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Are Electrolyte Imbalances Related to 3-Month Outcomes in Patients with an Acute Myocardial Infarction? A Cohort Study from Iran

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ABSTRACT

Background: Acute myocardial infarction (AMI) is one of the leading causes of death worldwide. Contradictory findings are available regarding the effects of changes in electrolytes in patients with an AMI.
Objectives: We aimed to investigate the effect of electrolyte changes on the 3-month outcome.
Methods: A total of 168 patients with AMI managed at Dr. Heshmat Hospital in Rasht, Iran, were investigated in this prospective cohort study by a census method. AMI was confirmed by biochemical, electrocardiographic, or angiographic evidence. Electrolyte serum levels, demographic characteristics, myocardial infarction type, ejection fraction (EF), and underlying diseases were collected in a checklist in the early hours after each patient entered the hospital. Information about patients' outcomes and echocardiographic data were collected after three months. All data were analyzed using SPSS software version 22.
Results: Out of 162 patients with AMI, most (44%) were aged between 50 to 59 years, and 76.8% were men. In all models, the odds of non-recovery remained constant with increasing electrolytes. On uni-variable and multi-variable models, sodium showed a significant positive association with initial EF (unstandardized coefficient = 0.8 in both uni-variable and multi-variable models, approximately), and phosphorus displayed a significant negative association with initial EF (unstandardized coefficient = -4.5 in both uni-variable and multi-variable models, approximately). There was no significant association of electrolytes with follow-up EF in all models.
Conclusions: In this study, the phosphorus and sodium serum levels were significantly related to the initial EF. However, none of the studied electrolytes impacted the 3-month outcome in AMI patients.

1. Introduction

Cardiovascular diseases (CVDs) are the most common cause of mortality and morbidity worldwide. In Iran, about 43% of all deaths are caused by CVDs (1). Acute myocardial infarction (AMI) is the most serious clinical manifestation of CVD (2).

Electrolyte homeostasis plays a significant role in maintaining normal cell metabolism, intracellular fluid osmotic pressure, acid-base balance, and nerve excitement. The abnormality of myocardial excitability and conductivity caused by electrolyte disturbance can lead to different degrees of arrhythmia, and severe cases can cause myocardial infarction or cardiac arrest (3, 4).

Electrolyte imbalances have a high prevalence and a major impact on mortality among patients with AMI. These electrolyte imbalances can predict mortality incidence in patients with AMI (5-7). Also, electrolyte imbalance and autonomic nervous system activity are believed to be primarily responsible for the sudden cardiac death that occurs after AMI (death within 1 hour) through changes in the

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environment at the level of myocytes and Purkinje fibers (8).

Serum electrolytes have been rarely studied in AMI, which is a leading cause of death worldwide (9).

2. Objectives

This study aimed to assess the relationship between electrolyte imbalances and outcomes in patients with AMI in the north of Iran.

2.1. Patients and Methods

2.1.1. Participants

In this prospective cohort study, 162 patients with AMI (both STEMI and NSTEMI) participated. These patients were managed at Dr. Heshmat Hospital, the only specialized heart center in the Guilan province, Rasht, Iran, in 2020. The diagnosis was confirmed by biochemical evidence, electrocardiography, or angiography.

2.1.2. Data Collection

Study participants were selected using the census method. Demographic information of the patients, myocardial infarction (MI) type, ejection fraction (EF), and their underlying diseases such as hypertension (HTN), hyperlipidemia (HLP), diabetes mellitus (DM), and ischemic heart diseases (IHD) were collected. The serum level of electrolytes, measured within one to three hours from the beginning of the hospitalization, was recorded.

Laboratory levels of examined serum electrolytes were reported with normal ranges as follows: sodium (Na): 135 – 145 mEq/dL, calcium (Ca): 8.5 – 10.5 mg/dL, phosphorus (P): 2.5 – 4 mg/dL, potassium (K): 3.5 – 5.4 mEq/dL, uric acid: 3 – 6.5 mg/dL and magnesium (Mg): 1.3 - 1.2 mg/dL. Fibrinolytic prescription and percutaneous coronary intervention (PCI) type were noted. All data were recorded in a prepared checklist.

