**Title:** Nurse knowledge about electrolyte monitoring: implications for patients with hypophosphatemia in an intensive care unit

**Running title:** Nurse Knowledge of Hypophosphatemia

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**Key words consistent with CINAHL/MeSH headings:** (<https://www.nlm.nih.gov/pubs/techbull/mj14/mj14_mesh_on_demand.html>)

**Acknowledgments, if any:**

**Grant or other financial support used in the study:**

**Background**

Patients in the intensive care unit (ICU) are at risk of developing hypophosphatemia (HP) and refeeding syndrome (RS). Providing overnutrition to a patient who has RS can be fatal, but early identification and prevention could save lives. Nurses’ inadequate understanding about their role and responsibility in nutrition therapy may result in negative outcomes.

**Objectives**

This study aimed to examine the knowledge and behaviors of ICU nurses regarding HP, RS, and nutrition in general. We analyzed the correlation between nurses’ knowledge of these subjects and the rate of HP in their unit, length of patients’ ICU stay, duration of mechanical ventilation and mortality.

**Methods**

Data were obtained during 2018 from 45 ICU nurses who were asked about their HP and RS knowledge and their role in nutrition of ICU patients. In addition, data about 275 medical-surgical ICU patients were collected retrospectively from observational study and drawn from the unit where the participant nurses worked.

**Results**

Analyses demonstrated the importance of monitoring patients’ phosphate levels and treating them accordingly, as HP and RS can result in complications such as increased length of hospitalization and mechanical ventilation. Analysis also showed a correlation between nurses’ knowledge and their approach toward current nutrition guidelines; the greater a nurse’s knowledge, the more he/she followed the guidelines.

**Conclusions**

Nurses’ knowledge directly influences patient complications resulting from HP and/or RS. Educating ICU nurses about clinical nutrition is an essential part of patient treatment. This can be crucial to patient outcomes and can ultimately save a patient’s life.

**Introduction**

Intensive care unit (ICU) patients often experience electrolyte imbalance in general and hypophosphatemia (HP) in particular. HP is a disruption in the body’s phosphorus level characterized by low levels of phosphorus in the bloodstream.1 ICU patients often have serious circumstances that put them at risk of developing hypophosphatemia, such as sepsis, acute respiratory alkalosis, diabetic ketoacidosis and levels of albumin and prealbumin, as well as malnutrition and a defective body phosphorus reservoir.1-2

Hypophosphatemia is found to be highly correlated with refeeding syndrome (RS),3 a process that occurs when an undernourished individual eats carbohydrates. As a result, insulin is released, which causes glucose and phosphorus to enter the cells. Refeeding syndrome is the abrupt imbalance of electrolytes through the intra-extracellular composition.4 Critically ill patients are at risk of adverse events during the start of food delivery.5

Providing overnutrition to a patient suspected of having RS might be fatal. Early identification and prevention could save lives.6

Prevalence of RS varies across studies due to deficiency in the global definition and in objective diagnostic criteria. The incidence of RS in ICU patients ranges from 25% to 45%.4,6-7 The rate of RS might be even higher due to the fact that RS is underdiagnosed, and therefore, in many cases, it is not reported.8 Hypophosphatemia and RS are associated with longer hospitalization, negative outcomes and mortality.9

If low phosphate levels are ignored by the nursing staff and a patient with HP is fed despite the low phosphate levels, this can lead to an additional and dangerous decrease in phosphate levels as well as rapid changes in other electrolytes (RS) and can result in death.5,10-11 Therefore, to provide effective nutritional treatment, it is necessary to monitor the phosphate levels of patients in the ICU.5

According to Tagney and Haines,12 knowledge provides the nurse with the tools to function in varying patient-care situations and to predict the outcomes of the desired intervention. In addition, the broader the nurse’s knowledge, the more inventive resources the nurse can rely on when needed, thereby providing knowledge-based care.

ICU nurses require a high level of knowledge and skills due to the complexity of the patients’ conditions. The nursing staff’s extended 24-hour stay with the patient brings a great deal of responsibility for continuous monitoring of the patient’s condition, so the nurse is responsible for identifying deterioration reflected in physiological or laboratory changes. However, Liaw et al. (2011)13 and Rischbieth (2006)14 stated that most deterioration cases are not detected in time due to lack of knowledge, lack of communication or failure to report.

The present study aimed to examine ICU nurses’ knowledge of HP, RS and nutrition in general. We analyzed the correlation between the nurses’ knowledge about these subjects and the rate of HP in their unit, length of patients’ ICU stay, duration of mechanical ventilation and mortality.

