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ORIGINAL RESEARCH

Hypophosphataemia after cardiopulmonary bypass – incidence and clinical significance, a South African perspective

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Background: Hypophosphataemia is well-known in the intensive care units (ICU), for example, in refeeding syndrome. There is limited research available for hypophosphataemia in the 'post-cardiac surgery' population.
Objectives: Defining the incidence of hypophosphataemia after cardiopulmonary bypass, in a South African population. Secondary objectives include the clinical implication of hypophosphataemia on duration of mechanical ventilation, ICU stay, and cardioactive drug support; and possible associations between demographic variables, intraoperative variables (including cardioplegic solution), and the postoperative phosphate levels.
Methods: This was a single-centre, non-blinded, prospective cohort analytical study at an academic hospital, in patients presenting for open cardiac surgery. Over a one-year period, 101 patients were included. Preoperative variables included all the factors of the EuroSCORE II risk evaluation score. Intraoperative variables recorded were drug and blood product administration, cardioplegic solution and cardiopulmonary bypass-related variables. Postoperatively, serum phosphate levels were taken daily and postoperative care measures, such as duration of cardioactive drug support, mechanical ventilation, and ICU stay, were recorded.
Results: The incidence of hypophosphataemia, immediately postoperative, was 12.6% (95% confidence interval [CI] 6.7–21.0%) and peaked on Day 3 at 29.0% (95% CI 20.1–39.4%). New onset hypophosphataemia at any stage during the ICU stay was 52.6% (95% CI 42.1–63.0%). No significant associations between hypophosphataemia and secondary objectives were found.
Conclusion: Hypophosphataemia was common with an incidence higher than expected. This did not translate into a clinical effect, as the degree was usually mild (0.66–0.79 mmol/L).

Keywords: cardioplegic solutions, cardiopulmonary bypass, hypophosphataemia, intensive care unit stay, incidence

Introduction

Phosphate is an essential micronutrient involved in numerous critical structural and physiological functions. It is structurally incorporated into the skeletal system (hydroxyapatite), cell membranes (phospholipids) and the cell nucleus (nucleic acids).[1,2] Phosphate is central in metabolism, functioning as a key component of adenosine triphosphate and creatinine phosphate. Severe decrease in phosphate levels may, therefore, result in energy depletion.[1] Phosphate is also present in 2,3-diphosphoglycerate which is a crucial factor that regulates haemoglobin's affinity for oxygen.[1,2] In the secondary messenger system, phosphate plays a critical role as cyclic adenosine monophosphate and phosphoinositide.[1] It is also involved in the regulation of protein function where dephosphorylation or phosphorylation can activate or deactivate different enzymes. Renally it acts as a urinary buffer where it binds with free hydrogen ions.[2] Less than one per cent of phosphate is present in plasma and two thirds of this phosphate is in the organic form, as a complex ion, or bound to proteins and lipids. The rest of the plasma phosphate is in the inorganic form ($H_2PO_4^-$, HPO_4^{-2} and PO_4^{-3}).[1,2] Intra-cellular shifts of phosphate take place with a glucose or insulin load that result in the intra-cellular phosphorylation of glucose.[1]

Hypophosphataemia, as determined by the serum inorganic phosphate level, is defined as a phosphate level below 0.80 mmol/L and is classified as mild (0.79–0.66 mmol/L), moderate (0.32–0.65 mmol/L) or severe (< 0.32 mmol/L).[3] The clinical implications of severe hypophosphataemia vary and include decreased cardiac contractility, acute cardiac failure, encephalopathy, delirium, seizures, skeletal myopathy, respiratory muscle failure, metabolic acidosis, hepatic dysfunction, and glucose intolerance.[1,4,5] Acute cardiac and respiratory muscle failure are considered the most important postoperative complications.

Current research demonstrates an incidence of hypophosphataemia after cardiac surgery ranging from 34.3% to 50%. The definition of hypophosphataemia unfortunately varied with values < 0.8 mmol/L, < 0.48 mmol/L and < 0.6 mmol/L.[6-8]

A number of studies have been done in patients undergoing hepatic surgery. Hypophosphataemia was common, with an incidence of 67% to 100%.[9,10] These were, however, small studies and should be interpreted in light thereof. There is also a transient hyperphosphaturia present after hepatic surgery that could exacerbate the hypophosphataemia.[11] Larger studies done in surgical and general intensive care units (ICUs) presented an incidence of 28% to 28.8%.[11,12]

The incidence of postoperative hypophosphataemia and the clinical implication thereof have not been investigated in a South African population.

