Factors affecting extubating time of postoperative patients who underwent congenital cardiac surgery: a randomized prospective study

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Abstract. – OBJECTIVE: Anesthesia management in pediatric cardiac surgery using health resources sparingly focuses on reducing morbidity and mortality and increasing patients' quality of life. The duration of postoperative mechanical ventilation (MV) heavily influences pediatric cardiac surgery recovery. Thus, in this study we aimed to determine factors influencing extubation times after pediatric cardiac surgery.

PATIENTS AND METHODS: A total of 72 pediatric patients with an ASA score of III or above undergoing cardiac surgery were included in the study. As a result of their extubation time, the patients were divided into three groups as follows: those who were extubated immediately after surgery or in the operating room (OR) were recorded as Immediate Extubators (IE); those who were extubated within 6 to 48 hours of entering the intensive care unit were recorded as Early Extubators (EE), and those who were extubated after 48 hours or not extubated were recorded as Delayed Extubators (DE).

RESULTS: A logistic regression analysis showed that anomalies and need of MV before surgery, airway difficulty, and prolonged cross-clamp (CC) time were observed as factors affecting DE. The risk of DE was significantly correlated with the presence of abnormality [Odds ratio (OR): 20.3, 95% Confident interval (CI): 2.8-142.7], with the need of MV before surgery (OR: 1,844, 95% CI: 1.8-1,790,461.9), and with the presence of airway difficulty (OR: 44.7, 95% CI: 4.4-445.0). In addition, it was determined that CC time increased the probability of DE 1.038 times per minute (95% CI: 1.004-1.072).

CONCLUSIONS: Early and immediate extubation in children who underwent congenital heart surgery was successfully performed in our clinic. Early and immediate extubation in pediatric cardiac surgery can be completed safely and successfully when suitable conditions are provided.

Key Words:
Congenital heart disease, Perioperative management, Pediatric cardiac surgery, Extubation, Early extubation.

Introduction

In pediatric cardiac surgery, decreasing postoperative mechanical ventilation requirement is essential for minimizing morbidity and providing optimal vital functions. For extubation in these cases, the general approach is to follow intubation until full awakening with adequate cardiac output and respiratory function[1].

The presence of immature organ systems in the pediatric age group and the unpredictability of the inflammatory response to cardiopulmonary bypass (CPB) impair the course of early extubation[2]. Today, as in all surgeries, early extubation in congenital heart surgery has become popular. Studies[3] have shown that early extubation reduces mechanical ventilator-related complications, length of hospital stays, cost, and mortality after surgery. In addition, reintubation after unsuccessful extubation has been associated with increased morbidity and mortality in children. Extubation is considered safe after full recovery from anesthesia, obtaining optimal temperature and hemodynamic parameters[4]. Also, anesthetic management with low-dose short-acting agents might be sufficient for early extubation success.

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Prematurity, low weight, accompanying chromosomal or airway anomalies, prolonged CPB times, and complicated surgical procedures have been considered[5,6] as the causes of unsuccessful extubating. However, these situations are mostly seen as non-interventive or unchangeable causes. Therefore, in this study, we aimed to evaluate predictable risk factors by examining the factors affecting extubating times in pediatric cardiac surgery cases in our hospital.

Patients and Methods

After obtaining the hospital Ethics Committee approval (2011-KAEK-25 2020/02-03) and Clinical trials number (NCT05332860), patients aged under 18 who planned to undergo pediatric cardiac surgery in our hospital between March 2020 and March 2021 and with ASA≥III were included in the study. Preoperative age, weight, gender, diagnosis, surgical status, whether elective or emergency, chromosomal or airway anomalies, airway difficulty, the referring clinic, and preoperative mechanical ventilator requirement were recorded. The surgical procedure complexity of the patients was graded according to the "Aristotle Basic Scoring" system (Levels 1, 2, 3, 4). At the end of the surgery, the patients were transferred to the intensive care unit, whether intubated or extubated, by the final decision of the anesthesia and surgical team. The patients included in the study were randomly divided into three groups. Patients were defined as follows: extubated immediately in the operating room or within 6 hours after surgery as Immediate Extubation (IE); extubated in the intensive care unit within 6-48 hours postoperatively as Early Extubation (EE), and extubated or not extubated after 48 hours as Delayed Extubating (DE). All patients were followed-up by the same anesthetic, surgical and intensive care team as those blinded to the study.

Preoperative Routine Procedure

Physical examination and laboratory tests were completed before surgery in patients who were diagnosed with congenital heart disease. In addition, the relatives of the patients were informed, and informed consent forms were obtained. Ketamine 5-10 mg/kg (Ketalar Phizer Pharmaceuticals Ltd., Turkey) and atropine 0.02 mg/kg (Atropine Sulfate, Galen Pharmaceuticals, Turkey) were administered intramuscularly to patients without vascular cannula just before surgery. If the intravenous route was available, ketamine 0.5-1 mg/kg was administered. All patients received routine premedication.