**Methods**

***Nurse Questionnaire***

This study included a convenience sample of 45 ICU nurses. The 45 nurses involved in the study all worked at the same tertiary care hospital and in the same unit. We developed a questionnaire for the ICU nurses to complete. The questionnaires were face validated by two nursing master’s degree students and two nurses from the academic staff in the nursing department at Tel Aviv University, one of whom is an expert in the field. Participating nurses were asked to rate how much they related to the variables in each of the questionnaire statements.

The questionnaire was divided into the following topics:

 (A) Sociodemographic data that included 13 items. Items 1-5 related to sociodemographic characteristics such as age, gender and country of birth. Items 6-11 referred to professional education, profession and seniority. Items 12-13 related to education about nutrition.

 (B) The nurses’ level of knowledge about HP and RS. This section was divided into four parts and included 20 statements. Nurses were asked to mark their agreement based on the following scale: 1 = *Yes*, 2 = *No*, and 3 = *I do not know*. Section B1 (questions 1-4) focused on the level of the nurse’s knowledge of his/her role in nutrition. Section B2 (questions 5-7) asked about the nurse’s knowledge regarding the importance of electrolyte monitoring before feeding ICU patients. Section B3 (questions 8-9) consisted of statements examining the nurse’s level of knowledge regarding intensive-care nutrition. Section B4 (questions 10-20) consisted of statements examining the nurse’s knowledge about RS: risk factors, consequences and treatment. The Cronbach’s alpha of this section of the questionnaire was 0.78.

(C) Items related to what actually happens in the ICU. Nurses were requested to rate their agreement with each of 11 statements on a scale ranging from 1 (*never*) to 5 (*always*). The Cronbach’s alpha of this section was 0.76.

***Patient Data***

In addition, data about 275 medical-surgical ICU patients were collected retrospectively from observational studies conducted in 2018. All 45 nurses as well as the 275 patients in the retrospective study were from the same facility and ICU unit. A standard statistical power analysis was performed to determine the size of the study population that would be necessary to evaluate the study hypothesis (for the model variables other than the nurses’ questionnaire). The sample size at a power level of 80% and a significance level of 0.05 was calculated using WinPepi software with the expectation that in patients with HP and RS, the expected difference in mortality and complications was less than 0.05. Patients’ data were collected in the patient data management system (MetaVision; iMDsoft, Tel Aviv, Israel). For each patient, a case report form (CRF) was prepared about the following characteristics: (A) demographic data such as age, sex, weight, height and body mass index (BMI); (B) blood laboratory tests at days 0, 1, 2, 3 and 4 of phosphate (2.5–4.5 mg/dl), magnesium (1.5–2.00 meq/l), glucose (70–110 mg/dl) and calcium (8.5–10.9 mg/dl), performed using the Au, Colorimetric method in the automated device < 2.5; (C) levels of sodium (136–145 mmol/l ) and potassium (3.5–5.2 mmol/l), which were tested using the indirect (analyzer) ion-selective electrode (ISE) method (Beckman-Coulter, Inc., Fullerton, CA, USA); and (D) data about complications: mechanical ventilation, length of ICU stay (days), and mortality after 28 days.

The study participants were divided into three groups: (A) patients with serum phosphates < 2.5 during the 4 days after receiving nutrition (*n* = 102); (B) patients whose phosphate levels remained normal (2.5–4.5) during the 4 days after initiation of nutrition (*n* = 63); and (C) patients with high phosphate levels (> 4.5) from ICU hospitalization to 4 days after initiation of nutrition (*n* = 90; see Fig. 1). Data were missing for 20 patients.

**Results**

The mean rate of response to the ICU nurses’ questionnaire was 84%. The majority of the nurses were female (64.6%). Sixty-two percent reported that they had studied a basic course in nutrition as part of their primary nursing studies. A majority, 91.1%, thought that nutrition followup of the ICU patient is not the nurse’s responsibility. Only 22% thought that it was not their duty to perform daily monitoring of electrolytes; however, 75.6% stated that they thought there is no significance for monitoring phosphate levels prior to initiation of feeding. More than 64.4% thought they should start to provide the patient with the full caloric intake immediately after hospitalization in the ICU, as opposed to 35.6% who believed they should withhold feeding, as instructed in the latest guidelines.5,15-16

Sixty-eight percent of the nurses were not aware of the increased risk of RS when the patients’ level of phosphate is low. More than half (59.1%) did not think that there is a correlation between RS and levels of electrolytes (potassium, sodium, calcium and magnesium).

