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Original Research Article

Evaluating the Correlation Between Hypokalemia and Hypomagnesemia in Critically Ill ICU Patients

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Abstract:

Background: Electrolyte imbalances are frequent and clinically significant complications in ICU patients. Among these, hypokalemia and hypomagnesemia are commonly observed and often coexist due to shared pathophysiological mechanisms. Magnesium deficiency can impair potassium repletion, leading to refractory hypokalemia and increased morbidity.

Aim: This study aimed to evaluate the correlation between serum potassium and magnesium levels in ICU patients and identify a potassium threshold predictive of hypomagnesemia.

Methodology: A cross-sectional descriptive study was conducted at Department of Anesthesiology, Jannayak Karpoori Thakur Medical College and Hospital, Bihar, over one year (April 2024–March 2025). Ninety adult ICU patients with hypokalemia (serum potassium ≤ 3.5 mEq/L) were included, excluding those on magnesium supplements or with chronic kidney disease. Serum potassium and magnesium levels were measured and statistically analyzed using SPSS and R. Correlation analysis and ROC curve were employed to determine associations and predictive thresholds.

Results: Hypomagnesemia was observed in 64.84% of the hypokalemic patients. A moderate positive correlation was found between serum potassium and magnesium levels ($r = 0.463$, $p < 0.0001$). ROC analysis showed a potassium cut-off of ≤ 3.1 mEq/L as predictive of hypomagnesemia, with an AUC of 0.652, sensitivity of 52.54%, specificity of 75%, and PPV of 79.50%.

Conclusion: Hypomagnesemia is highly prevalent in hypokalemic ICU patients and shows a significant correlation with serum potassium levels. Routine magnesium assessment is essential for effective management of hypokalemia, especially in critically ill patients, to prevent complications and optimize treatment.

Keywords: Electrolyte Imbalance, Hypokalemia, Hypomagnesemia, ICU, Magnesium Deficiency, ROC Curve, Serum Potassium.

Introduction

Electrolyte disturbance is one of the most common and difficult complications seen in critically ill patients in the Intensive Care Unit (ICU) [1]. Electrolyte disturbances can occur as a result of many complex factors typical of patients in the ICU setting, including underlying disease states, medications, fluid shifting, nutritional deficits, and organ dysfunction. Electrolytes N+ K+ Ca+ Mg++ Cl- and serum bicarbonate represent just several of the electrolytes that can be affected. Of the many electrolytes, potassium and magnesium have particular clinical relevance due to their contribution to cellular homeostasis, cardiac activity, neuromuscular function, and metabolic activity [2]. The occurrence of hypokalemia (serum $[K^+] < 3.5$ mEq/L) and hypomagnesemia (serum $[Mg^{++}] < 1.7$ mg/dL) is common in ICU patients and if left unrecognized and untreated can lead to additional morbidity and mortality.

Potassium is the major intracellular cation and is critical for maintaining resting membrane potential, controlling cellular excitability, and influencing the physiology of skeletal and cardiac muscle [3]. Potassium imbalances, particularly hypokalemia, may result in potentially life-threatening arrhythmias, weakness, muscle spasms, even paralysis, and disturbances to the metabolic system [4]. For critical ill patients, the causes of hypokalemia are numerous and may include normal renal or gastrointestinal losses, accumulation of intracellular potassium (as in alkalosis), poor intake or nutritional status, and certain medications (such as diuretics, corticosteroids).

Magnesium is the second most abundant intracellular cation and is an essential cofactor for over 300 enzymatic reactions, including those in ATP metabolism, DNA synthesis, and ion transport across membranes [5]. Magnesium also stabilizes the neuromuscular junctions and cardiac membranes, controlling excitability and contractility. Hypomagnesemia in patients in the ICU is often unrecognized because it is difficult to accurately measure total body magnesium stores, because serum magnesium levels do not reflect the intracellular stores [6]. Hypomagnesemia can commonly be from decreased intake, excessive renal or GI losses, and shifts due to sepsis, alcohol use, or drugs.

Emerging evidence supports the pathophysiological relationship between potassium and magnesium homeostasis [7]. Magnesium deficiency can be a significant contributor to refractory hypokalemia cases in which potassium levels do not correct despite adequate supplementation. The refractory nature can be explained by the ability of magnesium to regulate renal potassium excretion and cellular uptake of potassium. Magnesium inhibits potassium secretion in the distal nephron, primarily via its effects on renal outer medullary potassium (ROMK) channels. In the setting of magnesium deficiency, potassium loss increases via the ROMK channels which further contributes to the hypokalemia [8]. Magnesium also plays an important role in Na+/K+-ATPase pump activity which is critical for maintaining cellular potassium levels.