2.1.3. Follow-up

All participants were followed up three months after hospitalization, and the occurrence of recurrent AMI, arrhythmia, cardiogenic shock, and cerebrovascular accident, as well as information about the patient's outcome (recovery/non-recovery [including death]) and echocardiographic indicators were recorded.

2.2. Statistical Analysis

All analyses were performed using SPSS software version 22. Qualitative variables (outcome and mortality) are expressed as frequency (percentage). Quantitative variables (EF and electrolyte levels) are expressed as mean ± standard deviation and median (interquartile range).

Uni-variable and multi-variable (unadjusted and adjusted) regression models were conducted to determine the independent variables affecting mortality, troponin positivity, and mean EF. The significance level was considered as $P < 0.05$.

3. Results

A total of 162 AMI cases were included in this study. Most patients (44%) were aged between 50 and 59 years, and 76.8% were men. The type of MI was STEMI in 91% of cases. Moreover, 40.5% (n = 68) of patients did not have underlying diseases, and among those with underlying disease, HTN was more common than the rest (26.2%, n = 44), and DM and HLP were in the second and third ranks, respectively. About 59% (n = 99) of patients underwent primary PCI, while a fibrinolytic was prescribed for just 20.8% (n = 35). Based on angiography results, most (36.3%, n = 61) had three-vessel disease (3VD).

The mean Na, K, Ca, P, Mg, and uric acid levels were 137.05 ± 3.08 mEq/dL, 4.08 ± 0.53 mEq/dL, 9.32 ± 0.58 mg/dL, 3.50 ± 0.70 mg/dL, 1.97 ± 0.19 mg/dL, and 5.10 ± 1.51 mg/dL, respectively. The mean EF based on echocardiography results was 43.60 ± 15.19% in the primary assessment and 45.45 ± 14.79% in the follow-up assessment.

The outcomes in this study were considered as recovery and non-recovery (including death). According to the results of Table 1, in all of the models, the odds of non-recovery remained constant with increasing electrolytes. By increasing the age of participants, the odds of non-recovery increased by 6%.

The results in Table 2 show that the electrolytes had no relationship with troponin positivity before and after adjusting for sex and age.

On uni-variable and multi-variable models (Table 3), sodium showed a significant positive association with initial EF (unstandardized coefficient = 0.8 in both uni-variable and multi-variable models, approximately), while phosphor displayed a significant negative association with initial EF (unstandardized coefficient = -4.5 in both uni-variable and multi-variable models, approximately). There was no significant association of any other electrolyte with initial EF.

All models revealed no significant association of electrolytes with follow-up EF, as shown in Table 4.

Table 1. Logistic Regression Models for Non-Recovery Outcome after Three Months

	Uni-Variable Model	Multi-variable model	
		Unadjusted	Adjusted for Age and Sex
Sodium	0.96 (0.86 – 1.06)	0.94 (0.85 – 1.05)	0.93 (0.83 – 1.04)
Potassium	1.3 (0.73 – 2.32)	1.11 (0.6 – 2.05)	1.06 (0.56 – 2.03)
Calcium	0.64 (0.37 – 1.11)	0.62 (0.35 – 1.11)	0.67 (0.37 – 1.21)
Phosphor	1.02 (0.66 – 1.57)	1.01 (0.65 – 1.56)	0.93 (0.59 – 1.46)
Magnesium	0.69 (0.14 – 3.49)	0.97 (0.17 – 5.49)	1.04 (0.17 – 6.4)
Uric acid	1.13 (0.92 – 1.38)	1.14 (0.92 – 1.42)	1.13 (0.91 – 1.4)
Age	-	-	1.06 * (1.02 – 1.1)
Sex (male)	-	-	1.12 (0.49 – 2.57)

* $P < 0.05$ was considered statistically significant. Results are presented as odds ratio (95% confidence interval). The outcome after three months was considered the dependent variable in all models.