In addition, 63.6% thought that patients with RS do not need any changes or tuning of the maximum caloric intake. Sixty-two percent thought that there is no relationship between HP and length of ICU stay or weaning from mechanical ventilation. About a third of the nurses (34%) reported that there was no awareness in their department of early detection of RS.

The results show that there is a relationship between the level of knowledge of ICU nurses and behavior in preventing and treating HP and RS. The average of the knowledge test score for all ICU nurses was 61.7%. In the Pearson correlation test, the nurses’ knowledge level matched with the medical guidelines and protocol (*p* < 0.05). The results show that the higher the nurses’ knowledge level (*r*p = 0.303, *p* < 0.05), the more they adhered to the current nutrition guidelines. However, there was no difference between nurses who had undergone intensive-care training and those without a course in intensive care in their association of the nurse’s responsibility and the patient’s nutritional status.

Data for ICU patients were collected retrospectively. The patients’ mean age (±SD) was 57±20.3 years. The mean Acute Physiology and Chronic Health Evaluation II (APACHE II) score was 20.4±7.44. On the 2nd day after the start of feeding, 45% of the patients with HP had a significantly lower phosphate level (mean = 1.87), which developed into RS. Moreover, after 72 hours, the number of patients with HP was still double (31.4%) compared to the baseline (15%). About one-third (157) of the patients with normal phosphate levels developed HP after 24 hours of feeding. In addition, 40% of these patients still had a low phosphate level after 2 days, and about a quarter (22%) of them had a low phosphate level after 72 hours (Fig. 2). These patients also had abnormal levels of additional electrolytes such as potassium, sodium, calcium and magnesium compared to patients with normal phosphate levels.

From the HP group, 67% of patients developed RS and received dietary intake higher than 50% of the recommended intake. However, Cramer’s correlation test revealed no significant correlation between high caloric intake and development of RS in HP patients or in the normal-phosphate group.

In a *t*-test for independent samples, a significant difference was found (*p* < 0.006) in the length of ICU hospitalization between the groups. Patients with HP and RS with caloric intake greater than 50% of the recommended intake were likely to be hospitalized for a longer time in the ICU (mean of 14±9.9 days) than patients in the same group who received caloric intake lower than 50% of the recommended daily intake, whose mean length of stay was 10±7.5 days (*p* < 0.006).

In addition, in the HP and RS group, a significant difference was found in the number of days patients were on mechanical ventilation, with a mean of 14±10.1 days in the maximum caloric intake group compared to a mean of 8±7.3 days in the reduced caloric intake group (*p* < 0.015). No significant difference was found in mortality rate between patients with low and normal phosphate levels.

**Discussion**

The goal of the present study was to examine the correlation between nurses’ level of knowledge about HP, RS and nutrition and patient outcomes. Overall, the present study shows there is a direct influence of the nurses’ knowledge on patient complications that result from HP and/or RS.

The present study’s results show that the vast majority (91.1%) of nurses believe that nutrition followup of the ICU patient is not their responsibility. Nutrition is an interdisciplinary process17 and one of 13 domains in nursing practice.18 However, from 1950 to 1970, the nursing role in nutrition separated into two professional disciplines: nurse and dietitian.19 Since then, the nurse’s responsibility and involvement in patients’ nutrition therapy has largely been relegated to ancillary staff.20 These results are supported by the results obtained in the present study. Effective nutrition therapy should include collaboration between medical staff, nurses, dietitians and other healthcare professionals. In many institutions, malnutrition is managed in isolation, with responsibility belonging mainly to the dietitian.17 As such, the role of the nurse in providing nutrition therapy is not clearly defined.21

The results of the present study show that most of the nurses (75.6%) considered monitoring phosphate levels prior to initiation of feeding to be insignificant. In fact, many (64.4%) nurses believed that they should start to provide the patient with the full caloric intake immediately after admission to the ICU. According to the results of the data collected from the ICU patients, the majority of the patients who received more than 50% of the recommended caloric intake developed complications and RS. The current results suggest that ICU nurses should receive instruction on updated guidelines for patient nutrition to help lower the incidence of HP and RS. The nutrition education for nurses includes basic knowledge. There is no obligatory number of educational hours in basic nutrition for bachelor of science in nursing programs. Moreover, there are no strategies for implementing and continuing nutrition education about the role and responsibility of nurses in nutrition.20 According to a study by Stotts et al.,22 only 50% of nursing students feel satisfied with their nutrition studies.