Objectives

The primary objective was to assess the incidence of hypophosphataemia after cardiopulmonary bypass. Secondary objectives were to determine:

- the effect of hypophosphataemia on the duration of postoperative mechanical ventilation, duration of postoperative ICU stay and duration of cardioactive drug support (inotrope or vasopressor)
- if the use of different cardioplegic solutions had an effect on the incidence of postoperative hypophosphataemia
- other possible associations between serum phosphate levels and demographic variables (race, sex), intraoperative variables, and the immediate postoperative and during ICU stay.

Methods

Design

After obtaining approval from the local ethics committee, provincial health authorities and patients' written informed consent, a non-blinded, prospective cohort analytical study was carried out.

Population and setting

Adult patients (aged > 18 years) of either sex and of various races were screened for inclusion. The study was carried out between April 2017 and March 2018 at a university hospital. Patients scheduled for elective or urgent open-heart surgery and for whom postoperative mechanical ventilation had been planned in the ICU were included. Patients with an estimated mortality of > 5%, based on the EuroSCORE II Risk Evaluation, were excluded from the study.[13] The EuroSCORE II Risk Evaluation predicts perioperative mortality based on numerous preoperative indicators as well as the procedure performed.

Patients were also excluded from the study if they underwent offpump surgery, had incomplete biochemical results, or developed a complication postoperatively, which would necessitate emergency surgery or would have influenced the accuracy of the postoperative course variables. Patients were free to withdraw from the study at any time.

A pilot study was performed in January 2017 in three patients to screen for any problems with the design and datasheets, and to familiarise the personnel with the required procedures. The pilot study followed the same process as the planned study, and since no problems were identified, these patients were included in the study sample.

Assessments

Patients had a routine preoperative biochemistry blood profile, which included a baseline serum phosphate level. As per the primary anaesthetist's sole judgment for each patient, a routine anaesthetic was given. Data on the intraoperative course, interventions and treatment were recorded by the anaesthesiologist and perfusion technologists. Postoperatively, on arrival in the ICU and daily thereafter, a biochemical profile was performed. The serum phosphate level along with the postoperative care measurements, such as the duration of mechanical ventilation, duration of ICU stay, and the duration of cardioactive drug support, were recorded. A Roche® Cobas 6000 Analyzer (Roche Diagnostics, Indianapolis, IN, USA) was used to analyse the biochemical profile. The machine was maintained and calibrated according to the standard operating procedures of the National Health Laboratory Service, Universitas Hospital Complex, which is ISO: SANAS 15189 compliant.

Cardioplegic solutions

The type of cardioplegic solution used for each patient was dependent on the surgeon's preference. The two types of cardioplegic solutions used in the study site's Theatre Complex are the Bucksberg solution and the Modified St Thomas solution. The Bucksberg solution is commercially available ("Fresenius Kabi-Medsol" cardioplegic solution). The initial 500 ml solution used, is known as the cardiologic induction solution. When the cardioplegia had to be repeated, this was then followed by the cardioplegic maintenance solution. The Modified St Thomas solution was prepared preoperatively and used for induction and maintenance of cardioplegia. The solution consisted of potassium chloride (15 mmol/L), lignocaine (200 mg/L), magnesium sulphate (4 g/L), sodium bicarbonate (30 mmol/L) and hydroxyethyl starch 6% 130/0.4 (50 ml/L) that is added to one litre of Ringer's lactate solution.

Statistical analysis

A sample size of 100 patients was selected, based on a power analysis done by the institute's biostatistical department. This was calculated based on an estimated incidence of hypophosphataemia after cardiopulmonary bypass of 40%, as estimated from previous research.[6-8] A sample of 100 patients gave a confidence interval (CI) of 30% to 50%.

Factors that could have affected the absolute value of electrolytes, at any given time, included biological intra-individual variation (cyclic or random variations in an analyte, fluctuation around a specific set point) and analytical variation (standard deviation [SD] of the study's laboratory analyser around a given set point).

The biological variation for serum phosphate is 8.15%.[14] When considering the analytical variation, the SD of serum phosphate on the study's analyser was 0.036 mmol/L. To achieve a 95% CI, in order to confirm that the change in serum phosphate level is not due to an SD of the machine, the reference change value was calculated as 0.1 mmol/L.[15] These two factors were combined to calculate the combined variation value of 23.95%.[15] Therefore, a change in serum phosphate level > 23.95% cannot be attributed to either a biological variation or analytical variation. This is presented in the data as a significant change in serum phosphate value.