Table 2. Logistic Regression Models for Positive Troponin			
	Uni-Variable Model	**Multi-Variable Model**	
		Unadjusted	**Adjusted for Age and Sex**
Sodium	1.11 (0.85 – 1.46)	1.08 (0.79 – 1.46)	1.07 (0.81 – 1.42)
Potassium	0.93 (0.18 – 4.91)	0.93 (0.16 – 5.56)	0.83 (0.12 – 5.89)
Calcium	0.65 (0.14 – 3.09)	0.58 (0.11 – 3.08)	0.69 (0.12 – 3.92)
Phosphor	0.66 (0.32 – 1.34)	0.64 (0.3 – 1.36)	0.57 (0.26 – 1.27)
Magnesium	1.29 (0.01 – 151.39)	1.87 (0.01 – 299.57)	2.18 (0.01 – 494.66)
Uric acid	1.36 (0.71 – 2.6)	1.33 (0.68 – 2.6)	1.44 (0.67 – 3.08)
Age	-	-	1.09 (0.98 – 1.23)
Sex (male)	-	-	1.34 (0.1 – 17.43)

Results are presented as odds ratio (95% confidence interval). Troponin (positive/negative) was considered the dependent variable in all models.

Table 3. Linear Regression Models Investigating the Association of Electrolytes and Initial Ejection Fraction			
	Uni-Variable Model	**Multi-variable model**	
		Unadjusted	**Adjusted for Age and Sex**
Sodium	0.85 (0.1 – 1.59)*	0.79 (0.02 – 1.56)*	0.78 (0.002 – 1.56)*
Potassium	-2.44 (-6.79 – 1.92)	-1.29 (-5.78 – 3.19)	-1.50 (-6.13 – 3.13)
Calcium	-2.38 (-6.41 – 1.64)	-1.94 (-6.02 – 2.14)	-1.88 (-6.02 – 2.25)
Phosphor	-4.45 (-7.69 – -1.2)*	-4.49 (-7.72 – -1.25)*	-4.56 (-7.83 – -1.29)*
Magnesium	-3.93 (-16.02 – 8.16)	-4.16 (-16.49 – 8.17)	-3.69 (-16.34 – 8.95)
Uric acid	-0.48 (-2.03 – 1.06)	-0.64 (-2.19 – 0.9)	-0.63 (-2.19 – 0.93)
Age	-	-	0.033 (-0.22 – 0.29)
Sex (male)	-	-	-0.94 (-6.89 – 5.015)

* $P < 0.05$ was considered statistically significant. Results are presented as unstandardized coefficients (B) with a 95% confidence interval. Initial ejection fraction was considered as the dependent variable in all models.

Table 4. Linear Regression Models Investigating the Association of Electrolytes and Follow-up Ejection Fraction			
	Uni-Variable Model	**Multi-Variable Model**	
		Unadjusted	**Adjusted for Age and Sex**
Sodium	0.54 (-0.19 – 1.27)	0.6 (-0.17 – 1.37)	0.62 (-0.16 – 1.39)
Potassium	-2.02 (-6.26 – 2.23)	-0.93 (-5.39 – 3.54)	-0.81 (-5.42 – 3.79)
Calcium	-0.12 (-4.06 – 3.81)	0.61 (-3.45 – 4.67)	0.48 (-3.63 – 4.59)
Phosphor	-1.41 (-4.63 – 1.81)	-1.51 (-4.73 – 1.7)	-1.42 (-4.67 – 1.83)
Magnesium	-6.02 (-17.76 – 5.73)	-6.74 (-19.02 – 5.53)	-6.95 (-19.54 – 5.63)
Uric acid	-1.25 (-2.75 – 0.24)	-1.33 (-2.86 – 0.21)	-1.31 (-2.87 – 0.25)
Age	-	-	-0.07 (-0.32 – 0.19)
Sex (male)	-	-	0.21 (-5.71 – 6.13)

Results are presented as unstandardized coefficients (B) with a 95% confidence interval. Follow-up ejection fraction was considered as the dependent variable in all models.

