cases, and 55% of recurrent MI cases had serum sodium levels between 135 to 145 mmol/L. Only 1.5% of STEMI cases and none of the NSTEMI, unstable angina, or recurrent MI cases had serum sodium levels > 145 mmol/L. The majority of cases had serum sodium levels in the normal range (p = 0.5) (Table 3).

The majority (89%) of the ACS cases had normal serum potassium levels. Ten patients (7%) were found to have serum potassium levels < 3.5 mmol/L, and 4% had serum potassium levels > 4.5 mmol/L. Out of the 150 ACS cases, 7% of STEMI cases, 6% of NSTEMI cases, 8% of unstable angina cases, and 6% of recurrent MI cases had serum potassium levels < 3.5 mmol/L. In addition, 88% of STEMI cases, 90% of NSTEMI cases, 92% of unstable angina cases, and 92% of recurrent MI cases had serum potassium levels in the range of 3.5-4.5 mmol/L. Only 4.5% of STEMI cases, 4% of NSTEMI cases, 2% of recurrent MI cases, and none of the unstable angina cases had serum potassium levels > 4.5 mmol/L. The majority of cases had serum potassium levels in the normal range.

Table 3. Serum magnesium, sodium, potassium, and calcium levels in acute coronary syndrome patients

Variables		STEMI		NSTEMI		Unstable angina		Frequency	Percent	*P-value
		n	%	n	%	n	%			
Mg	< 1.8	22	33.33	29	40.27	3	25	51	34	0.9 (ns)
	1.8-1.9	17	25.75	16	22.22	4	33.33	40	26.7	
	2.0-2.1	12	18.18	15	20.83	2	16.66	28	18.7	
	2.2-2.3	11	16.66	9	12.5	1	8.33	23	15.3	
	≥ 2.4	4	6.06	3	4.16	2	16.66	8	5.3	
Na	< 135	21	31.8	32	44.44	5	41.66	57	38	0.5 (ns)
	135-145	44	66.7	39	54.16	7	58.34	92	61.3	
	>145	1	1.5	1	0	0	0	1	0.7	
K+	< 3.5	5	7.6	5	6.95	1	8.3	10	6.7	0.9 (ns)
	3.5-5.1	58	87.9	63	87.5	11	91.7	134	89.3	
	> 5.1	3	4.5	4	5.55	0	0	6	4	
Ca+	< 8.5	16	24.25	23	31.95	2	16.7	39	26	0.5
	8.5-10.1	49	74.25	49	68.05	10	83.3	110	73.3	
	> 10.1	1	1.5	0	0	0	0	1	0.7	

ns: non-significant.

The majority (73%) of the ACS cases had normal serum calcium levels. Thirty-nine patients (26%) were found to have serum calcium levels < 8.5 mg%, and 0.7% had serum calcium levels > 10.1 mg%. Out of the 150 ACS cases, 23% of STEMI patients, 31% of NSTEMI patients, 17% of unstable angina cases, and 23.5% of recurrent MI patients had serum calcium levels < 8.5 mg%. In addition, 76% of STEMI patients, 69% of NSTEMI patients, 83% of unstable angina cases, and 74.5% of recurrent MI cases had serum calcium levels between 8.5 and 10.1 mg%. Only 1.5% of STEMI cases and 2% of recurrent MI cases had serum calcium levels > 10.1 mg%. None of the NSTEMI or unstable angina cases had serum calcium levels > 10.1 mg%. The majority of cases had serum calcium levels in the normal range.

Association between serum magnesium and other variables:

The mean serum Mg levels (mg %) among low-risk, intermediate-risk, and high-risk ACS groups were 1.50 ± 0.71, 2.02 ± 0.32, and 1.72 ± 0.28, respectively. It was found that there is a statistically significant relationship between mean serum Mg levels and the HEART score.

