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Original

Perioperative factors associated with hyperglycemia after pediatric cardiac surgery and impact of hyperglycemia on morbidity and mortality

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SUMMARY: Ödek Ç, Kendirli T, Yıldırım-Yıldız N, Yaman A, Uçar T, Eyileten Z, Ateş C, Uysalel A, Tutar E, Atalay S. Perioperative factors associated with hyperglycemia after pediatric cardiac surgery and impact of hyperglycemia on morbidity and mortality. Turk J Pediatr 2018; 60: 497-505.

This retrospective, observational, single-center study aimed to determine the perioperative factors associated with postoperative hyperglycemia (blood glucose level ≥126 mg/dl) and the impact of hyperglycemia on morbidity and mortality in a cohort of children undergoing cardiac surgery. Non-diabetic children aged between 1 month to 18 years who were consecutively admitted to pediatric intensive care unit (PICU) after cardiac surgery for congenital heart disease between January 2008 and December 2013 were included. One hundred and twenty-six patients were qualified for inclusion during the study period. Seventy-four (57.8%) of the patients had at least one glucose measurement ≥ 126 mg/dl. Higher PRISM III-24 (OR 1.1, 95% CI 1.02-1.18, p= 0.004) and PELOD (p=0.006) scores, higher Wernovsky inotropic score (p=0.027) and vasoactive-inotropic score (p=0.029) were associated with hyperglycemia. Postoperative hyperglycemia was not associated with duration of mechanical ventilation), length of PICU stay, healthcare associated infections, or mortality. Our study establishes that hyperglycemia is common after pediatric cardiac surgery but not associated with short-term morbidity and mortality. Insulin therapy can be accomplished without hypoglycemia when a permissive glycemic target is used. A large prospective multiple institution trial is necessary to facilitate defined guidelines for postoperative hyperglycemia after pediatric cardiac surgery.

Key words: cardiac surgery, congenital heart disease, hyperglycemia, hypoglycemia, insulin.

The data was presented at the 12th Congress of Pediatric Emergency Medicine and Intensive Care, with International Participation, 15-19 April 2015, Antalya, Turkey.

Critically ill children admitted into a pediatric intensive care unit (PICU) were commonly found to exhibit hyperglycemia due to an inflammation-mediated increased endogenous glucose production and decreased utilization resulting from insulin resistance.[1] Hyperglycemia also develops after pediatric cardiac surgery and the incidence of hyperglycemia reaches to more than 90% in some reports.[2-4]

Hyperglycemia has been associated with poor outcomes in children with traumatic brain injuries, respiratory failure, septic shock, severe burn injuries, and general critical illness.[1] However, studies regarding the association between hyperglycemia and postoperative outcomes for pediatric cardiac surgery patients have conflicting results. Some retrospective studies have shown a relationship between hyperglycemia and adverse outcomes[2-5], whereas others showed that hyperglycemia was not detrimental.[6,7] A recent prospective cohort study showed that elevated postoperative glucose levels did not adversely affect 4-year

neurodevelopmental outcome in children operated for congenital heart disease[8]. Also, two multi-center prospective randomized trials reported that tight glycemic control after cardiac surgery in children had no significant effect on major clinical outcomes.[9,10] So, the management of hyperglycemia in the postoperative period remains controversial.

In the current study, our primary aim was to determine the perioperative factors associated with hyperglycemia after pediatric cardiac surgery. Our secondary aim was to determine whether there is an association between postoperative hyperglycemia and infection rates, duration of mechanical ventilation (MV), length of PICU stay, and mortality.

Material and Methods

Setting and patients

Our institution is a tertiary-care training children's hospital with an 8-bed PICU and approximately 300 patients are annually admitted to our unit. We performed a retrospective cohort study of non-diabetic children aged between 1 month to 18 years who were consecutively admitted to our PICU after cardiac surgery for congenital heart disease between January 2008 and December 2013. We excluded patients undergoing a cardiac surgical procedure that could not be classified using the Risk Adjustment in Congenital Heart Surgery-1 (RACHS-1) category.[11] We also excluded patients with missing data.

Study definitions and data collection

We considered hyperglycemia a blood glucose measurement ≥126 mg/dl, based on the 2006 American Diabetes Association definition.[12] We further stratified the severity of hyperglycemia into mild (126-199 mg/dl) and severe (≥200 mg/dl). Duration of hyperglycemia was assessed by calculating the number of hours to exposure to a glucose level ≥126 mg/dl. Hypoglycemia was defined as mean blood glucose level of <50 mg/dl.[13] Duration of MV was defined as the cumulative duration of ventilation during the entire PICU stay. Organ failure criteria were defined as shown in Table I.