Intraoperative Period Routine Procedure

The patient was placed on the preheated operating table. Electrocardiography and two peripheral oxygen saturation probes were placed. Invasive radial or femoral artery monitoring was performed optionally. For anesthesia induction, midazolam 0.1 mg/kg (Zolamid, Vem Pharmaceuticals, Turkey), rocuronium 1 mg/kg (Myokron, Vem İlaç, Turkey), and fentanyl five mcg/kg (Vem İlaç, Turkey) was used intravenously. Anesthesia was maintained with 0.1 mg/kg of rocuronium, midazolam 0.02 mg/kg, and fentanyl 0.3 mcg/kg intravenously. During Cardio-pulmonary bypass (CPB), sevoflurane (Severan, Abbott, USA) inhalation anesthesia was administered with a minimum alveolar concentration of 2% by adjusting the dose according to the patient's hemodynamics. After intubation, ventilation parameters were modified with a tidal volume of 8-10 mL/kg, age-appropriate respiratory rate, and $PaCO_2$ value between 35 and 40 mmHg.

A double-lumen catheter was inserted into the right internal jugular vein under ultrasound guidance. The central venous pressure from the internal jugular vein and urine output were carefully monitored before cannulation. Activated coagulation time (ACT) was assessed before cannulation and extracorporeal circulation to determine anticoagulation. During cannulation, 3 mg of heparin per kilogram was administered intravenously. A double-lumen catheter was inserted into the right internal jugular vein under ultrasound guidance. The central venous pressure from the internal jugular vein and urine output were carefully monitored before cannulation. During cannulation, 3 mg of heparin per kilogram was administered intravenously. ACT was assessed before cannulation and extracorporeal circulation to determine anticoagulation. The value was expected to rise above 450 seconds for extracorporeal circulation. In case of low ACT values, additional heparin 1 mg/kg was administered. Arterial blood gas monitoring was performed concurrently with ACT monitoring when necessary. Cardio-pulmonary bypass was started after cannulation was completed. Mechanical ventilation was stopped before the cross-clamp (CC). Cardioplegia was applied with Del-Nido solution at a dose calculated according to weight. During CPB, hypothermia was maintained between 26-32°C with the decision to surgery.

At the end of the surgery, the cross-clamp was removed, and the patient ventilated again. CPB was terminated when optimal temperature, stroke volume, and rhythm were achieved. Inotropic support was started in patients with ventricular dysfunction. When the venous cannula was removed, protamine sulfate (Promin, Vem Pharmaceuticals, Turkey) 3-3.5 mg/kg was started intravenously to antagonize the effect of heparin. Targeted ACT after decannulation was accepted between 90 and 140 seconds. Blood products were transfused to keep the hematocrit (Htc) value above 30%. Routinely lowest temperature, hemodynamic data, arterial blood gas and lactate values, urine output, drugs used in anesthesia, CC duration, CPB duration, pump blood flow, amount of bleeding and blood transfusion, whether filtering was performed, total circulatory arrest (TCA) duration, and inotropic support requirement were recorded during the operation.

Postoperative Routine Procedure and Extubating

If the patient was extubated, routine monitoring and follow-up (Electrocardiography, oxygen saturation, invasive artery, and CVP) were started. If the patient was followed-up as intubated, regular monitoring and mechanical ventilation support, as well as sedation for the patient were performed. If the patient was planned to be extubated, extubation preparation was made. Postoperative hemodynamic parameters and blood gas values of the patients, duration of stay in intensive care and mechanical ventilator, extubation times, reintubation status, mortality (10-day mortality), hemofiltration (CVVHDF) need, use of extracorporeal membrane oxygenation (ECMO), and presence of infection and any complications were recorded. Standardized extubation criteria were applied to each patient. The standards for extubation in ICU are as follows: a patient waking without stimulation, a patient with a spontaneous respiratory rate exceeding 24 breaths per minute, stable spontaneous respiratory effort, and positive end-expiratory pressure of 5 cmH_2O, an oxygenation index (OI, PaO_2/FiO_2) greater than 200, $PaCO_2$ more significant than 50 mmHg, pH greater than 7.25, and a stable hemodynamic condition.