4. Discussion

As electrolytes play an important role in determining the prognosis of patients with AMI (10), we conducted this study to investigate electrolyte imbalances and their relationship with the three-month prognosis in patients with AMI.

Of the 168 examined patients, nearly 77% were men, and the average age of the patients was 57.8 years. We found that the probability of non-recovery increased with an increment in age. The most common underlying diseases were HTN and DM. In a study conducted by Sanchez et al. in 2019 in Mexico, the average age of the patients with AMI was 63.2 years, and 75% of them were men; similarly, HTN and DM were the most common underlying diseases (11). In the Ebadi Fard Azar et al. study in 2021 (12), the average age of the patients was 60 years, and 71% were men. Again, DM and HTN were the most common underlying diseases.

In general, according to our findings, the three-month outcome of the patients and their EF in the follow-up were unrelated to the electrolyte serum levels, though the non-recovery outcome probability was higher in NSTEMI patients. Only two electrolytes, P and Na, were related to the initial EF.

As mentioned, one of our findings was the positive relation between Na and initial EF (but not follow-up EF). These findings corroborate the ideas of Chi et al.'s study (13), which suggested that hyponatremia during admission was a strong predictive factor and indicated a poor prognosis of AMI. They also found a positive association between Na and initial EF. Since the EF index indicates the ventricular function, it can be concluded that patients with lower Na serum levels have weaker ventricular function, which itself can have a relative effect on a patient's prognosis. Rathore et al. (14) found that Na was significantly lower in patients with AMI than in controls and could be used as a prognosis marker. In contrast, in a recent study by Hasan et al. (15), hypernatremia was observed in MI patients. The main mechanism responsible for hyponatremia in patients with CVDs is increased renin-angiotensin-aldosterone activation

(16). Hyponatremia can be dilutional or depletional in AMI because loop diuretics are used in this setting. These agents block the sodium, potassium, and chloride cotransporter in the thick ascending part of the loop of Henle, which is relatively water-impermeable (17).

An unanticipated finding in our study was a negative relation between serum P levels and EF on the primary assessment. This result differs from some published studies (Cao et al., (18), Aronson et al. (19), and Zhu et al. (20)) that found a positive correlation between these two variables, where elevated P serum levels were associated with mortality in patients with MI. This discrepancy may be because of their larger sample size. Vascular calcification of muscle cells has been recognized in patients with elevated P and Ca. In humans with reduced EF, a higher propensity for calcification was associated with worse outcomes (21).

Although we found no relation between the studied outcomes and the serum Ca, K, Mg, and uric acid levels, some previous studies suggested otherwise (22-27).

5. Conclusions

In this study, the serum P and Na levels were significantly related to the EF at the time of admission, which can indicate the effect of the serum level of these electrolytes on the heart function of patients with AMI. However, none of the studied electrolytes impacted the 3-month outcomes. According to our findings and comparing them with the results of other studies, further work is required to establish more generalizable results.

5.1. Ethical Approval

This study was approved under the ethical approval code IR.GUMS.REC.1399.610.

5.2. Informed Consent

Written informed consent was obtained from each participant.

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Authors' Contribution

S.N.: study concept and design, administrative, technical, and material support. E.R.: study supervision, critical manuscript revision for important intellectual content. Y.B.: drafting of the manuscript. B.G.: statistical analysis. B.A.: acquisition of data. S.K.: critical revision of the manuscript for important intellectual content. A.S.: study concept and design and drafting of the manuscript. S.F.M.: study supervision and acquisition of data.

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