Preoperative data included: age, sex, weight, failure to thrive (weight below the 3th percentile for age), diagnosis, and RACHS-1 category.

Intraoperative data included: presence of cardiopulmonary bypass (CPB), CPB time (CPBT), cross-clamp time (CCT), and use of systemic glucocorticoids.

Postoperative data included: Pediatric Risk of Mortality III-24 (PRISM III-24)[15] and Pediatric Logistic Organ Dysfunction (PELOD)[16] scores, Wernovsky inotropic score (IS)[17] (dopamine dose [μg/kg/min] + dobutamine dose [μg/kg/min] + 100 x epinephrine dose [μg/kg/min]) , vasoactive-inotropic score (VIS)[18] (IS + 10 x milrinone dose [μg/kg/min] + 10,000 x vasopressin score [U/kg/min] + 100 x norepinephrine dose [μg/kg/min]), arterial blood lactate levels, number of organ failure, systemic inflammatory response syndrome (SIRS), blood glucose level (BGL), presence of hyperglycemia, duration of hyperglycemia, requirement for intravenous infusion of regular human insulin, presence of hypoglycemia, duration of MV, length of PICU stay, occurrence of healthcare-associated infections, and outcomes. PELOD, IS, VIS, blood lactate levels, and number of organ failure data were collected at PICU admission.

Postoperative maintenance fluids, glucose monitoring and management of hyperglycemia

The dextrose content of postoperative intravenous fluids is typically 5% dextrose. Blood glucose levels were measured with a bedside blood glucose meter (Accu-Chek Active, Roche, USA and On Call Advanced, ACON Laboratories, Inc. San Diego, USA). Details of glucose monitoring and management of hyperglycemia were shown in Figure 1.

The Institutional Review Board approved the study before data collection began and waived

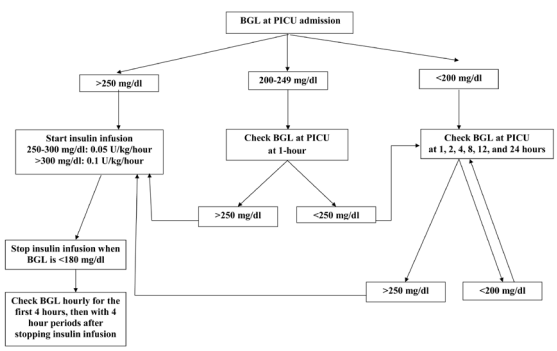

Fig. 1. Details of glucose monitoring and management of hyperglycemia. BGL: blood glucose level

the requirement for written informed consent.

Statistical analysis

Data are presented as mean±SD or median (minimum-maximum) for continuous variables and as frequencies (percentage) for categorical variables. In order to test whether the data were normally distributed, the Kolmogorov-Smirnov and Shapiro-Wilk tests were used. Continuous variables were compared using Student's t-test or the Mann-Whitney U test and categorical variables were compared using chi-square or Fisher's exact test, as appropriate. Logistic regression analyses were performed to seek unadjusted relationships between perioperative, intraoperative, and postoperative variables and hyperglycemia. Odds ratios with 95% confidence intervals (CI) were calculated. Multivariable models were chosen using a forward-selection process with inclusion criteria of $p<0.05$. Statistical analyses were performed by using SPSS 15.0 for Windows and p values less than 0.05 were considered as statistically significant.

Results

During the study period, 131 consecutive patients were admitted to PICU after cardiac surgery. Excluding five patients with missing data, 126 patients qualified for inclusion in the study.

Preoperative variables

The median age of the study population was 10 (1.5-168) months. Forty-nine percent of patients were male. The mean weight of patients was 8.5±5.01 (2-30) kg and 42% of them had failure to thrive. Ventricular septal defect repair was the most common procedure (n=39, 30.9%) followed by tetralogy of Fallot repair (n=21, 16.6%), atrioventricular septal defect repair (n=11, 8.7%), and atrial septal defect closure (n=10, 7.9%). For the total cohort of the patients, 17.4% were RACHS-1 category 1, 64.2% were category 2, 17.4% were category 3, and 0.7% were category 4. Type of cardiac lesions, procedures, and RACHS-1 categories are shown in Table II.

