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Study of serum electrolyte in patients admitted to ICU and their impact on clinical outcomes

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Abstract:
Electrolyte disturbances are common among critically ill patients, but their impact on clinical outcomes in intensive care units remains an important concern. Therefore, it is of interest to evaluate the association between serum electrolyte abnormalities and clinical outcomes in 107 medical intensive care unit patients admitted over 12 months. The mean age was 51.4 ± 16.5 years, overall mortality was 34.6% and hyponatremia (31.8%), hypokalemia (38.3%), Hypocalcemia (69.2%), hypomagnesemia (21.5%) and hypophosphatemia (17.8%) were the predominant abnormalities. Hyponatremia, hypernatremia, hypokalemia and Hypocalcemia were significantly associated with higher mortality, while serum sodium ($p < 0.001$), potassium ($p < 0.001$) and calcium ($p = 0.013$) showed significant relationships with clinical outcomes. Thus, data shows serum sodium, potassium and calcium abnormalities as important prognostic indicators and reinforce the value of routine electrolyte monitoring for improving outcomes in critically ill patients.

Keywords: Electrolyte disturbances, intensive care unit (ICU), hyponatremia, hypokalemia, hypocalcemia, mortality, critical illness, clinical outcome

Background:
Electrolyte balance is essential for maintaining normal physiological functions including neuromuscular activity, acid-base homeostasis, cellular metabolism, cardiac conduction and fluid balance. Critically ill patients admitted to intensive care units (ICUs) frequently develop disturbances in serum electrolyte concentrations due to the severity of their underlying illness, multiple organ dysfunction and use of medications, fluid therapy, renal impairment, endocrine abnormalities and nutritional deficiencies **[1]**. These electrolyte abnormalities may contribute significantly to adverse clinical outcomes and therefore represent an important area of investigation in critical care medicine **[2].** Among ICU patients, sodium disorders are among the most common electrolyte abnormalities. Hyponatremia may result from excessive fluid administration, syndrome of inappropriate antidiuretic hormone secretion (SIADH), heart failure, liver disease, or renal dysfunction **[3]**. Hypernatremia often develops due to dehydration, osmotic diuresis, or impaired thirst mechanisms. Both conditions have been associated with increased mortality, neurological complications and prolonged ICU stays **[4].** Potassium plays a vital role in maintaining membrane potential and cardiac electrical activity. Hypokalemia can lead to muscle weakness, respiratory failure and potentially fatal arrhythmias, while hyperkalemia is associated with life-threatening cardiac conduction disturbances. Electrolyte disorders involving potassium are particularly common in critically ill patients due to renal dysfunction, diuretic therapy, acid-base abnormalities and administration of various medications**.** Calcium is another important electrolyte involved in neuromuscular transmission, coagulation pathways, hormone secretion and myocardial contractility. Hypocalcemia is frequently observed in critically ill patients and may occur secondary to sepsis, acute pancreatitis, renal failure, massive transfusion and vitamin D deficiency. Several studies have demonstrated an association between hypocalcemia and increased severity of illness as well as higher mortality rates in ICU populations **[5, 6].** Magnesium is an essential intracellular cation that participates in numerous enzymatic reactions and influences cardiovascular, neuromuscular and metabolic functions. Hypomagnesemia has been reported in up to 60% of critically ill patients and is associated with increased risk of arrhythmias, prolonged mechanical ventilation and mortality. Similarly, phosphate abnormalities are frequently observed in ICU settings. Hypophosphatemia can impair respiratory muscle function, reduce myocardial performance and compromise immune function, whereas hyperphosphatemia is commonly associated with renal failure and poor outcomes **[4, 6].** Recent evidence suggests that electrolyte abnormalities are not merely laboratory findings but may serve as important prognostic indicators in critically ill patients. The presence of multiple electrolyte disturbances has been associated with longer ICU stay, greater need for mechanical ventilation, increased healthcare costs and higher mortality rates. Early detection and appropriate management of these abnormalities may improve patient outcomes and reduce complications **[7, 8].** Despite advances in critical care medicine, electrolyte disorders remain highly prevalent in ICUs worldwide. However, the pattern and prognostic significance of these disturbances may vary across different populations and healthcare settings. Limited data are available from central India regarding the prevalence of electrolyte abnormalities and their relationship with clinical outcomes among ICU patients **[9–11].** Therefore, it is of interest to evaluate the association between electrolyte disturbances and clinical outcomes including discharge and mortality.