The mean serum Mg levels in NSTEMI (1.86 ± 0.32) were lower than those in STEMI (1.92 ± 0.28) (Table 4). The mean serum Mg level in recurrent MI patients was lower than that in those with no recurrent MI (1.90 ± 0.31). Among the different types of STEMI, the mean serum Mg was lowest in posterior wall MI (1.88 vs. 1.60, p > 0.05).

Table 4. Association between serum magnesium and other variables

Variables	ACS						P-value
	STEMI (n=66)		NSTEMI (n=72)		Unstable Angina (n=12)		
	Mean	SD	Mean	SD	Mean	SD	
Sodium, Na+ (mmol/l)	135.76	5.005	135.22	4.7	134.37	8.05	0.6 (ns)
Potassium, K+(mmol/l)	4.09	0.57	4.2	0.6	4.13	0.49	0.3 (ns)
Calcium,Ca+ (mg %)	8.81	0.61	8.64	0.6	8.800	0.54	0.3 (ns)
Magnesium, Mg (mg %)	1.913	0.28	1.856	0.318	2.04	0.5	0.4 (ns)
Troponin	1.6	2.38	0.64	1.072	0.014	0.009	0.02

ns: Nonsignificant

In the 150 ACS patients, the mean serum sodium levels (mmol/l) among STEMI, NSTEMI, and unstable angina patients were 135.75 ± 5.0, 135.21 ± 4.79, and 134.36 ± 8.05, respectively. In recurrent MI patients, the level was 134.6 ± 5.2.

The mean serum potassium levels (mmol/l) among STEMI, NSTEMI, and unstable angina patients were 4.09 ± 0.56, 4.24 ± 0.60, and 4.13 ± 0.49, respectively. In recurrent MI patients, the level was 4.3 ± 0.6.

The mean serum calcium levels (mg%) among STEMI, NSTEMI, and unstable angina patients were 8.80 ± 0.61, 8.64 ± 0.66, and 8.80 ± 0.54, respectively. In recurrent MI patients, the level was 8.8 ± 0.6; the observed difference was not statistically significant (p > 0.05).

The mean serum Mg levels (mg%) among STEMI, NSTEMI, and unstable angina patients were 1.91 ± 0.28, 1.86 ± 0.32, and 1.97 ± 0.50, respectively. In recurrent MI patients, the level was 1.88 ± 0.33. Although the observed difference was not found to be statistically significant, the average value of serum troponin in different types of ACS was statistically significant (p < 0.05).

There was a significant positive correlation found between changes in serum sodium and serum Mg levels, with a correlation r value of 0.240 and p < 0.05. Subjects with higher serum sodium levels experienced greater changes in serum Mg levels in ACS patients (Table 5).

Table 5. Correlation between serum magnesium levels with other variables

Correlation of magnesium with other variables	Pearson Correlation, r value	p
SODIUM (mmol/l)	0.240	0.003
K+ (mmol/l)	0.078	0.344
Calcium (mg%)	0.107	0.194
Age	- 0.051	0.541

Discussion

In this study of 150 patients with ACS, those enrolled met the inclusion criteria. The majority of ACS cases occurred after the sixth decade of life (52.66%).

Among these 150 ACS cases, 103 were males and 47 were females. Of the males, 52.42% belonged to the age group >65, while 43.69% belonged to the age group of 45-65. Of the females, 47% were >65 and 46.81% belonged to the 45-65 age group. It was found that males were at a higher risk of developing ACS at an earlier age compared to females, but this was not statistically significant.

The majority of the patients in our study had NSTEMI rather than STEMI (48% vs. 44%). Those with STEMI had either anterior (39.4%) or inferior (42.4%) wall MI. Out of 150 cases, 34% had recurrent MI, 6% had inferior + posterior wall MI, and another 6% had lateral wall MI. Posterior wall MI alone and anterolateral wall MI were both <5%.

The mean serum Mg levels in NSTEMI (1.86±0.32) were lower than in STEMI (1.92±0.28). The mean serum Mg in recurrent MI patients (1.88±0.34) was lower than in those with no recurrent MI (1.90±0.31). Among the different types of STEMI, the mean serum Mg was lowest in posterior wall MI (1.6).

