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**ORIGINAL RESEARCH / *ÖZGÜN ARAŞTIRMA***

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# Evaluation of Electrolyte Imbalance on Intensive Care Unit Admission and Its Effect on Prognosis

## Yoğun Bakım Ünitesine Kabuldeki Elektrolit İmbalansı ve Prognoza Etkisinin Değerlendirilmesi

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**ABSTRACT** *Objective:* Electrolyte imbalance is an important factor that is frequently observed in the intensive care unit (ICU) and affects prognosis. We analyzed the type of electrolyte imbalance on ICU admissions and its relation to prognosis, mechanical ventilation day, ICU and hospital stay, and mortality.
*Materials and Methods:* The electrolyte values of 826 patients admitted to the ICU were analyzed. Demographic data, the type of electrolyte imbalance, mechanical ventilation day, length of stay in the ICU and hospital, acute physiology and chronic health evaluation-II (APACHE-II) scores, and mortality status were recorded.
*Results:* A total of 826 patients were included. Of the patients, 252 (30.5%) had dysnatremia, 193 (23%) had dyskalemia, 432 (52%) had dyscalcemia, 389 (47%) had dysmagnesaemia, and 625 (75%) had dysphosphatemia. APACHE-II score, mechanical ventilation day, and length of stay in ICU and hospital were significantly higher in hypernatremia than in normonatremia and hyponatremia. In hypokalemia, the length of stay in the ICU and mechanical ventilation day was significantly higher than in normokalemia. The mortality rate was 1.7 and 4.4 times higher in hyponatremia and hypernatremia, respectively, than in normonatremia. Mortality was 1.8 times higher in hypokalemia and 2.2 times higher in hyperkalemia than in normokalemia. Mortality was 11 times higher in hypercalcemia than in normocalcemia.
*Conclusion:* Electrolyte imbalance is frequently observed among ICU patients. In particular, in patients with dysnatremia and dyskalemia, the prognosis is worse.
**Keywords:** Water-electrolyte imbalance, critical illness, prognosis

**ÖZ** *Amaç:* Elektrolit imbalansı, yoğun bakım ünitesinde (YBÜ) sıklıkla görülen ve prognozu etkileyen önemli bir faktördür. YBÜ'ye yatışlardaki elektrolit imbalansı tipini ve bunun prognoz, mekanik ventilasyon günü, YBÜ ve hastanede kalış süresi ve mortalite ile ilişkisini analiz etmeyi amaçladık.
*Gereç ve Yöntem:* YBÜ'ye kabul edilen 826 hastanın elektrolit değerleri incelendi. Demografik veriler, elektrolit imbalansı tipi, mekanik ventilasyon günü, YBÜ ve hastanede kalış süresi, akut fizyoloji ve kronik sağlık değerlendirmesi-II (APACHE-II) skorları ve mortalite durumu kaydedildi.
*Bulgular:* Çalışmaya toplam 826 hasta dahil edildi. Hastaların 252'sinde (%30,5) disnatremi, 193'ünde (%23) diskalemi, 432'sinde (%52) diskalsemi, 389'unda (%47) dismagnezemi ve 625'inde (%75) disfosfatemi mevcuttu. APACHE-II skoru, mekanik ventilasyon günü, YBÜ ve hastanede kalış süresi, normonatremi ve hiponatremiye kıyasla hipernatremide anlamlı olarak daha yüksekti. Hipokalemide, YBÜ kalış süresi ve mekanik ventilasyon günü, normokalemiye kıyasla anlamlı derecede yüksekti. Normonatremiye kıyasla ölüm oranı hiponatremi ve hipernatremide sırasıyla 1,7 ve 4,4 kat daha fazlaydı. Normokalemiye göre hipokalemide mortalite 1,8 kat, hiperkalemide ise 2,2 kat daha fazlaydı. Hiperkalsemide, normokalsemiye kıyasla mortalite 11 kat daha fazlaydı.
*Sonuç:* Elektrolit imbalansı YBÜ hastalarında sıklıkla görülür. Özellikle disnatremisi ve diskalemisi olan hastaların prognozu daha kötüdür.
**Anahtar Kelimeler:** Sıvı-elektrolit imbalansı, kritik hastalık, prognoz

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## Introduction

Electrolytes play an important role in many vital functions such as; nerve cell transmission, bone metabolism, fluid balance, acid-base balance, muscle contraction mechanism, hormone function, cell membrane structure and function, metabolic and homeostatic functions. While many studies report the relationship between electrolyte imbalance (EI) and mortality and morbidity; EI is still one of the major problems among intensive care unit (ICU) patients (1-3). The complications of EI include a large variety of clinical disorders ranging from mild symptoms to life-threatening cardiac arrhythmias, and respiratory failure (4,5). Sodium, potassium, magnesium, calcium, and phosphorus are the most responsible electrolytes in regard to these complications in ICU. The main EI types are hypo- and hyper-states of sodium, potassium, magnesium, and calcium (6). Although there are publications analyzing EI in the literature, the studies examining each EI within itself and its effect on prognosis in ICU are rare.

