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25

Evaluation of Prevalence and Effect of Hypophosphatemia on Postoperative Outcomes in Open Heart Surgeries

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Abstract

Background: Hypophosphatemia is a common yet under-recognized complication following open-heart surgery, potentially impacting postoperative outcomes. Despite its reported association with prolonged mechanical ventilation (MV), ICU stay, and increased morbidity, its incidence and effects remain inconsistently described. **Objectives:** To establish the incidence of postoperative hypophosphatemia and assess its impact on MV duration, ICU stay, cardioactive drug support, arrhythmia, and mortality. **Methods:** A prospective case-control study was performed on one hundred cases admitted to the Cardiac Surgery ICU after elective open-heart surgery at Benha University Hospitals. Patients were categorized into hypophosphatemia and normophosphatemic groups. Perioperative parameters, laboratory findings, and clinical outcomes were analyzed. **Results:** Postoperative hypophosphatemia incidence was 40% immediately after surgery and 50% on day one. The hypophosphatemia group had significantly longer ventilation (16.78±3.85 vs. 5.9±2.87 hrs., p<0.001), ICU stay (4.53±1.15 vs. 2.22±0.94 days, p<0.001), hospital stay (7.4±1.65 vs. 5.25±1.2 days, p<0.001) and drain duration (41.43±13.07 vs. 28.98±9.2 hrs., p<0.001). IABP use (15% vs. 0%, p=0.002), re-intubation (12.5% vs. 0%, p=0.005), and arrhythmia (10% vs. 0%, p=0.021) were significantly higher. Mortality was higher in hypophosphatemia patients (7.5% vs. 1.67%, p=0.144), though not statistically significant. **Conclusion:** Postoperative hypophosphatemia is common in open-heart surgery and is associated with prolonged ICU stay, MV, and increased morbidity. Early identification and management may improve patient outcomes.

Keywords: Hypophosphatemia; Open-Heart surgery; Mechanical Ventilation; Phosphate Imbalance; Inotropic Support

Introduction

Phosphate is a vital micronutrient that plays a fundamental role in both structural and metabolic processes. It is an essential component of bones, cell membranes, and genetic material. Additionally, phosphate is crucial for energy metabolism, as it contributes to the formation of ATP and creatine phosphate. A severe deficiency in phosphate can lead to energy depletion and metabolic disturbances. (1)

Hypophosphatemia is characterized by a serum phosphate level of ≤0.8 mmol/L (2.5 mg/dL) and is classified based on severity, with mild cases ranging from 2 to 2.5 mg/dL, moderate cases between 1 and 2 mg/dL, and severe cases defined as levels below 1 mg/dl (2,3). Despite its clinical importance, the prevalence and impact of hypophosphatemia following cardiac surgery remain inadequately explored and require further research (4,5). Recent studies suggest that its occurrence varies significantly, with reported incidence rates between 34.3% and 50%. This condition has been linked to several serious complications, including respiratory failure, cardiac arrhythmias, and myocardial dysfunction, all of which can negatively affect postoperative recovery and overall patient outcomes (6). Hypophosphatemia has been associated with extended durations of mechanical ventilation (MV), increased morbidity and mortality rates, and prolonged stays in the intensive care unit (ICU). However, the exact extent of its impact remains uncertain, as findings across studies have been inconsistent due to the influence of various confounding factors (7,8).

Hypophosphatemia is commonly observed in postoperative periods, especially after cardiac surgeries. It can result from inadequate oral intake, reduced intestinal absorption, increased renal excretion, intracellular shifts, or hospital interventions (e.g., glucose infusions, insulin, catecholamines, diuretics), leading to widespread systemic complications. In severe cases, it may cause cardiac failure, encephalopathy, seizures, skeletal and respiratory muscle dysfunction, metabolic acidosis, hepatic impairment, and glucose intolerance (9,10).

This research aims to assess the incidence of hypophosphatemia in patients undergoing open-heart surgery and to evaluate its potential secondary effects. Specifically, it investigates the impact of postoperative phosphate levels on the duration of MV, length of stay in the ICU, and the necessity for cardioactive drug support. Additionally, the research seeks to identify correlations between postoperative phosphate levels and various demographic characteristics, as well as intraoperative factors.