The collected data were captured in an Excel spreadsheet and analysed using SAS Version 9.4. Results are summarised by frequencies and percentages (categorical variables), median and interquartile range [IQR] (numerical variables, due to skew distributions). Subgroups were compared using chi-squared or Fisher's exact tests (categorical variables) and Mann-Whitney tests (numerical variables).

Results

Patient characteristics

Of the 140 patients screened, 101 were included according to the inclusion criteria. Most patients were male (60.4%) with a median age of 50 years (Tables I and II).

Six patients had a low starting serum phosphate level and were not included in evaluating postoperative clinical variables. Thus, 95 patients were evaluated for associations between intraoperative care measures and postoperative serum phosphate levels and clinical care indicators (duration of mechanical ventilation, duration of ICU stay, and duration of cardioactive drug support).

The drug and blood products administered intraoperatively are compared to the immediate postoperative serum phosphate level in Table III.

Table I: Preoperative and intraoperative characteristics of the sample – numerical data (n = 101)

Variable	Median	Range
Age (years)	50	18–74
Final Euro II score	1.9	0.6–5
Duration of cardiopulmonary bypass (min)	134	39–501
Degree of hypothermia (˚C)	30	15.8–36.6
Cell saved blood transfused (ml)	638	150–2 403

Incidence of hypophosphataemia

Serum phosphate levels were evaluated daily and are graphically represented in Table IV. As seen in Table IV, the incidence of hypophosphataemia was 12.6% immediately postoperatively (95% CI 6.7–21.0%); 9.5% on Day 1 (95% CI 4.4–17.2%), 25.3%

Table II: Preoperative and intraoperative characteristics of the sample – categorical data (n = 101)

Variable	*n* (%)
Sex	
Male	61 (60.4)
Female	40 (39.6)
Race	
Black	53 (52.5)
White	30 (29.7)
Mixed race	11 (10.9)
Indian	7 (6.9)
Surgery urgency	
Elective	49 (48.5)
Urgent	52 (51.5)
Weight of intervention	
Isolated CABG	34 (33.7)
Single non-CABG*	43 (42.6)
2 procedures	23 (22.8)
≥ 3 procedures	1 (1.0)
Preoperative albumin	
Normal albumin level > 35 g/dL	60 (59.4)
Hypoalbuminaemia < 35 g/dL	41 (40.6)
Cardioplegic solution	
Bucksberg solution	55 (54.5)
Modified St Thomas solution	46 (45.5)

*Single non-CAPG is any single cardiac surgical procedure excluding CABG.
CABG – coronary artery bypass grafting

Table III: Association between intraoperative drug and blood product administration to postoperative serum phosphate level

Variable	Immediate postoperative serum phosphate level	Patients (*n*)	Group size	Percentage of group (%)
Blood products transfused intraoperative				
Packed red cells	≥ 0.8 mmol/L	46	83	55.4
	< 0.8 mmol/L	7	12	58.3
Fresh frozen plasma	≥ 0.8 mmol/L	29	83	34.9
	< 0.8 mmol/L	2	12	16.7
Pooled platelets	≥ 0.8 mmol/L	35	83	42.2
	< 0.8 mmol/L	3	12	25.0
Cryoprecipitate	≥ 0.8 mmol/L	33	83	39.8
	< 0.8 mmol/L	3	12	25.0
Intraoperative drug administration				
Corticosteroids	≥ 0.8 mmol/L	72	83	86.7
	< 0.8 mmol/L	11	12	91.7
Insulin	≥ 0.8 mmol/L	52	83	62.7
	< 0.8 mmol/L	11	12	91.7
Dextrose	≥ 0.8 mmol/L	8	83	9.6
	< 0.8 mmol/L	4	12	33.3

Table IV: Serum phosphate levels of the study sample taken preoperatively, immediately postoperatively and daily in the postoperative period until discharge from the ICU

Time point	Patients (*n*)	Percentage (%) of patients per level of hypophosphataemia			
		≥ 0.8 mmol/L	0.66–0.79 mmol/L	0.32–0.65 mmol/L	< 0.32 mmol/L
Preoperative*	101	94.1	4.9	1.0	0
Immediate postop	95	87.4	4.2	8.4	0
Day 1	95	90.5	6.3	2.1	1.1
Day 2	95	74.7	16.8	8.4	0
Day 3	93	71.0	20.4	8.6	0
Day 4	65	78.2	16.4	4.4	0
Day 5	23	91.3	8.7	0	0
Day 6	13	84.6	15.0	0	0
Day 7	8	75.0	12.5	12.5	0
Day 8	3	66.7	33.3	0	0
Days 9–16	1	100.0	0	0	0