Statistical Analysis

The distribution of the data was analyzed using the Kolmogorov-Smirnov test. Descriptive data are shown as numbers and percentages, and categorical data are shown as median (minimum-maximum) values. Categorical data were analyzed using the Chi-square test or Fisher's exact test. Intergroup comparisons were completed by the Kruskal-Wallis' test, where intragroup comparisons using Tukey's HSD test with Bonferonni correction. Logistic regression analysis was used to determine the factors that independently affect prolonged extubation. Statistical significance was set to $p<0.05$ for all analyses. All analyzes were performed with the SPSS version 20 program (IBM Corp., Armonk, NY, USA).

Results

A total of 72 pediatric patients were included in the study. 18 were VSD; seven were ASD; eight were aortic coarctation; seven were hypo-plastic left heart; six were transposition of great arteries, six were PDA, four were AV canal defects; three were tetralogy of Fallot, pulmonary artery atresia and double outlet right ventricle and two were right ventricular hypoplasia. The median age and weight were significantly lower in the DE group than in the IE and EE groups ($p<0.001$, $p<0.001$, respectively). The frequency of anomalies, the requirement of mechanical ventilation (MV) in the preoperative period, and the number of admissions to the intensive care unit were significantly higher in the DE group than in the IE and IE groups ($p<0.001$, $p<0.001$, $p<0.001$, respectively; Table I). The median prealbumin level in the IE group was significantly higher than in the DE and EE groups ($p=0.009$; Table I). Whether an emergency or elective, and the urgency of the operation showed no difference between groups ($p>0.05$; Table I).

Airway difficulty, CC time, CPB time, TCA, and filtration use rate were significantly higher in the DE group than in the IE and EE groups ($p<0.001$, $p=0.031$, $p=0.006$, $p=0.001$, $p=0.005$, respectively; Table II). The hypothermia level was significantly lower in the DE group than in the IE and EE groups ($p=0.008$; Table II). The amount of perioperative blood transfusion revealed no difference between the study groups (Table II).

ICU length of stay, use of ECMO and CVVHDF, and mortality rate were significantly higher in the DE group than in the EE and IE groups ($p=0.002$, $p=0.001$, $p=0.001$, $p<0.001$, respectively; Table II). In the postoperative period, lactate and Htc levels were significantly lower in the IE group than in the DE and EE groups ($p=0.025$, $p=0.020$, respectively; Table II). The presence of

Table I. Comparison of preoperative values of the groups.

N (%)		IE	EE	DE	*p*
		N (%)	N (%)		
Gender	**Male**	5 (41.7)	25 (65.8)	8 (36.4)	0.062[c]
	Female	7 (58.3)	13 (34.2)	14 (63.6)	
Age (days)*		790 (98-5,200)	250 (6-4,680)	80 (3-3,650)	**<0.001*[k]**
Weight (gram)*		11,800 (4,300-42,000)	7700 (2,100-42,000)	4,050 (2,100-12,000)	**<0.001*[k]**
Anomaly	**Present**	4 (33.3)	4 (10.5)	16 (72.7)	**<0.001*[c]**
	Absent	8 (66.7)	34 (89.5)	6 (27.3)	
Admission unit	**Home**	8 (66.7)	22 (57.9)	2 (9.1)	**<0.001*[f]**
	Clinic	3 (25)	13 (34.2)	8 (36.4)	
	ICU	1 (8.3)	3 (7.9)	12 (54.5)	
Preop-MV	**Yes**	-	-	8 (36.4)	**<0.001*[f]**
	No	12 (100)	38 (100)	14 (63.6)	
Preoperative albumin*		40.5 (36-43)	38 (32-48)	38 (26-49)	**0.009*[k]**
Urgency	**Yes**	3 (25)	8 (21.1)	8 (36.4)	0.428[c]
	No	9 (75)	30 (78.9)	14 (63.6)	

Preop-MV, preoperative mechanical ventilation requirement; IE, immediate extubation; EE, early extubation; DE, delayed extubation; ICU, intensive care unit. **p*<0.05. [c]Chi-square test, [f]Fisher's Exact test, [k]Kruskal-Wallis' test.

postoperative infection, need for blood transfusion, postoperative albumin level, and the company of open-chest showed no significance between study groups (Table II). Adrenaline and milrinone usage rates were significantly higher in the DE group than in IE and EE groups (*p*=0.004, *p*=0.010, respectively; Table II).

A logistic regression analysis showed that the presence of anomaly and MV before surgery, airway difficulty, and prolonged CC time were observed as factors affecting DE. The risk of DE was significantly correlated with the presence of abnormality (OR: 20.3, 95% CI: 2.8-142.7), with the need of MV before surgery (OR: 1,844, 95% CI: 1.8-1,790,461.9), and with the presence of airway difficulty (OR: 44.7, 95% CI: 4.4-445.0). In addition, it was determined that cross-clamp time increased the probability of DE 1.038 times per minute (95% CI: 1.004-1.072; Table III). Factors affecting mortality are presented in Table IV.