Patients and Method

Study design and population

This prospective case-control study was conducted on a cohort of 100 patients admitted to the Cardiac Surgery Intensive Care Unit (CSICU) following elective open-heart surgery at the Cardiothoracic Surgery Department of Benha University Hospitals between December 2022 and August 2023. The study was initiated upon obtaining formal approval from the Research Ethics Committee of Benha University, Egypt. Moreover, to ensure adherence to ethical guidelines and safeguard patient autonomy, informed written consent was obtained from all participants prior to their enrollment in the study.

Grouping

Case group:

(N=40) Hypophosphatemia patients with serum phosphate (<2.5mg/ dl).

Control group:

(N=60) Normophosphataemic patients with serum phosphate level (2.5-4.5mg/dl).

Eligibility Criteria

Inclusion criteria: Age of patient (18-75). Both sexes. Different races Patients admitted to CSICU after elective open-heart surgery and mechanically ventilated. **Exclusion criteria:** Pregnant or breastfeeding patients and those with an estimated mortality risk above 5% based on EuroSCORE II. Patients with severe renal failure (creatinine clearance <15 mL/min), severe liver impairment (Child-Pugh Class C), incomplete biochemical data, or preoperative serum phosphate levels below 2.5 mg/dL were also excluded. Additional criteria included electrolyte imbalances (serum K <3.5 or >5.5 mmol/L, Na <130 or >150 mmol/L, Mg <1.8 mmol/L), lung-heart transplantation, and off-pump surgery. Patients requiring emergency postoperative surgery or those with complications affecting postoperative variables were excluded.

Assessment

All patients were subjected to:

Complete history and physical examination: Age. Sex. Body mass index (BMI) Data included presenting symptoms, reason for surgery, medical history (diabetes, hypertension, renal/liver disease, malabsorption, alcoholism, eating disorders, cancer), medication use, prior surgeries, and family history of phosphate-wasting disorders. Clinical examination covered vital signs, chest assessment, and consciousness level (Glasgow Coma Scale, GCS). GCS, a neurological scale, evaluates eye, verbal, and motor responses, scoring from 3 (coma) to 15 (fully conscious). Euro SCORE II was calculated to assess surgical mortality risk, offering a refined estimate based on updated patient data (11).

Scoring system: Euro SCORE II includes age, sex, NYHA class, extracardiac arteriopathy, renal and pulmonary dysfunction, surgery urgency, previous cardiac surgery, comorbidities (diabetes, hypertension, COPD), and recent MI. Responses were "Yes" or "No," with risk categories:0 - ≤2: Low risk>2 - <5: Moderate risk>5: High risk.

Laboratory investigations: Complete blood count (CBC). Kidney function test. Liver function tests. Arterial blood gases. Lipid profile. Thyroid function tests (TSH, Free T3, Free T4). Coagulation profile (PT, PTT, INR). ABO grouping.

Radiological investigations: Chest Radiology Electrocardiogram. Echocardiography. Duplex Ultrasonography

Blood sampling: Serum levels of phosphate, potassium, magnesium, and ionized calcium were measured at three specific time points: the morning before surgery, immediately upon ICU admission, and on the first postoperative day. These measurements were done using the Hitachi 747 Automatic Analyzer (Boehringer Mannheim, Germany).

Operative and postoperative assessment

Type of surgery: Among the 100 patients, 55(55%) underwent coronary artery bypass graft (CABG) and 45(45%) underwent valve surgery.

A standardized anesthesia protocol was used for sedation. During surgery, patients were maintained on a heart-lung machine, with cardiac arrest achieved using anterograde or retrograde cardioplegia. Core temperature was maintained at 30°C during CPB and rewarmed to 37°C before discontinuation. Haemodilution was achieved with IV crystalloids to maintain haematocrit at 20-22%. After surgery, patients were transferred to the cardiothoracic ICU. Postoperatively On ICU arrival and after 24 hours, serum phosphate and vitals were assessed. MV, cardioactive support, and IV analgesia were provided as needed. Weaning required hemodynamic stability, minimal bleeding, adequate urine output, and SpO_2 >95%. Extubation preceded ICU discharge after 12–24 hours. In the ward, patients were monitored for stability, mobility, anticoagulation (INR 2–3), and wound healing. Hospital discharge required independence, no IV medications, sinus rhythm, and no infection.

Measurements

Operative data included CPB duration, cross-clamp time, transfused packed cells/FFPs, and intraoperative fluids. Postoperative data covered ventilation duration, ICU stay, cardioactive support duration, blood loss, transfusions, IABP use, hospital stay, and mortality. Surgical outcomes were assessed based on these parameters in both groups.