In our study, only 8% had unstable angina. The very few cases of unstable angina may be explained by the general perception among patients that symptoms related to unstable angina are insignificant or merely gastritis, leading to an unwillingness for further investigation or evaluation, or to visit the ED.

Patients who did not have STEMI were risk stratified using the HEART score to avoid missing low-probability ACS. In our study, 2.4% of cases were in the low-risk ACS group, 53.6% were in the intermediate-risk ACS group, while 44% were in the high-risk ACS group.

The high frequency of intermediate to high-risk ACS can be attributed to the fact that most patients who presented to the ED had multiple comorbidities and were mostly follow-up cases from the parent cardiology department of our hospital, presenting with symptoms suggestive of ACS.

It was found that there is a statistically significant relationship between mean serum Mg level and the HEART score. The mean serum Mg level was found to be lower in both the low-risk and high-risk ACS groups compared to the intermediate-risk ACS group.

Also, in this study, the mean serum Troponin levels in different types of ACS were statistically significant, and it was found that there was a statistically significant relationship between mean serum Mg levels and serum Troponin values. Our study, therefore, supports the views of other studies that serum Mg can be used as a prognostic indicator in ACS and can also be included in the diagnostic electrolyte panel for MI.

Out of the 150 ACS cases, 54 patients (36%) were found to have low serum Mg levels (<1.8 mg%), and 37 patients (24.66%) had serum Mg levels on the lower side, i.e., between 1.8 and 1.9 mg%. In addition, 19.33% and 14% had serum Mg levels between 2.0 to 2.1 mg% and 2.2 to 2.3 mg%, respectively. Only 6% had elevated serum Mg levels (⩾2.4 mg%). This indicates that the majority of the ACS cases had hypomagnesemia.

Most patients in our study had normal serum sodium, potassium, and calcium levels. The mean serum sodium, potassium, and calcium levels in different types of ACS (STEMI, NSTEMI, and unstable angina) and in recurrent MI were also within the normal range. These findings were not statistically significant. When comparing serum Mg levels in patients with ACS to other electrolytes, we found that the majority of patients had normal levels of other major cations, such as serum sodium, potassium, and calcium, in contrast to their serum Mg levels.

Correlation between changes in serum sodium and serum Mg levels was analyzed using Pearson correlation. There was a significant positive correlation between changes in serum sodium and serum Mg levels.

The Steg study (10) and the study by Baset et al. (11) showed that acute MI is more common in the age group of 51–60 (32%) and in males (72%), which is similar to this study. In their study, the most common risk factors for acute MI were smoking (70%), diabetes mellitus (36%), hypertension (30%), obesity (24%), and hyperlipidemia (12%). In the Steg study (10), the most common risk factors for acute MI were smoking (62%), hypertension (50%), diabetes mellitus (21%), prior infarction (19%), and hyperlipidemia (35%). Kelly et al. showed that family history contributes to a 25% risk of ACS. In our study, 63% were hypertensive, 50% were diabetic, 35% were hyperlipidemic, 34% had a previous history of CAD, 32% were smokers, while 23% were found to have other comorbidities like hypothyroidism and CVA.

In a study, serum Mg concentration in the AMI group ranged from 0.42 to 1.56 meq/L, with a mean value of 1.01 meq/L, and it was statistically significant ($P < 0.01$). Within the first 48 hours after a heart attack, 80% of patients had hypomagnesemia (12).

Abraham et al. (12) reviewed Mg levels in 65 consecutive patients with an admission diagnosis of AMI. Serum Mg concentrations were found to be low in patients who had AMI (Mean 1.70 mg/dL, $p < 0.001$) or acute coronary insufficiency (Mean 1.61 mg/dL, $p < 0.01$), but not in the control group or patients with non-cardiac chest pain (Mean 1.91 mg/dL).