Despite this well-established link, hypomagnesemia is often overlooked in the ICU because clinical attention is focused on fixing potassium alone, eventually hindering recovery and potentially causing complications like ventricular arrhythmias, neuromuscular irritability, and lengthened ICU stays. This is especially troubling with ICU patients because they are at a higher risk of electrolyte derangements with clinical considerations for renal dysfunction, sepsis, and poly-pharmacy transfers.

Previous studies have observed that among hypokalemic ICU patients, the prevalence of hypomagnesemia ranges from well over 40% to over 60% indicating a need for studies that take into account, geographical location and patient population. Nevertheless, there continues to be a clear lack of guidelines regarding the serum potassium thresholds to which hypomagnesemia becomes clinically important or predictive. Establishment of potassium thresholds would aid in better identification and treatment of patients at risk for concomitant electrolyte disturbances [9].

Given this background, the present study aims to investigate the correlation between hypokalemia and hypomagnesemia in ICU patients. The objectives are threefold: first, to examine the prevalence of hypomagnesemia in hypokalemic patients; second, to determine if a critical potassium level exists below which magnesium deficiency is more likely; and third, to analyze the severity of hypokalemia in relation to concurrent hypomagnesemia. By elucidating these relationships in a tertiary care ICU setting, the study seeks to inform clinical decision-making and optimize electrolyte management protocols, thereby improving patient outcomes.

Understanding the intricate association between magnesium and potassium homeostasis is essential for critical care physicians. Prompt recognition of this relationship can lead to more effective correction strategies, reduce the incidence of refractory hypokalemia, and prevent adverse cardiac and neuromuscular events in vulnerable ICU populations. This study therefore fills an important gap in critical care medicine by providing evidence-based insights into the co-occurrence of hypokalemia and hypomagnesemia, guiding clinicians in more comprehensive and precise electrolyte monitoring and supplementation strategies.

Methodology

Study Design: This research was designed as a cross-sectional descriptive study aimed at evaluating the correlation between serum potassium and magnesium levels in ICU patients.

Study Area: The study was conducted in the Department of Anesthesiology at Jannayak Karpoori Thakur Medical College and Hospital, Madhepura, Bihar, India.

Study Duration: The study period spanned from April 2024–March 2025.

Inclusion and Exclusion Criteria:

Inclusion Criteria:

- Adult ICU patients aged 18 years and above.
- Patients with documented hypokalemia, defined as serum potassium ≤ 3.5 mEq/L.

Exclusion Criteria:

- Patients currently receiving magnesium supplements or antacids containing magnesium.
- Patients with known chronic kidney disease or other conditions affecting magnesium/potassium homeostasis.

Sample Size: A total of 90 patients were included in the study. The sample size was determined based on previous literature indicating approximately 62%

prevalence of hypomagnesemia among hypokalemic ICU patients, and using systematic random sampling to ensure representativeness.

Procedure: The study population comprised adult patients admitted to the Intensive Care Unit (ICU) who were identified through systematic screening of electronic medical records during the study period. Initially, all patients aged 18 years and older with documented hypokalemia, defined as serum potassium levels ≤ 3.5 mEq/L, were considered for inclusion. The electronic database was regularly monitored to ensure timely identification of eligible participants. Patients receiving magnesium supplementation or antacid therapy containing magnesium, as well as those with underlying conditions known to significantly alter electrolyte metabolism (e.g., chronic kidney disease, inherited tubular disorders), were excluded to minimize confounding variables.

Upon identification, serum potassium and magnesium levels were obtained concurrently as part of routine blood investigations performed within 24 hours of ICU admission or during the hypokalemic episode. Blood samples were collected via standard venipuncture technique using appropriate anticoagulant-free tubes and transported immediately to the hospital laboratory to minimize pre-analytical errors. Serum potassium and magnesium concentrations were measured using automated analyzers based on ion-selective electrode (ISE) technology for potassium and colorimetric methods for magnesium, ensuring accuracy and reproducibility of results. In addition to biochemical parameters, demographic data—including age, sex, and relevant clinical details such as diagnosis at admission, medication history, and comorbidities—were recorded. These data were extracted retrospectively from patient records and anonymized to maintain confidentiality. Enrolment proceeded consecutively until the predetermined sample size was reached, following systematic random sampling protocols to reduce selection bias. All collected data were compiled into a secure database for subsequent statistical analysis.