Outcomes

Primary outcomes: Detect incidence of hypophosphatemia among patients underwent open heart surgery. **Secondary outcomes** included: Assessment clinical implication of hypophosphatemia on post-operative outcomes as: Duration of MV ICU stays Cardioactive drug support Arrythmia Mortality rate.

Sample size calculation

The sample size was determined using the G*Power Sample Size Calculator (version 3.1.9), which established a minimum requirement of 50 patients for the study.

Approval code: MS 22-11-2022

Statistical analysis

Statistical analysis was conducted using the Statistical Package for the Social Sciences (SPSS) software, version 28 (IBM Inc., Armonk, NY, USA), to ensure precise and reliable interpretation of the collected data. Quantitative variables were expressed as mean ± standard deviation (SD) and were subjected to comparative analysis between the two study groups using the unpaired Student's t-test. This parametric test is widely employed to determine significant differences in continuous numerical data between two independent groups. For qualitative variables, data were represented as frequencies and percentages (%) to provide a clear depiction of distribution patterns. The Chi-square test was applied for categorical comparisons when the expected frequencies were sufficiently large, whereas Fisher's exact test was utilized as an alternative for datasets with smaller expected counts, ensuring statistical accuracy. To determine the level of significance, a two-tailed p-value threshold of less than 0.05 was considered indicative of statistical significance.

Results

This prospective, case control study included patients admitted to CSICU after elective open-heart surgery and was conducted in Cardiothoracic Surgery Department at Benha University Hospitals.

Preoperatively, 90.91% (n=100) had normal phosphate, while 9.09% (n=10) had hypophosphatemia and were excluded. Hypophosphatemia occurred to 40% (n=40) immediately post-op and 50% (n=50) by day one, showing a progressive decline in phosphate levels. **Table 1**

The case group (hypophosphatemia patients) and the control group (normophosphatemic patients) exhibited comparable characteristics with respect to age (42.55 ± 9.94 vs. 40.95 ± 10.25 years, p = 0.480), sex distribution (67.5% vs. 73.33% male, p = 0.528), height (1.66 ± 0.04 vs. 1.66 ± 0.05 m, p = 0.882), weight (74.85 ± 7.65 vs. 72.15 ± 8.69 kg, p = 0.114), and BMI (27.19 ± 3.09 vs. 26.21 ± 3.65 kg/m², p = 0.163) **Table 2**

Serum potassium, sodium, calcium, and magnesium levels did not differ significantly between the hypophosphatemia and normophosphatemic groups (P = 0.100, 0.697, 0.588, and 0.660, respectively). However, phosphate levels were markedly lower in the hypophosphatemia group (2.08 ± 0.23 mg/dL) compared to the normophosphatemic group (3.62 ± 0.57 mg/dL) (P < 0.001). **Table 3**

The hypophosphatemia group demonstrated significantly greater intraoperative blood loss (1425 ± 375.36 mL vs. 740 ± 149.8 mL, p < 0.001), required more packed cell transfusions (2.16 ± 0.71 vs. 1.78 ± 0.58, p = 0.005), and had a higher frequency of blood transfusion requirements (30% vs. 1.67%, p < 0.001). Additionally, all patients in the hypophosphatemia group required inotropic support at ICU admission, compared to only 15% in the normophosphatemic group (p < 0.001). Other intraoperative parameters were comparable between the two groups. **Table 4**

Postoperative hypophosphatemia was significantly associated with adverse clinical outcomes, including prolonged MV duration (16.78 ± 3.85 vs. 5.9 ± 2.87 hours, p < 0.001), extended ICU stay (4.53 ± 1.15 vs. 2.22 ± 0.94 days, p < 0.001), and longer overall hospitalization (7.4 ± 1.65 vs. 5.25 ± 1.2 days, p < 0.001). Additionally, hypophosphatemia patients exhibited a higher incidence of complications, such as increased need for intra-aortic balloon pump (IABP) support (15% vs. 0%, p = 0.002), re-intubation (12.5% vs. 0%, p = 0.005), and postoperative arrhythmias (10% vs. 0%, p = 0.021). Although mortality was higher in the hypophosphatemia group (7.5% vs. 1.67%), the difference was not statistically significant (p = 0.144). **Table 5**

Table 1: Distribution of the studied patients

	Preoperatively (n=110)	**Immediately postoperatively (n=100)**	**At first postoperative day (n=100)**
Normal phosphate level	100 (90.91%)	60 (60%)	50 (50%)
Hypophosphataemia	10 (9.09%) (excluded)	40 (40%)	50 (50%)

