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Assessment of the factors that affect fast-track or early extubation following pediatric cardiac surgery

Pediatrik kardiyak ameliyatı sonrası hızlı veya erken ekstübasyonu etkileyen faktörler

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ABSTRACT

Background: This study aims to evaluate the early extubation rate and the factors affecting early extubation in pediatric patients undergoing cardiac surgery.

Methods: Between August 1st, 2020 and December 1st, 2021, a total of 528 pediatric patients (264 males, 264 females; median age: 4 months; range, 2 days to 24 months) who were followed in the pediatric cardiac intensive care unit after congenital heart surgery were retrospectively analyzed. Demographic and clinical characteristics of the patients including operation and intensive care data were obtained from the medical records. Patients included in the study were categorized into three groups as the group of patients who were extubated in the operating room (fast-track extubation), the group of patients who were extubated in the first 6 h of the operation (early extubation), the group of patients who were extubated after the postoperative 6 h or the group of patients who were not extubated or died (delayed extubation).

Results: Sixty-eight (12.9%) cases had fast-tract extubation, 124 (23.6%) cases had early extubation, and 335 (63.6%) cases had delayed extubation. The median age of the patients in the delayed extubation group was three months, which was significantly lower than those of the other groups ($p<0.05$). Reintubation rates were 1.5% in the fast-tract extubation group, 2.5% in early extubation group, and 9% in delayed extubation group ($p<0.05$). The median intensive care unit stay was 3, 5, and 10 days, respectively ($p<0.05$). Length of hospitalization was significantly higher in the delayed extubation group compared to the other groups ($p<0.05$). Neonatal age group, Risk Adjustment for Congenital Heart Surgery 1 score >4, Society of Thoracic Surgeons-European Association for Cardio-Thoracic Surgery mortality category >3, cardiopulmonary bypass time >100/min, vasoactive inotrope score >8, acute kidney injury >2, and low weight were found to be independent risk factors for delayed extubation.

Conclusion: Fast-track and early extubation can be successfully applied with low reintubation rates in selected cases with congenital heart surgery. Age, body weight, presence of genetic syndrome, operational risk category, and procedure time may affect the extubation time.

Keywords: Congenital heart surgery, early extubation, intensive care, pediatric.

ÖZ

Amaç: Bu çalışmada kalp cerrahisi yapılan çocuk hastalarda erken ekstübasyon oranı ve erken ekstübasyonu etkileyen faktörler incelendi.

Çalışma planı: 01 Ağustos 2020 - 01 Aralık 2021 tarihleri arasında konjenital kalp cerrahisi sonrasında pediatrik kardiyak yoğun bakım ünitesinde izlenen toplam 528 çocuk hasta (264 erkek, 264 kız; medyan yaş: 4 ay; dağılım, 2 gün-24 ay) retrospektif olarak incelendi. Ameliyat ve yoğun bakım verileri dahil olmak üzere hastaların demografik ve klinik özellikleri tıbbi kayıtlardan elde edildi. Çalışmaya alınan hastalar ameliyathanede ekstübe edilen hastalar (hızlı ekstübasyon), ameliyatın ilk 6 saatinde ekstübe edilen hastalar (erken ekstübasyon) ve ameliyattan ilk 6 saatten sonra ekstübe edilenler veya edilemeyen/kaybedilen hastalar (geç ekstübasyon) olmak üzere üç gruba ayrıldı.

Bulgular: Altmış sekiz (%12.9) olguda hızlı ekstübasyon, 124 (%23.6) olguda erken ekstübasyon ve 335 (%63.6) olguda geç ekstübasyon izlendi. Geç ekstübasyon grubundaki hastaların medyan yaşı üç ay olup, diğer iki gruba kıyasla anlamlı düzeyde daha düşüktü ($p<0.05$). Tekrar entübasyon oranları hızlı ekstübasyon grubunda %1.5, erken ekstübasyon grubunda %2.5 ve geç ekstübasyon grubunda %9 idi ($p<0.05$). Medyan yoğun bakım ünitesinde kalış süresi sırasıyla 3, 5 ve 10 gün idi ($p<0.05$). Diğer gruplara kıyasla geç ekstübasyon grubunda hastanede kalış süresi anlamlı düzeyde daha uzundu ($p<0.05$). Yenidoğan yaş grubu, >4 Konjenital Kalp Cerrahisinde Risk Belirleme 1 skoru, Göğüs Cerrahisi Derneği-Avrupa Kardiyotorasik Cerrahi Derneği mortalite kategorisi >3, >100/dk. kardiyopulmoner baypas süresi, >8 vazoaktif inotrop skoru, >2 akut böbrek hasarı ve düşük ağırlık geç ekstübasyonun bağımsız risk faktörleri olarak bulundu.