Intraoperative variables

One hundred and three (81.7%) patients underwent CPB. Mean CPBT and CCT were 105.87±39.83 (22-222) and 69.5±28.91 (14-168) mins, respectively. All patients who underwent CPB were given a single intravenous dose of methylprednisolone 1 mg/kg after induction of anesthesia.

Postoperative variables

Mean PELOD and PRISM III-24 scores were 11.15±7.14 (0-43) and 9.69±6.09 (0-39), respectively. Median VIS and IS scores were 15 (0-170) and 10 (0-125), respectively. The mean level of blood lactate level at PICU admission was 4.74±3.10 (0.7-18) mmol/L. Median number of organ failure was 2 (0-6). Systemic inflammatory response syndrome was seen in 63 (50%) patients.

Table I. Organ System Failure Criteria.[14]

Cardiovascular	BP $<5^{th}$ percentile for age or systolic BP <2 SD below normal age or need for vasoactive drug to keep BP in normal range or ≥2 of the following: Base deficit >5.0 mEq/L Lactic acidosis more than twice the upper limit of normal Urine output <0.5 ml/kg/hour Capillary refill >5 second Core to peripheral temperature gap >3°C
Neurologic	GCS score ≤11 or decrease in GCS ≥3 points from abnormal baseline
Hematologic	Platelet count <80,000/mm^3 or INR >2
Renal	Serum creatinine ≥2 times the upper limit of normal for age or two fold increase in baseline creatinine
Hepatic	Total bilirubin ≥4 mg/dl or ALT twice upper limit of normal
Respiratory	PaO_2/FiO_2 <300 in absence of cyanotic congenital heart disease or preexisting lung disease or $PaCO_2$ >65 torr or 20 torr over baseline or FiO_2 =0.50 to keep saturations ≥92% or need for invasive or noninvasive mechanical ventilation

ALT: alanine aminotransferase; BP: blood pressure; GCS: Glasgow Coma Scale; INR: international normalized ratio; SD: standard deviation

Seventy-four (57.8%) of the patients had at least one glucose measurement ≥126 mg/dl. Severe hyperglycemia were shown in 66.2% of these hyperglycemic patients. The median onset time of hyperglycemia was 1 (1-24) hour and 83.7% (62/74) of these patients were hyperglycemic at the time of PICU admission. Forty-eight (64.8%) of hyperglycemic patients received insulin infusion. The mean level of BGL at the beginning time of insulin infusion was 278.6±46.19 mg/dl. The mean duration of hyperglycemia was 4.29±2.72 (1-12) hours and the mean amount of insulin administered during hyperglycemia was 0.16±0.1 (0.05-0.6) U/kg/hour. No episode of hypoglycemia was seen during study period.

The median duration of MV was 21 hours (0-888) and median length of PICU stay was 4 (1-45) days. Six (4.7%) patients died in PICU. Healthcare-associated infections occurred in 3 (2.3%) patients and all were ventilator-associated pneumonia.

Perioperative Factors Associated with Postoperative Hyperglycemia

Perioperative variables for hyperglycemic and normoglycemic groups are shown in Table III. By univariate analysis, higher PRISM III-24 (p= 0.004) and PELOD (p= 0.006) scores, higher IS (p= 0.027) and VIS (p= 0.029) were associated with hyperglycemia. When combined into a multivariate model, we found higher PRISM III-24 score (OR, 1.1; 95% CI 1.02-1.18; p= 0.004) was significantly associated with postoperative hyperglycemia in the multivariate logistic regression model.

Outcomes

Postoperative hyperglycemia was not associated with duration of MV (p=0.840), length of PICU stay (p=0.299), healthcare associated infections (p=0.569), or mortality (p=0.690).

Discussion

In this study, we confirmed that hyperglycemia is a common event after pediatric cardiac

Table II. Cardiac Lesions and Type of Procedures.

Cardiac lesions	Procedures	RACHS-1 category	N
VSD	VSD closure	2	39
TOF	Pulmonary banding	3	2
	TOF repair	2	21
Complete AVSD	AVSD repair	3	11
Secundum ASD	ASD closure	1	10
ASD+VSD	ASD+VSD closure	2	9
PDA	PDA ligation	1	8
Pulmonary atresia	BT-shunt	3	5
	Glenn procedure	2	3
	Fontan procedure	3	2
VSD+PDA	VSD closure+PDA ligation	2	3
Coarctation of aorta	Coarctation of aorta repair	1	3
Subaortic ridge	Subaortic ridge resection	2	2
TAPVR	TAPVR repair	2	2
VSD+PAPVR	PAPVR repair+VSD closure	2	1
ASD+PAPVR	PAPVR repair+ASD closure	1	1
ALCAPA syndrome	Coronary switch	3	1
Double aortic arch	Double aortic arch repair	2	1
Aortic interruption	Homograph patch augmentation	4	1
Supravalvular aortic stenosis	Extended aortoplasty	3	1