Dimtruk (13), in his series of 67 patients with ischemic heart disease, showed a distinct reduction in plasma Mg during the first 3 days following the onset of the disease, with levels returning to normal by 15-25 days from the onset. In another study by Sachdev et al. (14), Mg levels in 30 patients with MI were determined within 24 hours, on the 5th day, and on the 8th day, reported as 1.83±0.087 mg%, 1.91±0.149 mg%, and 1.97±0.089 mg%, compared to a control of 2.44±0.162 mg%. The values were found to be statistically lower on all three days, showing a progressive rise.

Another study by Shafiq et al. (15) involving 10,806 patients with AMI found that 63% had serum Mg checked (With hospital variability ranging from 10% to 98%) during a median hospital stay of approximately 3.1 days. After dividing the Mg levels during admission into quartiles, they found that patients with admission Mg levels <1.8 and >2 had higher mortality than those in the middle quartiles ($p < 0.001$). Furthermore, the most recent Mg level was still associated with in-hospital mortality in a U-shaped manner ($p < 0.001$). For Mg levels around 1.8, the lowest hazard of death was seen, with increased hazards for serum Mg levels <1.7 and >1.9 (14).

One study found that patients with AMI had significantly lower serum Mg levels (Mean = 1.01, range = 0.42–1.56) than the control group (2.2 mEq/L). Although we did not compare our findings between AMI patients and the control group, we observed that ACS cases had low serum Mg levels, consistent with previous studies (7).

Another study conducted on AMI patients displayed that on the first day of admission, 16% and 34% of patients experienced serum Mg levels of less than 1.6 and between 1.6–2.4 mg/dL, respectively (16).

It was observed that subjects treated with intravenous Mg after MI had a considerably decreased chance of dying from ischemic heart disease-related sequelae (17,18).

Akila et al. found that AMI patients with low Mg levels were more likely to have arrhythmias (19).

A study of 9,005 patients with AMI found that serum Mg levels between 2.2 and ⩽2.4 and more than 2.4 mg/dL were significant predictors of all-cause in-hospital mortality (20). Serum Mg levels between 2.2 and ⩽2.4 mg/dL were associated with a greater risk of in-hospital death than those above 2.4 mg/dL (20).

Studies have shown that patients with AMI are prone to slight hypomagnesemia immediately after the development of infarction, and when reversed by treatment to a state of transient hypermagnesemia, the incidence of arrhythmias, especially supraventricular, can be lowered (21,22). Hence, it is one of the important reasons to measure serum Mg levels in all ACS patients, especially those with AMI.

Conclusion

Low Mg levels are associated with higher disease severity. Our study has shown considerable variations in serum Mg levels from the normal baseline values in ACS patients, especially when compared to those of other electrolytes. Reviewing previous studies that show its association with various risk factors and complications related to ACS emphasizes the significance of measuring serum Mg, which should be given as much importance as measuring other electrolytes like serum sodium and potassium in ACS patients. Further research is required to determine the prognostic role of serum Mg levels in ACS. More studies need to be conducted to assess whether serum Mg levels, along with other electrolyte levels, can be used as a complete electrolyte panel or as an adjuvant cardiac biomarker in the diagnosis and further management of ACS.

Recommendations: Most AMI patients experience low serum Mg levels on the first day of hospital admission. This study has demonstrated a definite association between Mg and various presentations of ACS.

The low level of serum Mg is associated with the development of other complications; hence, a better understanding of the association between serum Mg levels and ACS severity is necessary.

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Ethical statement

Informed patient consent was obtained from all patients before collecting data. The subject identities/initials were not revealed anywhere. This study protocol is approved by the Institutional Research Committee and the Institutional Ethical Committee of Sree Gokulam Medical College and Research Foundation (Code: 34/456/04/2019). The study followed the Declaration of Helsinki, and the subjects provided written informed consent.

Conflicts of interest

The authors declare that there is no conflict of interest.

Author contributions

LM and NM collected data, designed the experimental framework, and conceptualized the study. LM revised and analyzed the data. NM, RS, and AS drafted the manuscript. The final version of the draft was reviewed and approved by all authors.

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