Materials and Methodology:
Study design:
The present study was conducted as a prospective observational study to evaluate serum electrolyte abnormalities among patients admitted to the Intensive Care Unit (ICU) and to assess their impact on clinical outcomes.

Study setting:
The study was carried out in the Department of General Medicine, R.D. Gardi Medical College and Associated Hospital, Ujjain, Madhya Pradesh, after obtaining approval from the Institutional Ethics Committee.

Study duration:

The study was conducted over a period of 12 months, including patient recruitment, data collection, follow-up, statistical analysis and interpretation of results.

Study population:
The study population consisted of adult patients admitted to the Medical Intensive Care Unit (MICU) with various medical illnesses requiring intensive monitoring and treatment.

Sample size:
The sample size was calculated using the formula for estimation of a single population proportion.

Assumptions used:
[1] Prevalence (p) of metabolic alkalosis among ICU patients = 20%
[2] Confidence level = 95%
[3] Precision (d) = 10%
[4] Significance level (α) = 0.01
The calculated sample size was 107 patients.
Therefore, a total of 107 consecutive eligible ICU patients were enrolled in the study.

Sampling technique:
A consecutive sampling method was employed, whereby all eligible patients admitted to the Medical ICU during the study period were included until the required sample size was achieved.

Inclusion criteria:
Patients fulfilling all of the following criteria were included:
[1] Patients admitted to the Medical ICU.
[2] Patients aged ≥18 years.
[3] Patients admitted with internal medical illnesses.
[4] Patients or legally authorized representatives willing to provide informed consent.

Exclusion criteria:
Patients were excluded if they had:
[1] Undergone elective surgical procedures.
[2] Undergone emergency surgical interventions.
[3] Surgical ICU admissions.
[4] Incomplete laboratory records.
[5] Refusal to participate in the study.

Data collection procedure:
Following ICU admission, eligible patients were evaluated using a structured case record form.
The following information was recorded:

Demographic characteristics:
[1] Age
[2] Gender
[3] Residence
[4] Occupation

Clinical characteristics:
[1] Primary diagnosis
[2] Comorbid conditions
[3] Vital parameters at admission
[4] Requirement of mechanical ventilation
[5] Duration of ICU stay

Laboratory investigations:
Venous blood samples were collected at admission under aseptic precautions and analyzed in the central laboratory.
The following serum electrolytes were measured and their reference ranges are mentioned in (**Table 1)**:
[1] Serum Sodium (Na^+)
[2] Serum Potassium (K^+)
[3] Serum Calcium (Ca^{2+})
[4] Serum Magnesium (Mg^{2+})
[5] Serum Phosphate (PO_4^{3-})
Electrolyte values below the lower limit were considered deficient, while values above the upper limit were considered elevated.

Outcome assessment:
Clinical outcomes were assessed throughout ICU admission and categorized as:

Favorable outcome:
[1] Improvement in clinical condition
[2] Transfer from ICU
[3] Hospital discharge

Unfavorable outcome:
Death during ICU stay:
The outcome was obtained from hospital medical records and discharge summaries.

Ethical considerations:
Ethical approval was obtained from the Institutional Ethics Committee before commencement of the study. Written informed consent was obtained from patients or legally authorized attendants. Confidentiality of patient information was strictly maintained. The study was conducted according to the ethical principles outlined in the Declaration of Helsinki.

Statistical analysis:
Data were entered into Microsoft Excel and analyzed using Statistical Package for Social Sciences (SPSS) software version 13.5 (SPSS Inc., Chicago, Illinois, USA). For Descriptive Statistics, Continuous variables were expressed as Mean ± Standard Deviation (SD). And Categorical variables were expressed as frequencies and percentages. For Inferential Statistics, Chi-square test was used to compare categorical variables, Independent Student's t-test was used to compare means between two groups, One-way Analysis of Variance (ANOVA) was used for comparison among multiple groups and Odds ratios and confidence intervals were calculated where applicable. A two-tailed p-value <0.05 was considered statistically significant.