In our study, we aimed to investigate the EI types of ICU patients on admission and the effect of EI type on prognosis in terms of mechanical ventilation day (MVD), length of stay (LOS) in ICU and hospital, acute physiology and chronic health evaluation-II (APACHE-II) scores, and mortality.

## Materials and Methods

After the University of Health Sciences Turkey, Ankara Atatürk Sanatory Training and Research Hospital Clinical Research Ethics Committee approval (decision no: 2531, date: 14.06.2022) and clinical trial registration, we assessed retrospectively the charts of the patients hospitalized in our third-level ICU in the period between January 01, 2016 and July 31, 2019. Data were obtained from the hospital's biochemistry database and ICU patient files. Data was searched whether there is an EI on admission blood tests in ICU and if any EI was caught its type and severity were recorded according to ranges depicted in Table 1. Patients' age, sex, MVD, APACHE-II score, LOS in ICU and hospital, and mortality were recorded.

Corrected calcium was calculated according to Corrected Calcium = Total Calcium+ [0.8 × (4.0 – Albumin)] formulation. MVD was defined as the number of days from the first day of intubation to the day he was extubated or died.

### Statistical Analysis

Analysis of the data was made in SPSS for Windows 22 package program (Chicago, Illinois, USA). After determining whether the data show normal distribution or not with the Kolmogorov-Smirnov test, all data were given as mean ± standard deviation or the difference between the median value and the quartiles. The correlation between categorical data was demonstrated with the chi-square test or the Fisher's Exact test. In the comparison of the numerical variables, Student-t test or Mann-Whitney U test was used depending on the parametric conditions. The statistical significance level was accepted as $p<0.05$ for all calculations.

## Results

A total of 826 patients, 413 (50%) female, and 413 (50%) male were analyzed. The age range was between 16-101 years (69.19±19.33). Four hundred four (48.9%) patients were admitted to ICU from the emergency department, 81 (9.8%) were from the ward and 341 (41.3%) were postoperative patients (Table 2). The types and the numbers of patients with EI are depicted in Table 3. There was no EI in 100 of 826 patients (12%). In hypernatremia, APACHE-II score, MVD, and LOS in ICU and hospital were found to be significantly higher compared to normonatremia and hyponatremia

**Table 1. Hypo-hyper reference ranges**

| | Reference range | Hypo- | Hyper- |
|---|---|---|---|
| Sodium (mmol/L) | 136-145 | <136 | >145 |
| Potassium (mmol/L) | 3.5-5.5 | <3.5 | >5.5 |
| Albumin corrected calcium (mg/dL) | 8.8-10.6 | <8.8 | >10.6 |
| Magnesium (mmol/L) | 1.8-2.6 | <1.8 | >2.6 |
| Phosphate (mmol/L) | 2.5-4.5 | <2.5 | >4.5 |

**Table 2. Demographic data**

| | | n | Percent (%) | Mean ± SD |
|---|---|---|---|---|
| Age | | | | 69.19±19.33 |
| Gender | Male | 413 | 50 | |
| | Female | 413 | 50 | |
| Admission unit | Emergency department | 404 | 48.9 | |
| | Ward | 81 | 9.8 | |
| | Operating room | 341 | 41.3 | |

SD: Standard deviation

(p<0.05) (Table 4). Mortality in normonatremia, hyponatremia and hypernatremia was 26%, 44% and 71% respectively. In hyperkalemia, APACHE-II score was significantly higher compared to normokalemia and hypokalemia. In hypokalemia, MVD, and LOS in ICU was significantly higher than normokalemia (p<0.05). In dyscalcemia (corrected with albumin), there was no significant difference in terms of APACHE-II score, MVD, and LOS in ICU and hospital. In dysmagnesaemia, no significant difference was found in terms of MVD, and LOS in ICU and hospital. APACHE II score was found to be higher in hypermagnesemia compared to normomagnesaemia and hypomagnesaemia.

APACHE-II score in hyperphosphatemia was found to be significantly higher than normophosphatemia and hypophosphatemia (p<0.05). There was no significant difference between hypo-hyper and normophosphatemia in terms of MVD, and LOS in ICU and hospital.