Aristotle Basic Scoring was used to classify the surgical procedures based on their complexity, with 30 patients undergoing Level 2, 16 undergoing Level 4, 17 undergoing Level 1, and 9 undergoing Level 3. DE was not observed in any patient at Level 1, while IE was not at Levels 3 and 4. In the IE group, the length of stay in the intensive care unit, reintubation status, and mortality rates were statistically significantly lower than in IE and DE groups (*p*=0.002, *p*=0.012, *p*<0.001, respectively; Table V).

Discussion

The present study revealed that age, weight, the complexity of the surgery, admission unit, presence of preoperative MV need, preoperative albumin level, pump and CC duration, need for perioperative TCA and filtration, perioperative hypothermia level, postoperative ECMO and CVVHDF use, postoperative lactate and Htc, postoperative milrinone and adrenaline requirement may affect extubation times in pediatric cardiac surgery patients.

In addition, the present study also showed that age, weight, presence of anomaly, arrival from the intensive care unit to the operation, need for preoperative MV, preoperative albumin level, difficulty in the airway, length of CPB and CC period, deepening of hypothermia level, need for TCA and filtration in surgery, ECMO, CVVHDF and filtration, having reintubation, postoperative infection, lactate, Htc and albumin levels, dopamine and adrenaline need and presence of open-chest were observed as factors affecting mortali-

Table II. Comparison of perioperative and postoperative values of the groups.

		IE	EE	DE	*p*
Airway (n, %)	**Difficult**	-	2 (5.3)	12 (54.5)	**<0.001**^f**
	Easy	12 (100)	36 (94.7)	10 (45.5)	
Operation time(minute)		213 (135-250)	223 (125-313)	234 (145-278)	0.066^k
Preoperative blood transfusion (ml)		200 (150-400)	200 (50-400)	200 (100-400)	0.792^k
CC time (minute)		64 (54-108)	92 (29-154)	110.5 (52-147)	**0.031*^k**
CPB time (minute)		98 (68-173)	123 (56-188)	161.5 (74-234)	**0.006*^k**
TCA (n, %)	**Yes**	1 (8.3)	4 (10.5)	11 (50)	**0.001**^f**
	No	11 (91.7)	34 (89.5)	11 (50)	
Temperature		31 (28-34)	31 (28-34)	28 (26-34)	**0.008*^k**
Filtration (n, %)	**Yes**	4 (33.3)	20 (52.6)	19 (86.4)	**0.005*^c**
	No	8 (66.7)	18 (47.4)	3 (13.6)	
ICU stay time (days) Median (Min-Max)		3.5 (1-7)	4 (1-25)	6 (1-25)	**0.002*^k**
Reintubation (n, %)	**Yes**	1 (8.3)	10 (26.3)	12 (54.5)	**0.012*^c**
	No	11 (91.7)	28 (73.7)	10 (45.5)	
ECMO (n, %)	**Yes**	-	2 (5.3)	9 (40.9)	**0.001**^f**
	No	12 (100)	36 (94.7)	13 (59.1)	
CVVHDF (n, %)	**Yes**	-	4 (10.5)	10 (45.5)	**0.001**^f**
	No	12 (100)	34 (89.5)	12 (54.5)	
Postoperative lactate		2.3 (0.6-5.8)	4.2 (1.2-12.3)	3.8 (1.2-14)	**0.025*^k**
Postoperative Htc		35 (32-39)	36.5 (32-44)	38.5 (32-44)	**0.020*^k**
Milrinone (n, %)	**Yes**	-	11 (28.9)	11 (50)	**0.010*^c**
	No	12 (100)	27 (71.1)	11 (50)	
Adrenalin (n, %)	**Yes**	-	6 (15.8)	10 (45.5)	**0.004*^f**
	No	12 (100)	32 (84.2)	12 (54.5)	
Mortality (n, %)	**Exitus**	-	2 (5.3)	11 (50)	**<0.001**^f**
	Alive	12 (100)	36 (94.7)	11 (50)	

CC, Cross clamp; CPB, cardiopulmonary bypass, TCA: total circulatory arrest; ICU, intensive care unit; ECMO, extracorporeal membrane oxygenation; CVVHDF, continuous venovenous hemodiafiltration; Htc, hematocrit IE, immediate extubation; EE, early extubation; DE, delayed extubation. ^c Chi-square test, ^f Fisher's Exact test, ^k Kruskal-Wallis' test. *$p<0.05$, **$p<0.001$.

ty. Furthermore, the length of stay in the intensive care unit, intubation rate, and mortality were lower in the IE group than in the other groups.