Table 2: Baseline characteristics of the studied groups

		Case group (Hypophosphataemic patients) (n=40)	**Control group (Normophosphataemic patients) (n=60)**	**P value**
Age (years)	**Mean ± SD**	42.55± 9.94	40.95± 10.25	0.480
	Range	25-60	26-59	
Sex	**Male**	27 (67.5%)	44 (73.33%)	0.528
	Female	13 (32.5%)	16 (26.67%)	
Height (m)	**Mean ± SD**	1.66± 0.04	1.66± 0.05	0.882
	Range	1.60-1.73	1.59-1.73	
Weight (Kg)	**Mean ± SD**	74.85± 7.65	72.15± 8.69	0.114
	Range	60-86	59-87	
BMI (Kg/m^2)	**Mean ± SD**	27.19± 3.09	26.21± 3.65	0.163
	Range	21.55-33.2	19.94-33.62	

SD: Standard deviation; Kg/m²: Kilograms per Square Meter. BMI: Body Mass Index

Table 3: Serum electrolytes of the studied groups

		Case group (Hypophosphataemic patients) (n=40)	Control group (Normophosphataemic patients) (n=60)	P value
Potassium (mmol/L)	**Mean ± SD**	4.56± 0.65	4.34± 0.62	0.100
	Range	3.4-5.5	3.5-5.5	
Sodium (mEq/L)	**Mean ± SD**	137.58± 1.66	137.47± 1.11	0.697
	Range	135-140	136-139	
Calcium (mg/dL)	**Mean ± SD**	9.4± 0.57	9.46± 0.59	0.588
	Range	8.6-10.4	8.5-10.5	
Magnesium (mg/dL)	**Mean ± SD**	2.16± 0.26	2.14± 0.27	0.660
	Range	1.8-2.7	1.7-2.6	
Phosphate (mg/dL)	**Mean ± SD**	2.08± 0.23	3.62± 0.57	**<0.001***
	Range	1.7-2.4	2.7-4.5	

SD: Standard Deviation, mmol/L: Millimoles per Liter, *: Statistically Significant Value. mEq/L: Milliequivalents per Liter, mg/dL: Milligrams per Deciliter

Table 4: Intraoperative data of the studied groups.

		Case group (Hypophosphataemic patients) (n=40)	Control group (Normophosphataemic patients) (n=60)	P value
Units PCV transfused	**Mean ± SD**	2.16± 0.71	1.78± 0.58	**0.005***
	Range	1.1-3.3	0.9-3.1	
Units of FFPs		0 (0%)	0 (0%)	---
Duration on heart lung machine (min)	**Mean ± SD**	92.95± 6.35	88.53± 13.71	0.060
	Range	80-103	62-107	
Time of cross clamp (min)	**Mean ± SD**	58.75± 5.88	56.82± 6.25	0.124
	Range	50-69	45-68	
Intraoperative fluids (ml)	**Mean ± SD**	2070.08± 274.32	2010.67± 206.59	0.220
	Range	1619-2500	1616-2373	
Amount of blood loss (ml)	**Mean ± SD**	1425± 375.36	740± 149.8	**<0.001***
	Range	500-2000	500-1000	
Patients needed blood transfusion		12 (30%)	1 (1.67%)	**<0.001***
Ionotropic support at ICU admission		40 (100%)	9 (15%)	**<0.001***

PCV: Packed Cell Volume (referring to transfused packed red blood cell units), FFPs: Fresh Frozen Plasma, ICU: Intensive Care Unit

Table 5: Postoperative data of the studied groups

		Case group (Hypophosphataemic patients) (n=40)	Control group (Normophosphataemic patients) (n=60)	P value
Duration of ventilation (hrs.)	**Mean ± SD**	16.78± 3.85	5.9± 2.87	**<0.001***
	Range	9-22	1-11	
Duration ICU stay (days)	**Mean ± SD**	4.53± 1.15	2.22± 0.94	**<0.001***
	Range	3-6	1-5	
Duration of hospital stay(days)	**Mean ± SD**	7.4± 1.65	5.25± 1.2	**<0.001***
	Range	5-10	4-9	
Duration of drains required (hrs.)	**Mean ± SD**	41.43± 13.07	28.98± 9.2	**<0.001***
	Range	20-67	15-53	
IABP use		6 (15%)	0 (0%)	**0.002***
Re-intubation needed		5 (12.5%)	0 (0%)	**0.005***
Incidence of arrythmia		4 (10%)	0 (0%)	**0.021***
Mortality		3 (7.5%)	1 (1.67%)	0.144