When the readmission rates were examined, it was revealed that dysnatremia did not affect the readmission rates (p>0.05). Although the readmission was found to be higher in hyperkalemia compared to hypokalemia and normokalemia, the result was not statistically significant (p>0.05). Readmissions in hypocalcemia were higher than hypercalcemia and normocalcemia, but statistically, there was no difference (p>0.05). Similarly, there was no statistical difference in readmission rates of hypo-, hyper-, and normomagnesaemia (p>0.05).

Compared to normonatremia, the rate of mortality was 1.7 times higher in hyponatremia and 4.4 times higher in hypernatremia. The mortality rate was 1.8 times higher in hypokalemia and 2.2 times higher in hyperkalemia compared to normokalemia. While the mortality rate was similar in hypocalcemia compared to normocalcemia, mortality was 11 times higher in hypercalcemia. Mortality was unchanged in dysmagnesemia. Compared with normophosphatemia, mortality was 1.7 times higher in hypophosphatemia and 5.1 times higher in hyperphosphatemia.

**Table 3. Type and proportion of EI**

| Electrolyte | Type of EI | n | Proportion (%) |
|---|---|---|---|
| Sodium | Normonatremia | 574 | 69.5 |
| | Hyponatremia | 192 | 23.2 |
| | Hypernatremia | 60 | 7.3 |
| Potassium | Normokalemia | 633 | 76.6 |
| | Hypokalemia | 123 | 14.9 |
| | Hyperkalemia | 70 | 8.5 |
| Calcium (albumin-corrected)* | Normocalcemia | 394 | 47.7 |
| | Hypocalcemia | 419 | 50.7 |
| | Hypercalcemia | 13 | 1.6 |
| Magnesium | Normomagnesaemia | 437 | 52.9 |
| | Hypomagnesaemia | 337 | 40.8 |
| | Hypermagnesaemia | 52 | 6.3 |
| Phosphate | Normophosphatemia | 530 | 64.2 |
| | Hypophosphatemia | 95 | 11.5 |
| | Hyperphosphatemia | 201 | 24.3 |

*Corrected Calcium = Total Calcium + [0.8 × (4.0 – Albumin)]
EI: Electrolyte imbalance

**Table 4. Analysis of electrolyte imbalance in terms of APACHE-II score, mechanical ventilation day, length of stay in ICU and hospital**

| | EI | EI | Mean difference | Std. error | Sig. | 95% Confidence interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower bound | Upper bound |
| APACHE-II score | Normonatremia | Hyponatremia | -3,057 | 1,383 | 0.08 | -6.38 | 0.27 |
| | | Hypernatremia | -11,067 | 2,403 | <0.01* | -16.84 | -5.29 |
| | Hyponatremia | Hypernatremia | -8,010 | 2,600 | <0.01* | -14.26 | -1.76 |
| | Normokalemia | Hypokalemia | -2,602 | 1,652 | 0.34 | -6.57 | 1.37 |
| | | Hyperkalemia | -9,458 | 2,294 | <0.01* | -14.97 | -3.94 |
| | Hypokalemia | Hyperkalemia | -6,856 | 2,672 | <0.05* | -13,28 | -0.43 |
| | Normomagnesaemia | Hypomagnesaemia | 3,188 | 1,155 | <0.05* | 0,41 | 5.96 |
| | | Hypermagnesaemia | -13,856 | 2,685 | <0.01* | -20.31 | -7.40 |
| | Hypomagnesaemia | Hypermagnesaemia | -17,044 | 2,693 | <0.01* | -23.52 | -10.57 |
| | Normophosphatemia | Hypophosphatemia | -3,180 | 1,650 | 0.16 | -7.15 | 0.79 |
| | | Hyperphosphatemia | -12,511 | 1,333 | <0.01* | -15.71 | -9.31 |
| | Hypophosphatemia | Hyperphosphatemia | -9,331 | 1,903 | <0.01* | -13.90 | -4.76 |

**Table 4. Analysis of electrolyte imbalance in terms of APACHE-II score, mechanical ventilation day, length of stay in ICU and hospital**