Sonuç: Hızlı ve erken ekstübasyon, konjenital kalp cerrahisi yapılmış seçilmiş olgularda düşük tekrar entübasyon oranları ile başarılı bir şekilde uygulanabilir. Yaş, vücut ağırlığı, sendrom varlığı, cerrahi risk kategorisi ve ameliyat süresi ekstübasyon süresini etkileyebilir.

Anahtar sözcükler: Konjenital kalp cerrahisi, erken ekstübasyon, yoğun bakım, çocuk.

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The frequency of congenital heart disease (CHD) varies between 4 and 8/1,000 live births. Approximately 25% of these cases develop critical CHDs that require treatment in the first year of life.[1] Endotracheal intubation and anesthesia applications play a vital role in the surgery or angiography procedures administered to CHD patients with different anatomical and hemodynamic characteristics.[2,3]

The main goal of anesthesia in patients planning for surgery for CHDs is to provide hemodynamic stability, reduce mortality and morbidity, use resources economically, and prevent harm to the patient. Fulfilling these conditions is essential to tailor an anesthesia management strategy for CHD.[4]

Traditionally, patients were followed in the intensive care unit (ICU) with mechanical ventilator support after cardiac surgery. Recently, there has been an increase in the frequency of early extubation (EE) to avoid the adverse effects of positive pressure ventilation on the cardiovascular system, reduce airway irritation, and prevent complications such as ventilation-associated pneumonia. It has been advocated in different studies that factors such as age, body weight, the complexity of cardiac pathology, duration of operation, risk category, presence of syndrome, and anesthesia management are influential on extubation time. However, due to the adverse effects of cardiopulmonary bypass (CPB), the presence of immature organ systems, and sudden hemodynamic changes, when and where patients should be extubated is still a matter of debate.[5,6]

In the present study, we aimed to identify fast-track extubation (FTE), EE, and delayed extubation (DE) rates following a congenital heart operation and to evaluate the factors affecting FTE and DE.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at Başakşehir Cam and Sakura Hospital, Departments of Anaesthesiology and Reanimation and Pediatric Cardiology between August 1st, 2020 and December 1st, 2021. Pediatric patients younger than 18 years of age who underwent congenital heart surgery were screened. Patients with known neurological diseases (n=4), premature babies (n=14), and those who were previously dependent on mechanical ventilation (n=46) were excluded from the study. Finally, a total of 528 cases (264 males, 264 females; median age: 4 months; range, 2 days to 24 months) were included.

A study form was created for each case. This form included preoperative data (demographic characteristics, preoperative clinical status, cardiac diagnosis, echocardiographic information, presence of syndrome, and redo status); operative data (presence of CPB, duration of operation, Risk Adjustment for Congenital Heart Surgery 1 [RACHS-1] score, and the Society of Thoracic Surgeons [STS]-European Association for Cardio-Thoracic Surgery (EACTS) mortality categories [STAT] score); and postoperative data (extubation time, length of stay in the ICU and hospital, mortality, highest vasoactive inotrope score [VIS, blood gas analysis, reintubation status, and complications). The RACHS-1, STAT, and VIS scores were calculated as reported in the literature.[7,8]

The cases included in the study were divided into three groups as the group of patients extubated in the operating room (FTE group), the group of patients extubated in the first 6 h after the operation in the ICU (EE group), and the group of patients extubated after the postoperative 6 h or the group of patients who were not extubated or died (DE group).[2]

The extubation decisions were taken by consensus between a pediatric cardiac intensivist with a five-year experience and a cardiac anesthesiologist. Extubation criteria were defined as staying awake without any stimulus, presence of spontaneous respiratory effort, a positive end-expiratory pressure (PEEP) 5 cmH_2O, the fraction of inspired oxygen (FiO2) ≤0.4, oxygenation index (OI), arterial oxygen partial pressure (PaO_2)/FiO_2) >200, partial pressure of carbon dioxide ($PaCO_2$) ≤50 mmHg, pH ≥7.25, a stable hemodynamic status, absence of systolic and diastolic dysfunction in echocardiography, and a good cough reflex and swallowing function. Extubation was postponed in case of delayed sternum closure, excessive bleeding, hemodynamic instability, and high-risk surgery.[4] Reintubation was defined as the need for mechanical ventilation after initial extubation attempt either in the operating room or in the ICU during the same hospital stay.[5]