*Six patients had a low starting serum phosphate level (0.32–0.79 mmol/L) and were not included in evaluating postoperative clinical variables.

on Day 2 (95% CI 16.9–35.2%) and 29.0% on Day 3 (95% CI 20.1–39.4%). The incidence of hypophosphataemia at any stage during postoperative ICU stay was 52.6% (95% CI 42.1–63.0%). The sample size decreased as patients were discharged from the ICU.

A significant decrease in serum phosphate level (> 23.95%) was present in 26.3% (95% CI 17.8–36.4%) of patients immediately postoperatively, and 66.3% (95% CI 55.9–75.7%) had a significant decrease in serum phosphate level in their ICU postoperative stay.

The association between the patients' race and the incidence of hypophosphataemia is demonstrated in Table V, using various definitions of hypophosphataemia. No specific race was associated with an increased incidence of postoperative hypophosphataemia.

The two different cardioplegic solutions used were compared in terms of incidence of hypophosphataemia, by using various definitions (Table VI). No statistically significant difference was identified.

The volumes of the provided cardioplegic solutions were also comparable. In the Bucksburg group, the volume of cardioplegic solution given in the hypophosphataemia and non-hypophosphatemia groups had medians of 2 533 ml (IQR 1 313 ml) and 2 470 ml (IQR 1 268.5 ml), respectively. In the Modified St Thomas group, the volume of cardioplegic solution given in the hypophosphataemia and non-hypophosphatemia groups had medians of 1 887 ml (IQR 1 107 ml) and 1 906 ml (IQR 1 068 ml), respectively.

In terms of duration of mechanical ventilation and ICU stay, no statistically significant association was found between the immediate postoperative serum phosphate level and the duration of mechanical ventilation ($p = 0.81$). There was also no association between any of the serum phosphate measurements and duration of ICU stay. This was demonstrated by comparing any episodes of low serum phosphate to duration of ICU stay

Table V: Association of hypophosphataemia with race

Hypophosphataemia	Race (%)				*p*-value
	Black	Mixed race	Indian	White	
Immediate postop hypophosphataemia	14.0	18.2	16.7	7.1	0.64
Incidence of hypophosphataemia during total postop stay	42.0	54.6	66.7	67.9	0.14
Immediate significant decrease	24.0	45.5	33.3	21.4	0.41
Incidence of significant decrease during total postop stay	58.0	81.8	83.3	71.4	0.34

Table VI: Incidence of hypophosphataemia in the patients that received different cardioplegic solutions

Hypophosphataemia	Bucksberg solution (%)	Modified St Thomas solution (%)	*p*-value*
Immediate postop hypophosphataemia	13.7	11.4	0.73
Incidence of hypophosphataemia during total postop stay	56.9	47.7	0.37
Immediate significant decrease	23.5	29.6	0.51
Incidence of significant decrease during total postop stay	66.7	65.9	0.94

*No statistically significant difference between the Bucksberg and Modified St Thomas solutions.
postop – postoperative.

($p = 0.52$), and any significant decrease in serum phosphate to duration of ICU stay ($p = 0.96$).

No statistically significant differences were found between the two groups in terms of duration of cardioactive drug support, with any of the commonly used inotropic and vasopressor agents (Table VII).

Table VII: Duration of postoperative cardioactive drug administration associated with serum phosphate level in the first 24-hours postoperatively

Drug	Postoperative serum phosphate level	Median (days)	IQR (days)	*p*-value
Adrenaline	≥ 0.8 mmol/L	0	1	0.51
	< 0.8 mmol/L	0.5	1	
Noradrenaline	≥ 0.8 mmol/L	0	1	0.11
	< 0.8 mmol/L	0.5	1.5	
Phenylephrine	≥ 0.8 mmol/L	0	0	0.13
	< 0.8 mmol/L	0	0	

IQR – interquartile range.

Factors evaluated for possible association with immediate postoperative hypophosphataemia and which did not demonstrate a statistically significant association, included sex ($p = 0.52$), intraoperative steroid use ($p = 1.00$), intraoperative dextrose administration ($p = 0.25$), total intraoperative crystalloids used ($p = 0.59$), intraoperative cell saved blood transfused ($p = 0.45$), duration of cardiopulmonary bypass ($p = 0.85$) and duration of hypothermia ($p = 0.95$).