| | EI | EI | Mean difference | Std. error | Sig. | 95% Confidence interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower bound | Upper bound |
| Mechanical ventilation days | Normonatremia | Hyponatremia | -0,478 | 1,456 | 1.00 | -3.97 | 3.02 |
| | | Hypernatremia | -8,267 | 2,370 | <0.01* | -13.95 | -2.58 |
| | Hyponatremia | Hypernatremia | -7,789 | 2,584 | <0.01* | -13.99 | -1.59 |
| | Normokalemia | Hypokalemia | -5,397 | 1,724 | <0.01* | -9.53 | -1.26 |
| | | Hyperkalemia | -0,793 | 2,203 | 1.00 | -6.08 | 4.49 |
| | Hypokalemia | Hyperkalemia | 4,604 | 2,619 | 0.23 | -1.68 | 10.89 |
| | Normomagnesaemia | Hypomagnesaemia | 1,954 | 1,273 | 0.37 | -1.10 | 5.01 |
| | | Hypermagnesaemia | 3,023 | 2,577 | 0.72 | -3.16 | 9.20 |
| | Hypomagnesaemia | Hypermagnesaemia | 1,070 | 2,617 | 1.00 | -5.21 | 7.35 |
| | Normophosphatemia | Hypophosphatemia | -1,053 | 1,956 | 1.00 | -5.75 | 3.64 |
| | | Hyperphosphatemia | -2,832 | 1,454 | 0.15 | -6.32 | 0.66 |
| | Hypophosphatemia | Hyperphosphatemia | -1,779 | 2,186 | 1.00 | -7.02 | 3.46 |
| LOS ICU | Normonatremia | Hyponatremia | -0,223 | 1,486 | 1.000 | -3.79 | 3.34 |
| | | Hypernatremia | -7,825 | 2,418 | <0.01* | -13.62 | -2.03 |
| | Hyponatremia | Hypernatremia | -7,602 | 2,636 | <0.05* | -13.92 | -1.28 |
| | Normokalemia | Hypokalemia | -5,064 | 1,758 | <0.05* | -9.28 | -0.85 |
| | | Hyperkalemia | 0,690 | 2,247 | 1.00 | -4.70 | 6.08 |
| | Hypokalemia | Hyperkalemia | 5,754 | 2,671 | 0.09 | -0.65 | 12.16 |
| | Normomagnesaemia | Hypomagnesaemia | 1,755 | 1,298 | 0.53 | -1.36 | 4.87 |
| | | Hypermagnesaemia | 3,335 | 2,626 | 0.61 | -2.96 | 9.64 |
| | Hypomagnesaemia | Hypermagnesaemia | 1,580 | 2,667 | 1.00 | -4.82 | 7.98 |
| | Normophosphatemia | Hypophosphatemia | -1,359 | 1,997 | 1.00 | -6.15 | 3.43 |
| | | Hyperphosphatemia | -1,514 | 1,484 | 0.92 | -5.08 | 2.05 |
| | Hypophosphatemia | Hyperphosphatemia | -0,155 | 2,231 | 1.00 | -5.51 | 5.20 |
| LOS Hospital | Normonatremia | Hyponatremia | -0,213 | 1,529 | 1.00 | -3.88 | 3.46 |
| | | Hypernatremia | -6,819 | 2,484 | <0.05* | -12.78 | -0.86 |
| | Hyponatremia | Hypernatremia | -6,606 | 2,709 | <0.05* | -13.11 | -0.11 |
| | Normokalemia | Hypokalemia | -4,501 | 1,803 | <0.05* | -8.82 | -0.18 |
| | | Hyperkalemia | 3,089 | 2,304 | 0.54 | -2.44 | 8.62 |
| | Hypokalemia | Hyperkalemia | 7,589 | 2,738 | <0.05* | 1.02 | 14.16 |
| | Normomagnesaemia | Hypomagnesaemia | 0,073 | 1,331 | 1.00 | -3.12 | 3.27 |
| | | Hypermagnesaemia | 4,719 | 2,693 | 0.24 | -1,74 | 11.18 |
| | Hypomagnesaemia | Hypermagnesaemia | 4,646 | 2,735 | 0.26 | -1.91 | 11.21 |
| | Normophosphatemia | Hypophosphatemia | -0,353 | 2,049 | 1.00 | -5.27 | 4.56 |
| | | Hyperphosphatemia | 0,102 | 1,524 | 1.00 | -3.55 | 3.76 |
| | Hypophosphatemia | Hyperphosphatemia | 0,455 | 2,290 | 1.00 | -5.04 | 5.95 |

APACHE-II: Acute physiology and chronic health evaluation-II, ICU: intensive care unit, EI: electrolyte imbalance, LOS: length of stay, *p<0.05 statistically significant