Despite technological advancements, pediatric cardiac surgery is still a complicated procedure for managing the surgical and postoperative

Table III. Logistic regression analysis for independent factors affecting delayed extubation.

	OR	95% CI for OR		*p*
		Lower	Upper	
Presence of anomaly	20.316	2.891	142.776	**0.002***
Preoperative MV requirement	1,844.030	1.899	1,790,461.953	**0.032***
Airway difficulty	44.734	4.497	445.011	**0.001***
CC time (minute)	1.038	1.004	1.072	**0.028***

MV, mechanic ventilation; CC, cross clamp. *$p<0.05$.

Table IV. The association between mortality and perioperative features.

N (%)		Exitus	Alive	*p*
		N (%)		
Gender	**Male**	4 (10.5)	34 (89.5)	0.079[c]
	Female	9 (26.5)	25 (73.5)	
Age (days)*		95 (3-3,650)	255 (4-5,200)	**0.002*[m]**
Weight (gram)*		3,100 (2,300-6,500)	8,000 (2,100-42,000)	**<0.001*[m]**
Anomaly	**Absent**	5 (10.4)	43 (89.6)	**0.025*[f]**
	Present	8 (33.3)	16 (66.7)	
Admission unit	**Home**	-	32 (100)	**<0.001*[f]**
	Clinic	4 (16.7)	20 (83.3)	
	ICU	9 (56.3)	7 (43.8)	
Preoperative MV	**Yes**	6 (75)	2 (25)	**<0.001*[f]**
	No	7 (10.9)	57 (89.1)	
Preoperative albumin*		35 (26-41)	38 (32-49)	**0.002*[m]**
Airway	**Easy**	7 (50)	7 (50)	**0.002*[f]**
	Difficult	6 (10.3)	52 (89.7)	
Operation time*		255 (145-313)	223 (125-278)	**0.003*[m]**
CPB time (minute)*		172 (78-234)	114 (56-188)	**0.002*[m]**
TCA	**Yes**	8 (50)	8 (50)	**0.001*[f]**
	No	5 (8.9)	51 (91.1)	
Temperature*		28 (26-32)	31 (26-34)	**<0.001***
Filtration	**Yes**	11 (25.6)	32 (74.4)	**0.043*[c]**
	No	2 (6.9)	27 (93.1)	
ICU stay time (days)*		6 (1-25)	4 (1-16)	**0.001*[m]**
Reintubation	**Yes**	12 (52.2)	11 (47.8)	**<0.001*[f]**
	No	1 (2)	48 (98)	
ECMO	**Yes**	11 (100)	-	**<0.001*[f]**
	No	2 (3.3)	59 (96.7)	
CVVHDF	**Yes**	11 (78.6)	3 (21.4)	**<0.001*[f]**
	No	2 (3.4)	56 (96.6)	
Postoperative lactate*		7.1 (2.9-14)	3.4 (0.6-8.4)	**0.001*[m]**
Postoperative Htc*		40 (36-44)	36 (32-42)	**0.006*[m]**
Postoperative albumin*		35 (28-44)	38 (28-44)	**0.033*[m]**
Postoperative infection	**Yes**	8 (42.1)	11 (57.9)	**0.003*[f]**
	No	5 (9.4)	48 (90.6)	
Dopamine	**Yes**	8 (38.1)	13 (61.9)	**0.015*[f]**
	No	5 (9.8)	46 (90.2)	
Adrenalin	**Yes**	10 (62.5)	6 (37.5)	**<0.001*[f]**
	No	3 (5.4)	53 (94.6)	
Open-chest	**Yes**	6 (100)	-	**<0.001*[f]**
	No	7 (10.6)	59 (89.4)	

ICU, intensive care unit; MV, mechanic ventilation; CPB, cardiopulmonary bypass; TCA, total circulatory arrest; ECMO, extracorporeal membrane oxygenation; CVVHDF, continuous venovenous hemodiafiltration; Htc, hematocrit. *$p<0.05$. [c]Chi-square test, [f]Fisher's Exact test, [m]Mann-Whitney U test.

Table V. Extubation times according to Aristotle scoring system.

	IE (n=12)	EE (n=38)	DE (n=22)
Level 1 (n= 17)	9	8	0
Level 2 (n= 30)	3	24	3
Level 3 (n= 9)	0	4	5
Level 4 (n= 16)	0	2	14

IE: Immediate extubation, EE: Early extubation, DE: Delayed extubation.

phases. In addition, the lower age and weight of the patients create difficulties in terms of surgery and anesthesia. In some studies[5-8], patients' age, weight, preoperative cardiopulmonary status, anesthetic drug dose, procedure complexity, CPB, and CC duration were shown as independent predictors of early extubation.