ICU: Intensive Care Unit, IABP: Intra-Aortic Balloon Pump, SD: Standard Deviation

Discussion:

Phosphate plays a key role in various physiological functions, yet hypophosphatemia often goes undiagnosed, leading to delays in appropriate medical intervention. Its severity varies by age and is linked to postoperative complications and increased mortality. Despite its potential impact on respiratory and cardiac function, the specific consequences of hypophosphatemia in the context of cardiac surgery remain insufficiently explored, necessitating further study (10,12,13,14,15) .

This study aimed to determine the prevalence of hypophosphatemia and its impact on crucial surgical outcomes such as mechanical ventilation (MV) duration, ICU stay, and cardioactive support. It included 100 patients undergoing elective cardiac surgery, divided into two groups based on their postoperative phosphate levels: hypophosphatemia and normophosphatemic.

Immediately after surgery, most patients exhibited normal phosphate levels, but by the first postoperative day, 50% developed hypophosphatemia. This pattern aligns with previous findings (16,17).

Baseline characteristics such as age, gender, height, weight, and BMI were similar between two groups. This is consistent with Paediatric ICU studies showing no demographic differences between hypophosphatemic and normophosphatemic group (18) .

Risk factors including DM, HTN, dyslipidaemia, and IHD were similarly distributed across both groups. This matches previous studies with no significant variation in comorbidities (18).

Furthermore, the type of surgical procedure performed (CABG or valve replacement) did not differ significantly between groups. Prior case-control studies also showed no procedural distribution difference (16).

Scores like Glasgow Coma Scale (GCS) and Euro SCORE II were also , consistent with other studies showing preoperative risk scores did not differ with phosphate status (19).

In the present study, vital signs and lab findings such as HB, WBC, PLT, ALT, AST, creatinine, and urea showed no significant difference between groups.

Postoperative phosphate level was significantly lower in the hypophosphatemia group, while other electrolytes remained comparable. These findings support prior studies linking phosphate and lactic acidosis (20).

Intraoperative data showed greater volume blood loss, higher number of packed cell volume (PCV) units transfused, and more need for inotropic support at ICU admission in the hypophosphatemic group. Though, the duration of cardiopulmonary bypass (heart-lung machine time), aortic cross-clamp time, and intraoperative fluid administration were similar. Additionally, none of the patients in either group required fresh frozen plasma (FFP) transfusion.

This aligns with studies of 3,260 cardiac surgery patients who also experienced longer surgical times with hypophosphatemia. However, those studies also showed higher fluid and RBCs transfusion, unlike this one (20).

Similarly, other studies confirmed longer surgery duration in hypophosphatemia patients, but also reported greater fluid and RBCS transfusion, indicating variable intraoperative influences (16).

Our postoperative findings demonstrated that the duration of MV, ICU stay, hospital stay, and drainage duration were significantly prolonged in the hypophosphataemia group Intra-aortic balloon pump (IABP) use, incidence of re-intubation, and occurrence of arrhythmia were also more common. Mortality was higher but not statistically significant.

Some studies contrast these findings, showing no significant correlation between phosphate levels and MV duration or ICU stay, suggesting inconsistencies across research (19).

Hypophosphatemia has been documented in up to 20% of critically ill ICU patients, with evidence suggesting a significant increase in ICU mortality among those affected (21).

A study of 566 individuals who had elective major heart surgery found that severe hypophosphatemia led to longer MV duration, more drug support, and extended hospital stays, but no significant mortality difference consistent with this study (17).

This research has a few limitations, including its single-center design, which may limit the results' external validity and generalizability. The sample size reduces the statistical power, potentially affecting the detection of specific associations. Additionally, the ability to evaluate the prolonged impact of postoperative hypophosphatemia on patient outcomes.

Conclusion

The findings of this study indicate that hypophosphatemia is a common occurrence following cardiac surgery, with its peak incidence observed on the first postoperative day. Moreover, it is associated with significant respiratory and cardiac morbidity, underscoring the importance of routine phosphate level monitoring in the postoperative period. Early detection and timely management, particularly in high-risk patients, may help mitigate complications and improve overall surgical outcomes.

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