## Discussion

In different clinics, the prevalence and type of EI may vary. Our study was conducted in a third-level ICU running under the anesthesiology and reanimation department. Tazmini et al. (7) conducted a retrospective study in an emergency department. In their population, the prevalence of hyponatremia was 24%, hypokalemia was 8.6% and hypocalcemia (albumin-corrected) was 1.6%. Our hyponatremia, hypokalemia and hypocalcemia (albumin-corrected) prevalence were 23.2%, 14.7% and 50.7% respectively. While their hypernatremia, hyperkalemia and hypercalcemia prevalence were 1.7%, 3.3% and 10.9%, ours were 7.3%, 8.5% and 1.6% respectively. In our ICU study, the ratios are notably higher except hypercalcemia in comparison to their study. This may be explained by the condition of the critically ill patients who were exposed to many medications, fluid shifts and interventional approaches before ICU admission. Hyponatremia ratios are closer to each other in both studies. The biggest difference is between hypocalcemia ratios which are 50.7% in our study and 1.6% in theirs. One of the reasons for this notable difference may be the different reference values between the centers. Sedlacek et al. (8) reported that electrolyte imbalances in ICU can be prevented by attention to the usage of intravenous fluids and nutrition. In our study we analyzed the admission blood tests in ICU, so we didn't have the chance to prevent the electrolyte disturbances but the initial treatment was done as soon as the ICU team received the blood test results.

In their prospective cohort, Mestrom et al. (9) analyzed ICU-acquired hypernatremia. They enrolled 183 patients including 70 with ICU-acquired hypernatremia. The APACHE-IV scores of hypernatremic and normonatremic patients were 62 and 48, respectively. ICU mortality of hypernatremic and normonatremic patients were 23% and 12%; 90-day mortality were 33% and 14% respectively. Although our study is not about ICU-acquired EI, the comparison of this study with ours may reveal the differences between the admission electrolyte disturbances and the ICU-acquired ones. In our study, while there was no statistically significant difference between APACHE-II scores for hyponatremia and normonatremia, the APACHE-II scores for hypernatremia were significantly higher than the patients with hyponatremia and normonatremia. In their study mortality in hypernatremic patients was 2.35 times higher than normonatremic patients and 4.4 times higher in ours. This difference may be due to the severity of critically ill patients in our study.

A systematic review and meta-analysis reported that hyponatremia is associated with a prolonged LOS in hospital and higher risk of readmissions (10). In our study, the difference in readmission rates of hyponatremia, normonatremia and hypernatremia was not statistically significant. We also found that patients with hypernatremia had a significantly longer ICU stay compared to patients with hyponatremia ($p<0.05$).

In their retrospective cross-sectional study Lindner et al. (11) revealed that there is no significant correlation between serum calcium level and LOS in hospital. In our study, there was no statistically significant difference in patients with dyscalcemia in terms of MVD, and LOS in ICU and hospital. Mortality rates in normocalcemic, hypocalcemic and hypercalcemic patients were 34%, 32% and 84% respectively. In a retrospective cohort, acute medical admissions were evaluated in terms of potassium levels (12). Hospital mortality rates were 3.9%, 5%, and 18% in normokalemic, hypokalemic and hyperkalemic patients respectively. In our ICU, the mortality rates of patients who have potassium imbalance on admission were; 29%, 40% and 68% in normokalemic, hypokalemic and hyperkalemic patients respectively. Our study was performed in a third-level ICU which may be the reason for the big difference between mortality rates in the two studies. In their study, hypokalemic patients had a longer LOS compared to normokalemia which is the same as our results. In our study, we also revealed that hypokalemic patients had longer LOS than hyperkalemic patients ($p=0.017$).

A large study reported that higher serum phosphorus levels influence mortality in patients with normal kidney function (13). In our trial, the mortality rates were 22%, 32% and 67% in normophosphatemic, hypophosphatemic and hyperphosphatemic patients respectively.

Our study has some limitations. In our ICU, the diseases of patients in admission vary, so the patient population is not homogenized. Our patients have many comorbidities, and different therapies and there are many other factors which may affect mortality, LOS, APACHE-II score and readmissions. In addition, the source of the ward patients was lacking.

## Conclusion

In conclusion, EI is one of the most frequent diagnoses in ICU admissions. Mortality, LOS, and prognosis differ in EI types. In our study, we revealed that dysnatremic and dyscalcemic patients have more negative prognosis.

### Ethics

**Ethics Committee Approval:** Approval was received from the Clinical Research Ethics Committee of the University of Health Sciences Turkey, Ankara Atatürk Sanatorium Training and Research Hospital (decision no: 2531, date: 14.06.2022).

**Informed Consent:** For this type of study formal consent is not required.

### Authorship Contributions

Concept: E.T., Design: E.T., A.S., Data Collection and Process: M.K., E.O.T., A.K., Analysis or Interpretation: E.Ö., A.S., Literature Search: E.T., E.Ö., Writing: E.T., E.Ö.

**Conflict of Interest:** No conflict of interest was declared by the authors.

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