ALCAPA: anomalous left coronary artery from the pulmonary artery; ASD: atrial septal defect; AVSD: atrioventricular septal defect; BT: Blalock-Taussig; PAPVR: partial anomalous pulmonary venous return; PDA: patent ductus arteriosus; TAPVR: total anomalous pulmonary venous return; TOF: tetralogy of Fallot; VSD: ventricular septal defect;

surgery. Although different cut-off values were defined for hyperglycemia in different studies, the incidence of hyperglycemia has been reported to range from 43 to 98%.[2,6] Similar to those studies, 57.8% of our patients were hyperglycemic and 66.2% of these patients had severe hyperglycemia.

There are limited data about perioperative factors associated with hyperglycemia after pediatric cardiac surgery. Alaei et al.[19] showed that perioperative factors such as age, height, weight, pump time, and inotropic score were not associated with hyperglycemia. Rossano et al.[7] reported that lower body weight and preoperative inotrope use were associated with hyperglycemia. In a retrospective observational study, Moga et al.[3] showed that <31 days and 5-10 years age groups, preoperative prostaglandins, MV, cyanosis, higher Aristotle score, longer CPBT, deep hypothermic circulatory arrest, and perioperative steroids were associated with hyperglycemia. In our study, by univariate analysis higher PRISM III-24 and PELOD scores, higher IS and higher VIS were associated with postoperative hyperglycemia. In a multivariate model, higher PRISM III-24 score was significantly associated with postoperative hyperglycemia.

PELOD is the most frequently used score aiming to describe the severity of cases of multiple organ failure (MOF). The relationship between mortality and number of dysfunctioning organs is stronger than that with presence or absence of MOF[16]. PRISM III-24 score is unique in that it can predict both mortality and length of stay in PICU[15]. Our data indicated that both PELOD and PRISM III-24 are associated with postoperative hyperglycemia after pediatric cardiac surgery. One possible explanation for this may be that these scoring systems show the severity of illness and patients with more severe diseases have higher risk for developing postoperative hyperglycemia. One can argue that presence of a BGL above 200 mg/dl is a variable of PRISM III-24 score and this may adversely affect the statistical analysis in this study. However, the PRISM III score has 17 physiologic variables subdivided into 26 ranges and the difference in PRISM III-24 score between hyperglycemic and normoglycemic patients is still significant when we exclude BGL variable.

Most of the children undergoing cardiac surgery require inotropic support after CPB especially those with compromised ventricular function. The degree of inotropic support is defined by Wernovsky IS and VIS.[17,18] The amount of inotropic support after cardiac surgery is a marker of illness severity and increasing doses are associated with increased morbidity and mortality[18]. Previous studies showed that exogenously administered catecholamines in the postoperative period have been linked to the development of insulin resistance and hyperglycemia.[20] Similar to those studies, our results showed that there was a significant difference in IS and VIS between normoglycemia and hyperglycemia groups and higher scores were associated with hyperglycemia.

Surgery, with its associated stress response, increases the counter-regulatory hormones (epinephrine, glucagon, growth hormone, and cortisol) and causes hyperglycemia. This is further complicated by the insulin resistance found in cardiac surgery patients associated with CPB[21]. Cardiopulmonary bypass activates SIRS which results in insulin resistance and hyperglycemia.[22] Activation of systemic inflammation is explained with several possible mechanisms including contact of the blood with the surface of CPB circuit, mechanical shear stress as the blood passes through suction systems and filters, tissue ischemia and reperfusion, hypotension and hemodilution, administration of blood products, and hypothermia.[23] The incidence of SIRS varies from 22-38%.[24, 25] Different from those studies SIRS was seen in 50% of our patients. We suggest that the high incidence of SIRS in our study was related with the low dose of glucocorticoid given at the beginning of the CPB when compared with other studies (1 mg/kg vs. 20-30 mg/kg methylprednisolone). Previous studies showed that both CPB and CPBT were associated with postoperative hyperglycemia.[19,23] In contrast to those studies, neither CPB nor CPBT were associated with postoperative hyperglycemia in our study. However 83.7% (62/74) of our patients were hyperglycemic at the time of PICU admission. We concluded that postoperative hyperglycemia after pediatric cardiac surgery may be associated with stress response related with surgery and intraoperatively administered exogenous catecholamines rather than CPB and CPBT.