A retrospective study[9] including more than 900 pediatric patients who underwent congenital heart surgery showed an inverse relationship between the patient's age and weight and IE. The same results were reported in a similar study[10]. In our study, the median age was 80 days for the DE patients, 790 days for the IE patients, and 250 days for EE patients. A 98-day-old patient was the youngest to undergo IE successfully, and a 4,300-gram patient was the smallest. As for the youngest and smallest patients who successfully underwent DE, the youngest was three days old, while the smallest was 2,100 grams. In our study, the likelihood of having DE increases with younger age, lower weight, anomaly, and airway difficulty. In our study, unlike other studies, it was observed that preoperative albumin levels and mechanical ventilation requirements affected extubation times. It is suggested that this situation is associated with both existing developmental delay and malnutrition in children with advanced congenital cardiac disease. We attribute the fact that there is no difference between the urgent admission of the patients and the extubation times due to the complete preparation of the patients in our clinic.

CPB surgery can result in low cardiac output syndrome due to inflammation, ischemia-reperfusion injury, and hypothermia caused by aortic cross-clamping. During cardiopulmonary bypass, pulmonary endothelial damage occurs, resulting in decreased pulmonary compliance and increased pulmonary vascular resistance. Cardiopulmonary bypass damages pulmonary endothelial cells, which increases pulmonary vascular resistance and decreases pulmonary compliance[11]. The duration of the CPB plays an essential role in determining the extubation time[12]. A five-year cohort study[13] of infants after surgery of transposition of the great arteries showed that longer CPB and CC times (173 min *vs.* 86 min) and hypothermia levels less than or equal to 30.4°C were associated with a lower probability of IE. In another study[14] with a 5-year follow-up, a negative relationship was shown between the age and duration of CPB and early extubation. An investigation of similar data found that the time of CPB, the course of CC, the duration of deep hypothermia, the length of regional low-flow perfusion, the need for epinephrine or inotropes other than milrinone, excess blood loss, and the need for red blood cell transfusion were all negatively correlated with IE incidence. It has been concluded[15] that IE can be successfully performed in most pediatric patients who underwent surgery for congenital heart disease. Consistent with previous studies[2,4-8], the duration of CPB and CC in the IE group was shorter than in our study's EE and DE groups. The need for milrinone and adrenaline in the postoperative period has been associated with IE or DE. This finding is strongly related to our preference for milrinone and adrenaline in patients with greater surgical complexity and poor ventricular function.

In a study[16] conducted in a hospital where early extubation was successful, reintubation rate, nasal continuous positive airway pressure rate, and length of stay in the intensive care unit and hospital were found to be shorter in patients with early extubation. Early extubation was affected by age, weight, preoperative pneumonia, CPB type, duration of CPB, deep hypothermic circulatory arrest, ultrafiltration, and Society of Thoracic Surgeons-European Association for Cardiothoracic Surgery Congenital Heart Surgery (STAT) categories. In our study, none of the patients were diagnosed with pneumonia at the time of surgery.

Less need for TCA and hemofiltration was found to be significant in IE. Similar to the previous studies[16,17], IE was not observed in any patients with Levels 3 and 4 according to the Aristotle score system. Also, DE was not observed in Level 1 patients.

Preoperative respiratory support requirement and prolonged CPB duration were negatively correlated with IE[6,17]. Our study observed no patient who received mechanical ventilation support in the IE and EE groups in the preoperative period. This finding could be associated with the increased need for preoperative MV due to low cardiac reserves in patients with high surgical complexity, which led to the difficulty of early extubation in these patients or the fact that teams do not prefer it.

A meta-analysis showed that various researchers[18] define early extubation differently. Early extubation covers the time from the operating room/ to 24 hours after surgery. Anesthetic protocols and preferred inhalation agents differed widely between studies[19-21] regarding anesthetic drugs and doses. In many surgeries involving complex repairs, early and immediate extubation is possible with modern, short-acting anesthetics such as remifentanil, dexmedetomidine, and propofol, as well as various regional techniques such as intrathecal morphine delivery[19]. Previous articles[20,21] discussing early extubation have referred to an excessive intraoperative narcotic use as an indication of failure of immediate or early extubation. However, this association did not play a significant role in unsuccessful extubation in patients due to the standard perioperative dose of opioid agents. In our hospital, we prefer anesthetic protocols in which the use of opioids is as low as possible. Therefore, the anesthesia method, which may affect the extubation times, was standardized for all our study patients.

The studies[1] demonstrated that urgent extubations resulted in shorter stays in intensive care units, minimal operating room turnovers, and no increase in reintubations. In our study, the length of stay in the intensive care unit was significantly lower in the IE group. Similar to the studies[22,23], the need for reintubation in 8.3% of the patients in the IE group, 26.3% in the EE, and 54.5% in the DE caused a significant difference between the groups. In our study, the percentage of reintubation in the IE group was close to the reintubation rate of 11% reported in the pediatric cardiac intensive care consortium study[22].