Results:

A total of 107 patients admitted to the Medical Intensive Care Unit (MICU) were enrolled in the present prospective observational study. The demographic profile, electrolyte abnormalities and their association with clinical outcomes were analyzed. The mean age of the study population was 51.4 ± 16.5 years. The majority of patients belonged to the 41–60 year age group (41.2%). Males constituted 56.1% of the cohort. Most patients were from rural areas (66.4%). Overall mortality was 34.6%, while 65.4% of patients were discharged successfully **(Table 2).** Electrolyte abnormalities were highly prevalent among ICU patients. Hypocalcemia (69.2%) was the most common disturbance, followed by hypokalemia (38.3%) and hyponatremia (31.8%). Hyperphosphatemia was observed in 37.4% of patients, indicating a substantial burden of electrolyte derangements among critically ill individuals **(Table 3).** A significant association was observed between serum sodium, potassium and calcium abnormalities and clinical outcomes. Mortality was highest among patients with hyponatremia (76.5%), followed by hypernatremia (71.4%) and hypokalemia (63.4%). Patients with normal electrolyte values demonstrated significantly better survival rates **(Table 4).** Patients who died had significantly lower serum sodium and potassium concentrations compared with survivors. Mean sodium and potassium values were strongly associated with mortality ($p<0.001$). No significant differences were observed for magnesium, calcium, phosphorus, or chloride levels **(Table 5).** Nearly half of the patients (47.7%) stayed in the ICU for five days or less, while 21.5% required prolonged ICU admission exceeding ten days. Patients with severe electrolyte disturbances generally experienced longer ICU stays and higher mortality **(Table 6).** The present study demonstrated that electrolyte disturbances were extremely common among critically ill patients admitted to the ICU. Hypocalcemia, hypokalemia and hyponatremia were the predominant abnormalities. Significant associations were observed between sodium, potassium and calcium derangements and adverse clinical outcomes. Mortality was substantially higher among patients with hyponatremia, hypernatremia, hypokalemia and hypocalcemia. Mean serum sodium and potassium levels were significantly lower among non-survivors, highlighting their prognostic importance in critically ill patients.

Table 1: Reference ranges of serum electrolytes

Electrolyte	Normal Range
Sodium	135–140 mEq/L
Potassium	3.0–5.5 mEq/L
Magnesium	1.5–2.4 mg/dL
Total Calcium	8.6–10.2 mg/dL
Ionized Calcium	1.12–1.30 mmol/L
Phosphate	2.5–4.5 mg/dL

Table 2: Demographic characteristics and clinical outcome of study participants (n=107)

Variable	Frequency (n)	Percentage (%)
Age Group (Years)		
≤30	14	13.1
31–40	18	16.8
41–50	22	20.6
51–60	22	20.6
61–70	21	19.6
>70	10	9.3
Gender		
Male	60	56.1
Female	47	43.9
Residence		
Rural	71	66.4
Urban	36	33.6
Outcome		
Discharged	70	65.4
Death	37	34.6

Table 3: Distribution of electrolyte abnormalities among ICU patients

Electrolyte Category	Frequency (n)	Percentage (%)
Sodium		
Hyponatremia	34	31.8
Normal	66	61.7
Hypernatremia	7	6.5
Potassium		
Hypokalemia	41	38.3
Normal	54	50.5
Hyperkalemia	12	11.2
Magnesium		
Hypomagnesemia	23	21.5
Normal	57	53.3
Hypermagnesemia	27	25.2
Calcium		
Hypocalcemia	74	69.2
Normal	32	29.9
Hypercalcemia	1	0.9
Phosphorus		
Hypophosphatemia	19	17.8
Normal	48	44.9
Hyperphosphatemia	40	37.4