Table III. Results of Univariable Analyses for Preoperative, Intraoperative, and Postoperative Variables.

Variables	All patients (N= 126)	Normoglycemic group (N=52)	Hyperglycemic group (N=74)	p value
Preoperative				
Age, months	10 (1.5-168)	10 (1.5-168)	10 (1.5-120)	0.278
Sex, M/F	62/64	25/27	37/37	0.832
Weight, kg	7 (2.07-30)	7.35 (3-30)	7 (2.07-25)	0.328
Failure to thrive, n (%)	53 (42.1)	24 (46.2)	29 (39.2)	0.436
RACHS-1 category, n (%)				
	22 (17.5)	8 (15.4)	14 (18.9)	
	81 (64.3)	35 (67.3)	46 (62.2)	0.783
	22 (17.5)	9 (17.3)	13 (17.6)	
	1 (0.8)	-	1 (1.4)	
Intraoperative				
CPB, n (%)	103 (81.7)	45 (86.5)	58 (78.4)	0.243
Glucocorticoids, n (%)	103 (81.7)	45 (86.5)	58 (78.4)	0.243
CPBT, minute	100 (22-222)	91 (38-222)	105.5 (22-190)	0.951
CCT, minute	63 (14-168)	63 (21-168)	67 (14-147)	0.757
Postoperative				
PRISM III-24 score	9 (0-39)	7.5 (0-24)	11 (0-39)	0.004
PELOD score	11 (0-43)	11 (0-22)	11 (0-43)	0.006
VIS	15 (0-170)	11.25 (0-125)	20 (0-170)	0.029
IS	10 (0-125)	8 (0-98)	15 (0-125)	0.027
Lactate, mmol/L	4.1 (0.7-18)	3.6 (0.7-16.4)	4.2 (1.1-18)	0.247
Number of organ	2 (0-6)	2 (0-5)	2 (0-6)	0.291
Failure, n (%)				
Cardiovascular	114 (90.5)	46 (88.5)	68 (91.9)	0.518
Respiratory	124 (98.4)	51 (98.1)	73 (98.6)	1.000
Renal	47 (37.3)	18 (34.6)	29 (39.2)	0.601
Hepatic	13 (10.3)	6 (11.5)	7 (9.5)	0.706
Hematologic	25 (19.8)	7 (13.5)	18 (24.3)	0.132
Neurologic	2 (1.6)	0 (0.0)	2 (2.7)	0.511
SIRS, n (%)	63 (50)	22 (42.3)	41 (55.4)	0.148
Duration of MV (hour)	20 (1-480)	18 (1-24)	48 (25-480)	< 0.05
Infection, n (%)	3 (2.4)	2 (3.8)	1 (1.4)	0.569
Length of PICU stay, days	4 (1-45)	3 (1-45)	4.2 (1-39)	0.299
Mortality, n (%)	6 (4.8)	3 (5.8)	3 (4.1)	0.690

Data is presented as n (%) or median (minimum-maximum).
CCT: cross-clamp time; CPB: cardiopulmonary bypass; CPBT: cardiopulmonary bypass time; NIV: noninvasive ventilation; PHT: pulmonary hypertension; IS: inotropic score; PELOD: pediatric logistic organ dysfunction; PICU: pediatric intensive care unit; PRISM: pediatric risk of mortality; RACHS-1: the risk adjustment for congenital heart surgery-1; SIRS: systemic inflammatory response syndrome; VIS: vasoactive inotropic score;

Hyperglycemia is a well-known side effect of glucocorticoid use. Children undergoing cardiac surgery receive perioperative glucocorticoids to attenuate the systemic inflammatory response associated with CPB. Verhoeven et al.[26] showed that treatment with glucocorticoids during surgery was the main factor associated with postoperative hyperglycemia after pediatric cardiac surgery. Moga et al.[3] reported similar findings. Our patients received glucocorticoids intraoperatively at the beginning of CPB (a single dose of methylprednisolone 1 mg/kg) and/or to treat SIRS in the postoperative period (2 mg/kg/day methylprednisolone in four divided

doses). However glucocorticoid administration was not associated with hyperglycemia in our study. One possible explanation for this may be that our patients were given lower doses of glucocorticoids when compared with patients in studies mentioned above (1-2 mg/kg vs. 20-30 mg/kg methylprednisolone).