Studies[23] showing that most children with congenital heart surgery can be extubated in the operating room are becoming widespread. In addition, some studies[18] reported that many newborns, including those who have undergone complex procedures, can be extubated within the first 24 hours after surgery. In these studies[23], early extubation has been associated with lower morbidity/ mortality rates, shorter intensive care units, and hospital stays. In our study, 16% of the patients were extubated within the first 6 hours postoperatively, and 69% within the first 48 hours. In addition, early extubation time was associated with a decrease in intensive care unit length of stay, which supports the previous studies[24,25].

In our study, the need for postoperative ECMO, CVVHDF, high lactate, low Htc, milrinone, and adrenaline also affected extubation times. We observed that these conditions, which are more common, especially in patients with poor ventricular function and requiring support, reduce the possibility of IE. We frequently encounter hyperlactatemia caused by tissue hypoperfusion after hypoxia and hyperactive anaerobic glycolysis, including in postoperative cardiac patients. Researchers[24] found that high lactate levels in the early postoperative period were associated with increased morbidity and mortality. They also concluded that the first postoperative lactate level might indicate the extubation time.

Similarly, postoperative lactate levels showed an inverse correlation with IE in our study. Increased consumption of inotropic drugs after cardiac surgery is associated with poor ventricular function, morbidity, and mortality[11]. Our research observed less IE in patients who needed inotropic support, especially with milrinone and adrenaline.

Similar to another study[25] conducted in our hospital, mortality was 18%. In our study, mortality was not observed in the IE group, where it was 5.3% in the EE group and 50% in DE. In our study, prolonged intubation time resulted in increased mortality.

Higher nursing hours per patient per day and critical care certified nursing staff percentage was associated with a lower probability of extubation failure[8]. Although the predictors were similar in our study, the absence of any follow-up in nursing care can be considered a limitation of our study.

Conclusions

Early extubation in children who underwent congenital heart surgery has been successfully performed in our hospital. Patients with early extubation had lower mortality and a shorter length of stay in the ICU. The present study revealed that age, weight, complexity of the surgery, admission unit, CPB and CC time, preoperative MV need, hypothermia level, postoperative lactate, milrinone, and adrenaline need might affect extubation times. More studies are required to elucidate the importance of early extubation after pediatric cardiac surgery.

Conflict of Interest

The Authors declare that they have no conflict of interests.

Informed Consent

Written informed was obtained from the patients' parents before their surgeries.

Ethics Approval

The Internal Review Board of the Bursa Yuksek Ihtisas Training and Research Hospital Clinical Research Ethics Committee approved the study protocol (Protocol number: 2011-KAEK-25 2020/02-03).

Funding

None.

Authors' Contribution

All authors contributed to: (1) conception and design, acquisition of data, or analysis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content, and (3) final approval of the version to be published.

Availability of Data and Materials

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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References

1) Barash PG, Lescovich F, Katz JD, Talner NS, Stansel HC Jr. Early extubation following pediatric cardiothoracic operation: a viable alternative. Ann Thorac Surg 1980; 29: 228-233.
2) Joshi RK, Aggarwal N, Agarwal M, Dinand V, Joshi R. Assessment of Risk Factors for a Sustainable "On-Table Extubation" Program in Pediatric Congenital Cardiac Surgery: 5-Year Experience. J Cardiothorac Vasc Anesth 2016; 30: 1530-1538.
3) Zhou ZG, Liu R, Tan HL, Ji XY, Yi XL, Song JF. The application of dexmedetomidine combined with dezocine in thoracoscopic radical resection of lung cancer and its effect on awakening quality of patients. Eur Rev Med Pharmacol Sci 2019; 23: 7694-7702.
4) Davis S, Worley S, Mee RB, Harrison AM. Factors associated with early extubation after cardiac surgery in young children. Pediatr Crit Care Med 2004; 5: 63-68.
5) Beamer S, Ferns S, Edwards L, Gunther G, Nelson J. Early extubation in pediatric heart surgery across a spectrum of case complexity: impact on hospital length of stay and chest tube days. Progr Pediatr Cardiol 2017; 45: 63-68.
6) Mahle WT, Jacobs JP, Jacobs ML, Kim S, Kirshbom PM, Pasquali SK, Austin EH, Kanter KR, Nicolson SC, Hill KD. Early Extubation After Repair of Tetralogy of Fallot and the Fontan Procedure: An Analysis of The Society of Thoracic Surgeons Congenital Heart Surgery Database. Ann Thorac Surg 2016; 102: 850-858.
7) El-Rassi I, Soueide A. Early extubation following cardiac surgery in neonates and infants. Heart Lung Circ 2010; 19: 100-101.
8) Rooney SR, Donohue JE, Bush LB, Zhang W, Banerjee M, Pasquali SK, Gaies MG. Extubation Failure Rates After Pediatric Cardiac Surgery Vary Across Hospitals. Pediatr Crit Care Med 2019; 20: 450-456.
9) Neirotti RA, Jones D, Hackbarth R, Paxson-Fosse G. Early extubation in congenital heart surgery. Heart Lung Circ 2002; 11: 157-161.
10) Davis S, Worley S, Mee RBB, Harrison AM. Factors associated with early extubation after cardiac surgery in young children. Pediatr Crit Care Med 2004; 5: 63-68.
11) Li S, Zhang Y, Li S, Wang X, Zhang R, Lu Z, Yan J. Risk Factors Associated with Prolonged Mechanical Ventilation after Corrective Surgery for Tetralogy of Fallot. Congenit Heart Dis 2015; 10: 254-262.
12) Varghese J, Kutty S, Abdullah I, Hall S, Shostrom V, Hammel J. Preoperative and intraoperative predictive factors of immediate extubation after neonatal cardiac surgery. Ann Thorac Surg 2016; 102: 1588-1589.
13) Li S, Zhang Y, Li S, Wang X, Zhang R, Lu Z, Yan J. Risk Factors Associated with Prolonged Mechanical Ventilation after Corrective Surgery for