Intraoperative variables that were associated with a lower incidence of hypophosphataemia in the total postoperative period included fresh frozen plasma transfused ($p = 0.0056$) and pooled platelet transfusion ($p = 0.036$).

Insulin administration intraoperatively led to a higher incidence of immediate postoperative significant decrease in serum phosphate ($p = 0.034$).

When the preoperative albumin levels of the hypophosphataemic group was compared with the preoperative albumin levels in the normophosphataemic group, no correlation could be demonstrated ($p = 0.93$).

Discussion

The median age of the study population was lower than reported in other studies.[6-8,16] This could be explained by the lower life expectancy in the South African population of 59 years.[17] The study population included a larger percentage of females than previous studies, although this is not equal to the sex ratio in the South African population (female 51.3%, male 48.7%).[18] This can be expected as the incidence of cardiovascular disease is higher in males than females younger than 75 years.[19] The population distribution according to the 2011 national census done in South Africa described the population composition as follows: Black 79.2%, Mixed Race 8.9%, White 8.9% and Indian/Asian 2.5%. Although the largest race group in this study was Black, the White population composed a relatively large percentage of the study population – presumably due to the historically higher incidence of cardiovascular disease associated with diseases of lifestyle in this population.[19]

Hypophosphataemia occurred in 52.6% of the study population during the postoperative stay. This correlates with results reported by Goldstein et al.[7] Immediate postoperative hypophosphataemia was only demonstrated in 12.6% of the study population, which was lower than expected. There was a delayed presentation of hypophosphataemia with the highest incidence of hypophosphataemia on Days 2 and 3 postoperatively.

The postulated causes for the decrease in serum phosphate postoperatively are intra-cellular shifting, increased losses, and delayed replacement. Intra-cellular shifting of phosphate is seen with a severe inflammatory response. This is expected due to the exposure to the extra-corporeal circuit.[6,20,21] Intra-cellular shifting also occurs with a glucose load and increased glycolysis, as is seen in acute alkalosis (perioperative hyperventilation). This is well described in refeeding syndrome and is commonly seen on the second to third day postoperatively when the patient changes from a catabolic to an anabolic state.[1,5,7]

The delayed response noted in this patient group can be attributed to the current postoperative care protocol of enteral feeding initiated on Day 1 postoperatively. The perioperative starvation was for a limited duration (the day of surgery). Refeeding syndrome is more commonly seen with fasting times of more than five days, but postoperative patients are at a higher risk.[22]

Other preoperative risk factors for refeeding syndrome include the nutritional state, long-term use of diuretics and elderly population. All of these are common factors in this type of population.

No formal nutritional assessment was done during the preoperative visit, but the albumin levels were recorded preoperatively. Albumin has been shown to be a useful as a predictor of malnutrition in cardiac transplant patients. In the study done by Prenner et al., serum albumin level was found to be a better predictor of malnutrition than the body mass index or a subjective global assesment.[23]

We could not demonstrate any correlation between the preoperative albumin value and the incidence of postoperative hypophosphataemia.

The increased loss of phosphate can also be ascribed to the cold diuresis that is typically seen with hypothermic conditions during cardiopulmonary bypass. In this study, only three patients were kept at an intraoperative temperature of > 32˚C. This, coupled with the use of osmotic diuretics as part of the pump priming solution, can increase phosphate excretion.

Associated factors such as hypomagnesaemia or other co-morbidities, hypothyroidism and renal phosphate wasting, compound the situation. Further renal losses from vomiting,

nasogastric tube suctioning or the chronic use of phosphate binding antiacids can also cause hypophosphataemia.[1,7,9] These additional factors were, however, not present in the study sample.

The use of intravenous fluid without phosphate previously led to the inadequate replacement of the phosphate that was lost, resulting in hypophosphataemia.[6] At the study site, a balanced crystalloid without phosphate was used for intraoperative maintenance and cell saving. No association was demonstrated between the volume of crystalloid and the incidence of hypophosphataemia ($p = 0.59$).

Two cardioplegic solutions were compared in terms of incidence of hypophosphataemia. No significant difference in postoperative serum phosphate levels could be demonstrated. The volumes of cardioplegic solutions given also did not differ significantly between the two types of solutions.