All cases were planned to be extubated in the shortest time possible. In the perioperative anesthesia management, the appropriate medications were administered within the protocol framework used in the clinic where this study was conducted. Per protocol, in children aged six months, midazolam 0.1 mg/kg, fentanyl 1 μg/kg, and rocuronium bromide 0.6 mg/kg were administered at induction; and remifentanil 0.1 μg/kg/min, rocuronium bromide 5 μg/kg/min, and a minimum of 1 to 1.2 alveolar concentration sevoflurane were administered for maintenance. In children older than six months, midazolam 0.1 mg/kg, fentanyl 1 μg/kg, and rocuronium bromide 0.6 mg/kg were administered

at induction; and remifentanil 0.25 μg/kg/min, rocuronium bromide 5 μg/kg/min, minimum of 1 to 1.2 alveolar concentration sevoflurane, and dexmedetomidine 0.5 μg/kg/h were administered for maintenance. The effects of neuromuscular agents were antagonized by sugammadex. Remifentanil and rocuronium were discontinued after the sternum was closed. Sevoflurane was discontinued before the skin was closed. Dexmedetomidine was continued, until the patient was transferred to the pediatric cardiac ICU.

The patients were initiated on milrinone 0.5 μg/kg/min at the beginning of the operation. The anesthesiologist decided the maintenance dose on a case-by-case basis, taking into consideration the initiation of catecholamine and the patient's hemodynamic status in the volume management during the operation.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 22.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in median (interquartile range [IQR]) and number and frequency, where applicable. The Pearson chi-square test and one-way analysis of variance (ANOVA) test were used to compare the variables between groups. The model developed for assessing the factors affecting extubation featured the determination of independent risk factors in the combined FTE and EE groups based on the univariant analysis. Subsequently, the factors which were determined to be independent risk factors affecting extubation were analyzed using the multivariate logistic regression analysis. The estimated final model of the parameters predicting FTE or EE was expressed in terms of odds ratio (OR) within 95% confidence interval (CI). A p value of <0.05 was considered statistically significant.

Table 1. Main cardiac pathology results of the cases

Main diagnosis	Fast-track extubation group (n=68)	Early extubation group (n=124)	Delayed extubation group (n=336)	Total (n=528)
ALCAPA	-	-	2	2
Aortic valve pathology	2	4	12	18
Arcus hypoplasia or coarctation	2	6	34	42
Atrial septal defect	16	4	-	20
Atrioventricular septal defect	6	12	32	50
DORV	4	8	10	22
Ebstein anomaly	1	1	2	4
Hypoplastic left heart syndrome	-	2	30	32
Mitral valve pathology	3	6	8	17
Other	2	6	12	20
Pulmonary atresia	1	6	14	21
RAI or LAI	5	10	19	34
Tetralogy of Fallot	4	18	41	63
TAPVR/PAPVR	3	3	16	22
Transposition of great artery	1	2	37	40
Tricuspit atresia	2	2	6	10
Truncus arteriosus	-	2	11	13
Vascular ring	2	4	5	11
Ventricular septal defect	14	28	45	87

ALCAPA: Anomalous origin of the left coronary artery from the pulmonary artery; DORV: Double outlet-right ventricle; RAI: Right atrial isomerism; LAI: Left atrial isomerism; TAPVR: Total partial anomalous pulmonary venous return; PAPVR: Partial anomalous pulmonary venous return.