Additional results of the current study reveal that a majority of the nurses were not aware of the increased risk of RS when a patient’s phosphate level is low. According to the ICU patients’ results, on the 2nd day after the start of feeding, 45% of patients with HP had a significantly lower phosphate level, which developed into RS, and after 72 hours, the number of patients with HP doubled. As mentioned above, HP is the indicator of RS.23 Marik et al.’s7 prospective study of ICU patients showed that 34% of patients were diagnosed with RS, and all of those patients had additional decrease of phosphate levels during their ICU stay.

Other metabolic irregularities in blood tests are observed in the present study results and are defined as part of RS, including hypokalemia, hypomagnesaemia and hypocalcemia. These findings are similar to those of other studies.3,24-25 Nonetheless, the present study results show that more than half of the nurses who completed the questionnaire did not think there is a correlation between RS and electrolyte levels.

In addition, the present study results show that 63.6% of the nurses thought patients with RS do not need any changes or tuning of the maximum caloric intake. A study by Zeki et al.3 showed that around one third of patients who started artificial nutrition developed refeeding hypophosphatemia (RH). Moreover, Doig et al.10 showed in a randomized control trial that restricted caloric intake compared to normal caloric intake in critically ill patients with RS significantly reduced complications and the mortality rate in the ICU. According to the guidelines for ICU patients at nutritional risk, the healthcare team should monitor phosphate and electrolyte levels, correct fluid insufficiency and provide thiamine additive. The healthcare team should also restrict their feeding.5,15-16 In the current study, results shown no increase of mortality rate in the RH groups. These results are similar to the results obtained by Zeki et al.,3 who concluded that these results are because there are already many comorbidities that can cause death in ICU patients; therefore, it is hard to distinguish the cause.

The results of the current study demonstrate that there is a lack of knowledge about the relationship between HP and patient outcomes. Nurses stated that there is no correlation between HP and the length of ICU stay or weaning from mechanical ventilation. In a prospective cohort study conducted by Alsumarain et al.26 on 66 ICU ventilated patients, the results showed an association between HP and failure to wean from mechanical ventilation. Some studies link the need for mechanical ventilation to metabolic discombobulation. For example, Boles et al.27 provide an explanation of each metabolic discombobulation to failure to wean from mechanical ventilation. Coşkun et al.28 showed that RH was found in 52.14% of 117 ICU patients. According to the Coşkun study, the mortality rate was higher and the ICU length of stay was longer in patients with RH.

The results of the current study show that there is a relationship between the level of knowledge and the behaviors of ICU nurses and the prevention and treatment of HP and RS. The results show that the higher the nurses’ knowledge level, the more the nurses followed the current nutrition guidelines (Fig. 3). Currently, the role of nurses in patient nutrition is suboptimal. Many factors affect nurses’ knowledge of nutrition therapy and their responsivity in the ICU, including lack of nutrition education, lack of interprofessional collaborative practice, interprofessional team-based care etc.29 Studies examining ICU patients’ nutrition therapy for a period of time have shown that most ICU patients are underfed during their ICU stay.30-31 Nutritional treatment starts quite slowly and does not in any way reach the fulfilled caloric targets. The results of the present study demonstrate that there is a direct relationship between nurses’ knowledge and their following current nutrition guidelines, which eventually will improve outcomes. These results indicate that if nurses receive more education and have a positive attitude toward nutrition, it may reduce the incidence of malnutrition in ICUs and hospitals. In light of the above, we need to develop an interprofessional approach to implementing nutrition therapy to improve quality of care in ICU patients.

***Limitations***

Our convenience sample of nurses might be unique in their perceptions of the topic, since all participants were selected from the same ICU. Additionally, the accuracy of the questionnaire could be adversely affected by the nurses’ high workload that limited their time to answer the questionnaire. A further issue of concern is that patient data were collected retrospectively, and there is no certainty that the same nurses who participated in the study treated those patients, although the patients were admitted to the same unit where the participating nurses worked.

In conclusion, the present study demonstrates the importance of monitoring patients’ levels of phosphate and treating them accordingly. HP and RS can result in a higher rate of complications such as length of hospitalization and length of mechanical ventilation. In addition, there is a correlation between the level of nurses’ knowledge and their approach toward current nutrition guidelines: the higher the nurse’s knowledge, the more he/she will follow the current nutrition guidelines. This can be crucial to patient outcomes and can ultimately save a patient’s life. Therefore, it is essential to increase nurses’ education about their role in ICU nutrition.

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