The primary focus of the procedure was to assess the association between serum potassium and magnesium levels in the ICU population. Particular attention was given to identifying specific potassium thresholds that could reliably predict the presence of hypomagnesemia. To this end, the data collection process was structured to enable Receiver Operating Characteristic (ROC) curve analysis, correlational studies, and subgroup comparisons based on potassium levels. Throughout the study, quality control measures were maintained, including calibration of laboratory instruments, adherence to standardized blood collection protocols, and cross-validation of electronic data entries. Any discrepancies or missing data points were addressed promptly to maintain the integrity and reliability of the dataset.

Statistical Analysis: SPSS version 25.0 and R version 4.0.3 were used for data analysis. Descriptive statistics were used to characterize patient demographics and biochemical data. Associations between categorical variables were assessed with the chi-square test. Pearson's correlation coefficient established the strength and significance of the relationship between potassium and magnesium serum levels. The Receiver Operating Characteristic (ROC) curve analysis established potassium cut-off values sensitive to the identification of hypomagnesemia, calculating sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV). Statistical significance was defined as $p < 0.05$.

Result

Table 1 presents the demographic and clinical characteristics of the 90 ICU patients included in the study. The mean age of the patients was 54.3 years with a standard deviation of 16.7 years, indicating a wide age range among the participants. The gender distribution showed a male predominance, with 56 males and 34 females. As per the study's inclusion criteria, all patients (100%) had hypokalemia. Additionally, hypomagnesemia was observed in 64.84% of the patients, with 58 out of 90 cases affected, highlighting a substantial co-occurrence of these electrolyte imbalances in the ICU setting.

Table 1: Demographic and Clinical Characteristics of ICU Patients (n=90)

Parameter	Value
Age (mean ± SD)	54.3 ± 16.7 years
Gender (M:F)	56:34
Prevalence of Hypokalemia	100% (by inclusion)
Prevalence of Hypomagnesemia	64.84% (58/90)

Table 2 presents the ROC (Receiver Operating Characteristic) analysis evaluating serum potassium as a predictive marker for hypomagnesemia. The area under the curve (AUC) is 0.652, indicating a fair level of diagnostic accuracy. The optimal potassium cut-off value determined was ≤ 3.1 mEq/L. At this threshold, the sensitivity was 52.54%, suggesting that just over half of the true hypomagnesemia cases were correctly identified. The specificity was higher at 75%, indicating a good ability to correctly identify those without the condition. The positive predictive value (PPV) was relatively strong at

79.50%, meaning a high proportion of patients with potassium levels below the cut-off truly had hypomagnesemia. However, the negative predictive value (NPV) was lower at 46.20%, suggesting a limited ability to rule out hypomagnesemia in patients with potassium levels above the cut-off.

Table 2: ROC Analysis of Serum Potassium as a Predictor for Hypomagnesemia

Parameter	Value
Area Under Curve (AUC)	0.652
Optimal Potassium Cut-off	≤ 3.1 mEq/L
Sensitivity	52.54%
Specificity	75%
Positive Predictive Value (PPV)	79.50%
Negative Predictive Value (NPV)	46.20%

Table 3 presents the correlation between serum potassium and magnesium levels, revealing a moderate positive correlation with a correlation coefficient (r) of 0.463. This indicates that as serum potassium levels increase, serum magnesium levels also tend to rise. The p-value is less than 0.0001, suggesting that this relationship is statistically highly significant. Therefore, the data support a meaningful association between potassium and magnesium concentrations in the studied population.

Table 3: Correlation Between Serum Potassium and Magnesium Levels

Parameter	Correlation Coefficient (r)	p-value
Potassium vs Magnesium	0.463	< 0.0001

Discussion

The findings of this study highlight a significant association between hypokalemia and hypomagnesemia among ICU patients, emphasizing the clinical relevance of monitoring both electrolytes concurrently in critical care settings. The observed mean age of 54.3 years, coupled with a broad standard deviation, reflects the inclusion of a diverse adult population. The male predominance among patients is consistent with the general demographic trends seen in ICU admissions but may also reflect gender-related differences in disease presentation or comorbidities. Likewise, Whang et al. (1992) [10] showed that in a group of 104 hospitalized hypokalemic patients, 42% had hypomagnesemia, and potassium supplementation alone could not bring potassium back to baseline levels unless magnesium was restored. This adds credence to the results of our study that hypomagnesemia contributed to persistent hypokalemia and emphasizes the need for combined electrolyte management in the ICU.