Both the hypophosphataemia and non-hypophosphatemia patients were ventilated for a median of one day (IQR 0 days). A conservative extubation protocol was followed where patients were only assessed on the first postoperative day for tracheal extubation. Only one patient developed a serum phosphate level < 0.32 mmol/L, and this improved the following day. Respiratory muscle weakness and other major effects of hypophosphataemia predominantly occur with serum phosphate levels < 0.32 mmol/L. This could explain why no difference could be demonstrated in this study group – a fast track protocol might show a difference in duration of mechanical ventilation. When comparing this data to previous research, Cohen et al. demonstrated prolonged postoperative mechanical ventilation in the hypophosphataemia group (defined as < 0.48 mmol/L).[6] The duration of mechanical ventilation (days) was a mean of 2.1 (SD 1.7) in the hypophosphataemia group and 1.1 (SD 0.9) in the non-hypophosphatemia group ($p = 0.05$). The difference in results could be attributed to the fact that the postoperative serum phosphate levels in their study were significantly lower than in the current study. Naeem et al. found an increase in the duration of mechanical ventilation (11.9 ± 11.6 hours versus 6.15 ± 5.5 hours, $p = 0.002$) in the hypophosphataemia (defined as < 0.8 mmol/L) group.[16] A more liberal extubation protocol was followed, and the level of hypophosphataemia was not specified in the study by Naeem et al.[16]

No significant difference could be demonstrated between the onset of any new postoperative hypophosphataemia versus normophosphataemia and the duration of ICU stay ($p = 0.54$). The duration of ICU stay in the hypophosphataemia and non-hypophosphatemia groups was four days (IQR 1 day) and four days (IQR 2 days), respectively. This is in line with the results by Cohen et al. reporting a mean duration of ICU stay (days) of 2.6 (SD 2.9) and 2.1 (SD 2.7), which was not statistically significant.[6] Naeem et al., however, found an increase in the duration of ICU stay (3.5 ± 1.5 versus 2.4 ± 0.7 days, $p = 0.01$). A difference in ICU discharge criteria could confound these results.[16]

No association could be demonstrated between the duration of inotropic or vasopressor use and serum phosphate levels. There was a trend towards longer duration of adrenaline and noradrenaline use in the hypophosphataemia group, although statistical significance was not reached. In contrast, studies suggested a prolonged duration of cardioactive drug support in hypophosphataemia patients with a longer duration of cardioactive support.[6,16]

In the current study, the intraoperative administration of fresh frozen plasma and pooled platelets led to a lower incidence of hypophosphataemia immediately postoperatively. This may be attributed to the citrate phosphate dextrose anticoagulant that is added to donor blood before plasmapheresis. This was not seen with packed red cell transfusion, as these products were also given while the patient was on cardiopulmonary bypass and red cells were washed before administration, which would eliminate most of the red cell preservatives. Fresh frozen plasma and pooled platelets were given only after liberation from the cardiopulmonary bypass circuit, thus having a smaller volume of distribution and a greater clinical effect.

Study limitations

This was a single-centre study and did not necessarily represent the total South African population. The patient's preoperative disease profile is a major determining factor of the postoperative ICU clinical care indicators. In an attempt to minimise the variation in the preoperative factors of the study population, patients with an estimated perioperative mortality greater than 5% were excluded from the study. Since the sample size calculation was based on the primary outcome, the study may have lacked the power to detect all potentially significant associations or differences.

Patients were assessed for extubation postoperatively only on the morning of the first postoperative day, as per unit protocol. This was done to ensure the availability of senior staff during normal working hours, if reintubation was deemed necessary. In clinical units that follow a more liberal extubation approach, (i.e. 'fast-tracking') a difference in duration of postoperative mechanical ventilation may be demonstrated.

No formal assessment of nutritional state and other risk factors for refeeding syndrome were included in the preoperative assesment; this could be an area for further research in the study population.

When comparing the two cardioplegic solutions, blinding was not done as this was a prospective cohort analytical study. The patients were not randomised, and the type of cardioplegic solution was determined by the surgeon's preference. This study, therefore, serves as an indicator, but future randomised, controlled trials may provide additional information.

Conclusion

Hypophosphataemia was common after cardiopulmonary bypass in this population. The incidence was higher than

expected, with 52.6% (95% CI 42.1–63.0%) of patients developing hypophosphataemia postoperatively. However, this did not translate into clinically significant effects, as the degree was usually mild (0.66–0.79 mmol/L).

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Conflict of interest

The authors declare that they have no financial or personal relationship(s) which may have inappropriately influenced them in writing this paper.

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