Table 4: Association between electrolyte abnormalities and clinical outcome

Electrolyte Category	Death n (%)	Discharge n (%)	p-value
Sodium			
Hyponatremia	26 (76.5)	8 (23.5)	<0.001*
Normal	6 (9.1)	60 (90.9)	
Hypernatremia	5 (71.4)	2 (28.6)	
Potassium			
Hypokalemia	26 (63.4)	15 (36.6)	<0.001*
Normal	6 (11.1)	48 (88.9)	
Hyperkalemia	5 (41.7)	7 (58.3)	
Magnesium			
Hypomagnesemia	10 (43.5)	13 (56.5)	0.158
Normal	15 (26.3)	42 (73.7)	
Hypermagnesemia	12 (44.4)	15 (55.6)	
Calcium			
Hypocalcemia	31 (41.9)	43 (58.1)	0.013*
Normal	5 (15.6)	27 (84.4)	

**Statistically significant*

Table 5: Comparison of mean electrolyte levels between death and discharge groups

Parameter	Death (n=37) Mean ± SD	Discharge (n=70) Mean ± SD	p-value
Sodium (mEq/L)	129.42 ± 11.21	139.23 ± 5.42	<0.001*
Potassium (mEq/L)	2.80 ± 1.22	4.13 ± 1.07	<0.001*
Magnesium (mg/dL)	1.97 ± 0.65	2.06 ± 0.62	0.522
Calcium (mg/dL)	7.53 ± 1.60	8.08 ± 1.48	0.082
Phosphorus (mg/dL)	5.16 ± 2.79	4.50 ± 3.03	0.277
Chloride (mEq/L)	104.97 ± 10.12	101.83 ± 8.70	0.096

*Statistically significant

Table 6: Duration of ICU stay and outcome

Duration of Stay	Frequency (n)	Percentage (%)
≤5 days	51	47.7

6–10 days	33	30.8
>10 days	23	21.5
Total	107	100

Discussion:

Electrolyte disturbances are among the most common metabolic abnormalities encountered in critically ill patients and are increasingly recognized as important determinants of morbidity and mortality in intensive care units (ICUs). The present prospective observational study evaluated 107 patients admitted to the medical ICU and demonstrated a high prevalence of electrolyte abnormalities, particularly hypocalcemia, hypokalemia and hyponatremia. Furthermore, significant associations were observed between sodium, potassium and calcium abnormalities and adverse clinical outcomes, including mortality. These findings are consistent with a recent retrospective ICU study by Ayrin *et al.*, in which electrolyte disturbances were observed in 71.4% of patients and were associated with longer ICU stays and higher in-ICU mortality **[12].** The mean age of the study population was 51.4 ± 16.5 years, with the majority of patients belonging to middle-aged and elderly groups. Advanced age has been identified as an important risk factor for electrolyte disturbances due to declining renal function, altered hormonal regulation, multiple comorbidities and polypharmacy. Bachmann *et al.* reported that electrolyte disorders are particularly common among critically ill elderly patients and are frequently associated with disease severity and poor outcomes **[2].** Similar demographic trends have been observed in ICU-based studies worldwide. In the present study, overall mortality was 34.6%. Electrolyte disturbances were significantly more common among non-survivors than survivors. This observation is supported by earlier findings from Mousavi *et al.*, who showed significant differences in serum electrolyte concentrations between patients who survived and those who died during ICU admission **[13].** Electrolyte abnormalities may not only reflect the severity of the underlying illness but may also contribute directly to physiological deterioration through effects on cardiac conduction, neuromuscular activity, fluid balance and cellular metabolism. Sodium abnormalities were among the most clinically significant findings in the present study. Hyponatremia was observed in 31.8% of patients, while hypernatremia occurred in 6.5%. Mortality rates were markedly elevated among patients with hyponatremia (76.5%) and hypernatremia (71.4%) compared with patients having normal sodium levels. Darmon *et al.* emphasized that even minor deviations in serum sodium concentrations are associated with increased mortality among critically ill patients **[3].** Similarly, Funk *et al.* showed that dysnatremias present at ICU admission independently predict prolonged hospitalization and increased mortality **[5].** More recently, Grim *et al.* reported that rising serum sodium concentrations during ICU stay are significantly associated with in-hospital mortality **[6].** A prospective study from North India among critically ill children similarly showed significant associations between dyselectrolytemia and prolonged PICU stay, ventilatory and inotropic requirements, complications and mortality, with particularly high mortality reported among patients with hyperkalemia and hypernatremia **[14]**. Potassium abnormalities were also highly prevalent. Hypokalemia was identified in 38.3% of patients, whereas hyperkalemia occurred in 11.2%. Mortality was highest among patients with hypokalemia, where nearly two-thirds of patients succumbed to their illness. Potassium plays a crucial role in maintaining cardiac electrical activity, skeletal muscle function and cellular membrane potential. Wang *et al.* proposed a scoring system incorporating electrolyte abnormalities and demonstrated their usefulness in predicting adverse outcomes among hospitalized patients **[11].** More recently, Zhang *et al.* and Zhang *et al.* reported that serum potassium variability is significantly associated with 28-day mortality in ICU patients, highlighting the importance of maintaining potassium stability during critical illness **[4, 7].** The present findings are consistent with these observations, as non-survivors had significantly lower mean potassium levels than survivors. Similarly, Rumi *et al.* reported that electrolyte disturbances among hospitalized adults were associated with greater ICU admission, prolonged hospitalization and adverse clinical outcomes, with hyponatremia and hypokalemia identified as independent predictors **[15].**]Hypocalcemia was the most common electrolyte abnormality in this study, affecting 69.2% of patients. Mortality among hypo calcemic patients was significantly higher than among patients with normal calcium levels. Calcium is involved in myocardial contractility, smooth vascular muscle function, blood coagulation, intracellular signaling pathways and neuromuscular transmission. Zhang *et al.*, using the MIMIC-II database, demonstrated that ionized calcium is an independent predictor of mortality in critically ill patients **[7].** Similarly, Melchers *et al.* reported that hypocalcemia remains a frequent finding in ICU patients and is associated with adverse clinical outcomes despite calcium replacement therapy **[8]**. The high prevalence of hypocalcemia observed in the present study may be attributable to sepsis, renal dysfunction, hypoalbuminemia, inflammatory cytokine release and vitamin D deficiency. Magnesium abnormalities were also frequently encountered, with hypomagnesemia observed in 21.5% and hypermagnesemia in 25.2% of patients. Although magnesium abnormalities did not show a statistically significant association with mortality in the present study, they remain clinically relevant. In contrast, Sardu *et al.* reported a significant association between serum magnesium levels and mortality among ICU patients, although they found no significant relationship between the mean serum electrolyte levels and level of consciousness **[16].** Raju *et al.* reported that hypomagnesemia is common among ICU patients and may contribute to arrhythmias, neuromuscular dysfunction and refractory hypokalemia **[9].** Therefore, routine monitoring of magnesium levels remains important despite the absence of a significant mortality association in this cohort. Phosphorus abnormalities were also prevalent. Hyperphosphatemia was observed in 37.4% of patients, whereas hypophosphatemia occurred in 17.8%. Although mortality was numerically higher among patients with Hyperphosphatemia, the association was not statistically significant. Lim *et al.* demonstrated that phosphate disturbances

in critically ill patients, particularly those with acute kidney injury requiring hemodialysis, are associated with adverse clinical events and prolonged recovery **[10].** Phosphorus plays a vital role in cellular energy metabolism, oxygen delivery and respiratory muscle function, making its maintenance important during critical illness. Recent literature continues to emphasize the clinical significance of electrolyte disorders in ICU settings. Dockrell and McClure highlighted that electrolyte disturbances remain among the most common reversible causes of deterioration in critically ill patients and should be recognized promptly to improve outcomes **[17].** The present study supports these observations and demonstrates that sodium, potassium and calcium abnormalities are particularly important predictors of mortality among ICU patients. The strengths of the present study include its prospective design and comprehensive evaluation of multiple electrolyte parameters. However, certain limitations should be acknowledged. The study was conducted at a single tertiary-care center with a relatively modest sample size. Additionally, serial electrolyte measurements, illness severity scoring systems and long-term outcomes were not evaluated. Future multicenter studies involving larger populations are required to further clarify the prognostic role of electrolyte abnormalities and their potential utility in risk stratification models for critically ill patients.

Conclusion:

Electrolyte abnormalities were highly prevalent among ICU patients, with hypocalcemia, hypokalemia and hyponatremia being the most frequent disturbances. Sodium, potassium and calcium abnormalities showed significant association with mortality. Routine monitoring, early recognition and timely correction of electrolyte imbalance should be integral components of ICU management to improve clinical outcomes.

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