A key observation was the high prevalence of hypomagnesemia (64.84%) among patients already diagnosed with hypokalemia. This co-occurrence underscores the potential interdependence of these two electrolyte disturbances. Magnesium plays a crucial physiological role in maintaining intracellular potassium balance, and its deficiency has been shown to impair potassium retention by the kidneys, contributing to treatment-resistant hypokalemia. Therefore, the frequent coexistence of hypomagnesemia in this cohort may partly explain the persistence or severity of hypokalemia in ICU patients, necessitating a combined approach to correction. Ryzen et al. (1985),[11] in a contrastive study, also indicated a high prevalence of hypomagnesemia in ICU patients (61%), but only a weak relationship between magnesium and potassium also detected in our study (r = 0.28) compared to our r = 0.463. Their lack of correlation may have been due to patient populations or clinical illness severity. However, they commented that magnesium and potassium's physiological relationship is shown by renal tubular interactions, consistent with our mechanistic rationale. Another comparison study by Elisaf and ME Kouropoulos (1995) [12] also noted that hypokalemia from diuretics or aminoglycoside antibiotics was often associated with hypomagnesemia; therefore, this suggests a common iatrogenic cause with ICU patients and therefore clinical significance in having both corrected together.

The ROC analysis further supports the utility of serum potassium as a predictive marker for hypomagnesemia. Although the AUC of 0.652 suggests only fair diagnostic accuracy, the findings remain clinically useful. A potassium cut-off of ≤ 3.1 mEq/L yielded a sensitivity of 52.54%, indicating modest detection of true hypomagnesemia cases, but a relatively higher specificity of 75%, meaning the marker more reliably excludes non-hypomagnesemic individuals. Notably, the positive predictive value of 79.50% suggests that low potassium levels are strongly associated with true hypomagnesemia, reinforcing the clinical decision to assess and manage magnesium status when hypokalemia is present. However, the low negative predictive value (46.20%) indicates that normal or slightly low potassium levels cannot reliably exclude hypomagnesemia, warranting independent evaluation of magnesium in borderline or ambiguous cases. Additionally, complementing our findings, a study by Ayuk and Gittoes (2014) [13] discussed that the deficiency of magnesium can elevate renal loss of potassium by decreasing intracellular magnesium, thereby degrading Na^+/K^+-ATPase activation. This pathophysiological evidence added support to our idea that hypomagnesemia in hypokalemic individuals is not incidental, but mechanistically tied, supporting the emphasis on addressing both deficiencies simultaneously.

The moderate positive correlation ($r = 0.463$, $p < 0.0001$) between serum potassium and magnesium levels provides strong statistical evidence of their interrelationship. This relationship likely reflects shared physiological mechanisms, such as renal tubular handling and cellular co-transport systems, which link the homeostasis of these two electrolytes. Clinically, this reinforces the importance of assessing magnesium levels in patients with refractory or recurrent hypokalemia. Failure to address underlying magnesium deficiency may lead to ineffective potassium repletion and prolonged hospitalization or complications in ICU patients. When compared to a study by Aziz et al., (2012), [14] which reported that potassium values <3.2 mEq/L are associated with a significantly higher probability for hypomagnesemia (p<.01) using ROC analysis to evaluate diagnostic performance of our model produced an AUC of 0.652 and a potassium threshold of ≤3.1 mEq/L as a poor predictor of hypomagnesemia. While it seems appropriate to conclude that potassium levels can serve as a weak predictor for magnesium status, it can also be reasonably admonished that potassium values may not be sufficient as a single-screening tool, and direct measurement of magnesium will always be required for accurate diagnosis and clinical management.

In summary, this study demonstrates that hypomagnesemia is highly prevalent among hypokalemic ICU patients, and serum potassium levels show a statistically significant, moderately strong association with magnesium levels. These results suggest that routine magnesium assessment should be integrated into the management protocol of ICU patients presenting with hypokalemia. Doing so could facilitate more effective correction of electrolyte imbalances, ultimately improving patient outcomes in critical care settings.

Conclusion

The present study concludes that hypomagnesemia is highly prevalent among ICU patients with hypokalemia, affecting approximately 64.84% of the cohort. The findings reveal a statistically significant moderate positive correlation ($r = 0.463$, $p < 0.0001$) between serum potassium and magnesium levels, emphasizing the physiological interdependence of these electrolytes. The ROC analysis identified a potassium cut-off of ≤ 3.1 mEq/L as a modest predictor for hypomagnesemia, with a fair diagnostic accuracy (AUC = 0.652). While the specificity and positive predictive value were relatively high, the low sensitivity and negative predictive value underscore the need for direct magnesium assessment rather than relying solely on potassium levels. These insights highlight the clinical importance of concurrent monitoring and correction of both electrolytes in ICU settings to prevent refractory hypokalemia and reduce complications. Integrating magnesium evaluation into standard hypokalemia management protocols could lead to more efficient treatment and improved outcomes in critically ill patients.

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