Previous studies regarding the association between hyperglycemia and postoperative outcomes for pediatric cardiac surgery patients have conflicting results. Yates et al.[5] showed that the peak glucose level and duration of hyperglycemia in the immediate postoperative period were associated with increased morbidity and mortality. They also showed that prolonged hyperglycemia was associated with increased length of PICU and CICU stay, and increased duration of MV.[5] Polito et al.[27] reported that perioperative glycemic derangement was associated with poor outcomes and they concluded that the ideal BGL may be 110 to 126 mg/dl. Falcao et al.[4] concluded that the duration of hyperglycemia is significantly associated with postoperative morbidities and increased mortality. In a prospective cohort study, Alaei et al.[19] reported that patients with severe hyperglycemia (>200 mg/dl) showed a higher mortality rate and more morbidities. In contrast to these studies, Rossano et al.[7] showed that hyperglycemia was not detrimental in infants who have undergone cardiac surgery. They concluded that infants with BGLs between 80 and 100 mg/dl were at increased risk for adverse events.[7] Lou et al.[6] found similar results. In a recent study, Krueger et al.[8] reported that hyperglycemia has no adverse effect on 4-year neurodevelopmental outcome in children operated for congenital heart disease. In our study, postoperative hyperglycemia was not associated with duration of MV, length of PICU stay, healthcare associated infections, and mortality. However, our study cohort consists of low-risk patients and these patients usually have shorter durations of MV, length of PICU stay, and lower mortality rates. We suggest that high-risk patient groups may have different results.

As previous studies provide conflicting evidence about the association between hyperglycemia and morbidity and mortality, the management of hyperglycemia in the postoperative period remains controversial. There is still a considerable debate about the optimum target range for BGL after pediatric cardiac surgery. In a randomized trial in critically ill children, three quarters of whom were cardiac surgery patients, Vlasselaers et al. [28] concluded that tight glycemic control was associated with a decrease in PICU stay and mortality. However, it was also associated with extremely high rates (25%) of hypoglycemia (<40 mg/dl) which may adversely affect the developing brain. In SPECS trial, Agus et al.[9] showed that tight glycemic control (TGC) (with the use of an insulin-dosing algorithm targeting a BGL of 80-110 mg/dl) can be achieved with a low hypoglycemia rate (3%) after pediatric cardiac surgery, but it does not significantly change the infection rate, length of stay, measures of organ failure, or mortality as compared with standard care. In a CHiP trial, Macrae et al.[10] reported that TGC (targeting a BGL of 72-126 mg/dl) did not have a significant effect on major clinical outcomes after pediatric cardiac surgery. Mahle[29] suggested that hyperglycemia can be considered as a common finding following pediatric cardiac surgery and one should be cautioned against overaggressive treatment of hyperglycemia. In the current study, we used a more permissive glycemic target. Insulin infusion was started when BGL exceeded 250 md/dl and discontinued when BGL fell below 180 mg/dl. No episode of hypoglycemia was seen during study period.

The present study has some limitations. The major limitation was the retrospective analysis of prospectively collected data. Another important limitation was the small size of this single-center study, which may pose barriers to the generalization of the results. Also, the study could be underpowered to identify the differences in some of the variables due to small size. RACHS-1 scores averaged 1.99 for all patients in our cohort, indicating a low-risk patient population, and our findings may not translate to populations with higher RACHS-1 scores. Also, we were unable to account for differences in carbohydrate administration during intraoperative and postoperative period, including glucose infusion from maintenance fluids and feeding regimens. Finally, this study was not designed to determine whether postoperative hyperglycemia predicts long-term, particularly neurodevelopmental, outcomes.

In conclusion, hyperglycemia is common after pediatric cardiac surgery but not associated with short-term morbidity and mortality. Higher PRISM III-24 and PELOD scores, higher IS and VIS were associated with postoperative hyperglycemia indicating that children with more severe diseases have higher risk for developing hyperglycemia after cardiac surgery. Our study establishes that insulin therapy can be accomplished without hypoglycemia when a permissive glycemic target was used. However, postoperative hyperglycemia (both peak glucose level and duration of hyperglycemia) was not associated with short-term morbidity and mortality so the need for insulin infusions can be questioned. As there is no clear consensus on the optimal range of postoperative BGL and the management of hyperglycemia, a large prospective multiple institution trial is necessary to facilitate defined guidelines for postoperative hyperglycemia after pediatric cardiac surgery.

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