Tetralogy of Fallot. Congenit Heart Dis 2015; 10: 254-262.

14) Varghese J, Kutty S, Moukagna KSB, Craft M, Abdullah I, Hammel JM. Five-year experience with immediate extubation after arterial switch operations for transposition of great arteries. Euro J Cardio Thorac Surg 2017; 51: 728-734.

15) Halimic M, Dinarevic SM, Begic Z, Kadic A, Pandur S, Omerbasic E. Early extubation after congenital heart surgery. J Health Sci 2014; 4: 156-161.

16) Tirotta CF, Alcos S, Lagueruela RG, Salyakina D, Wang W, Hughes J, Irizarry M, Burke RP. Three-year experience with immediate extubation in pediatric patients after congenital cardiac surgery. J Cardiothorac Surg 2020; 15: 1.

17) Wu K, Chen F, Wang Y, Ti Y, Liu H, Wang P, Ding Y. The Experience of Early Extubation After Paediatric Congenital Heart Surgery in a Chinese Hospital. Heart Lung Circ 2020; 29: 238-244.

18) Alghamdi AA, Singh SK, Hamilton BCS, Mus M, Yadava M, Holtby H, Van Arsdell GS, Al-Radi OO. Early extubation after pediatric cardiac surgery: systematic review, meta-analysis, and evidence-based recommendations. J Card Surg 2010; 25: 586-595.

19) Mittnacht AJ, Hollinger I. Fast-tracking in pediatric cardiac surgery – the current standing. Ann Card Anaesth 2010; 13: 92-101.

20) Suominen PK, Haney MF. Fast-tracking and extubation in paediatric cardiac surgery. Acta Anaesthesiol Scand 2017; 61: 876-879.

21) Bainbridge D, Cheng DC. Early extubation and fast-track management of off-pump cardiac patients in the intensive care unit. Semin Cardiothorac Vasc Anesth 2015; 19: 163-168.

22) Bennyworth BD, Mastropietro CW, Graham EM, Klugman D, Costello JM, Zhang W, Gaies M. Variation in extubation failure rates after neonatal congenital heart surgery across Pediatric Cardiac Critical Care Consortium hospital. J Thorac Cardiovasc Surg 2017; 153: 1519-1526.

23) Harris KC, Holowachuk S, Pitfield S, Sanatani S, Froese N, Potts JE, Gandhi SK. Should early extubation be the goal for children after congenital cardiac surgery? J Thorac Cardiovasc Surg 2014; 148: 2642-2648.

24) Charpie JR, Dekeon MK, Goldberg CS, Mosca RS, Bove EL, Kulik TJ. Serial blood lactate measurements predict early outcome after neonatal repair or palliation for complex congenital heart disease. J Thorac Cardiovasc Surg 2000; 120: 73-80.

25) Özyaprak B, Ata F, Dayıoğlu M, Anarat K, Kaydul M, Apaydın Y, Gamlı M, Karaca Ü, Seçici S, Eriş C, Ata Y, Kahraman N, Erkan G, Eroğlu A. Our Experience in Anesthesia Management in Operations for Congenital Pediatric Cardiac Diseases. EJCM 2020; 8: 35-44.