Table 2. Preoperative, operative, and intensive care data

	Fast-track extubation group				Early extubation group				Delayed extubation group				
	n	%	Median	IQR	n	%	Median	IQR	n	%	Median	IQR	*p*
Age (month)			14	5-36			6	3-11			3.0	0.1-5	<0.001
Sex													
Male	33				64				166				NS
Newborn	1	1.5			4	3.2			140	42			<0.001
Weight (kg)			13	6-25			6	3-9			3.2	3-6	<0.001
Cyanotic congenital heart disease	20	29.4			56	45			180	54			NS
Syndromic condition	6	8.8			13	10.4			53	16.1			<0.001
Pulmonary hypertension	17	25			42	33.8			140	42			0.025
Redo	3	4.4			8	6.4			32	9.6			0.018
RACHS-1 >4	2	2.9			8	6.4			82	24			<0.001
STAT >3	3	4.4			19	15.3			162	48			<0.001
Cardiopulmonary bypass use	55	80			102	82			287	85			NS
Cardiopulmonary bypass time (min)			65	50-75			77	60-100			105	80-145	<0.001
Aortic cross-clamp time (min)			27	20-36			42	35-54			60	48-74	<0.001
Reintubation	1	1.5			3	2.5			30	9			0.012
Non-invasive ventilation	1	1.5			3	2.5			10	3			NS
Peak lactate		4.1				4.3				5.2			NS
Peak vasoactive inotrope score			5	2-8			5	2-8			12	3-16	<0.001
Infection	1	1.5			4	3.2			23	6.9			NS
Acute kidney injury	1	1.5			4	3.2			31	9.3			<0.001
Arrhythmia	1	1.5			6	4.8			22	6.6			NS
Bleeding requiring revision	1	1.5			3	2.4			8	2.4			NS
Extracorporeal membrane oxygenation	-	-			4	3.2			14	4.2			NS
Pulmonary hypertensive crisis	-	-			3	3.2			15	4.5			NS
Length of intensive care stay (day)			3	2-4			5	3-7			10	8-12	<0.001
Length of hospital stay (day)			6	5-7			7	5-10			13	10-21	<0.001
Mortality	-	-			3	2.4			34	10.2			0.040

IQR: Interquartile range; RACHS-1 Risk Adjustment for Congenital Heart Surgery 1; STAT: European Association for Cardio-Thoracic Surgery mortality categories.

Table 3. Independent risk factors causing delayed extubation in multivariate logistic regression analysis

Variables	OR	95% CI	*p*
Newborn	1.2	0.7-1.5	0.020
Weight	0.8	0.6-1.1	0.030
RACHS-1 >4	3.7	2.1-8	0.010
STAT >3	2.8	0.9-7.4	0.004
CPB time >100/min	4.4	3.1-12	0.008
Vasoactive inotrope score >8	2.7	1.8-5.1	0.001
Acute kidney injury >2	2.1	1.4-6	0.007

OR: Odds ratio; CI: Confidence interval; RACHS-1: Risk Adjustment for Congenital Heart Surgery 1; STAT: Society of Thoracic Surgeons-European Association for Cardio-Thoracic Surgery mortality categories; CPB: cardiopulmonary bypass.

RESULTS

Of a total of 528 cases included in the study, 68 (12.9%) had FTE, 124 (23.6%) had EE, and 336 (63.6%) had DE. The most common cardiac pathology among the cases was ventricular septal defect (n=87), followed by tetralogy of Fallot (n=63), and complete atrioventricular septal defect (n=50). The primary cardiac diagnoses of the cases are shown in Table 1.

The preoperative, intraoperative, and ICU data and univariant analysis results of the patients are summarized in Table 2.

Preoperative data

The median age of the patients in the DE group was significantly lower than those of the other groups (p<0.05). The number of newborn cases was significantly higher in the DE group (p<0.05). The median bodyweight of the patients was 13 kg in the FTE group, 6 kg in the EE group, and 3.2 kg in the DE group (p<0.05). The presence of syndrome, presence of pulmonary hypertension, and frequency of cyanotic heart disease were all statistically significantly higher in the DE group than the other two groups (p<0.05).

Operative data

Cardiopulmonary bypass was used in 84% of all cases. The overall median CPB time was 75 (range, 60 to 95) min. The median CPB time in the FTE, EE, and DE groups were 65 (range, 50 to 75), 77 (range, 60 to 100), and 105 (range, 80 to 125) min, respectively, which was significantly higher in the DE group compared to the other groups (p<0.001). Similarly, the RACHS-1 scores and STAT mortality categories were significantly higher in the DE group than the FTE and EE groups (p<0.05).

Postoperative data

The overall reintubation rate was 6.4%. The reintubation rates in the FTE, EE, and DE groups were 1.5%, 2.5%, and 9%, respectively (p<0.05). Non-invasive ventilation (NIV) rates in the FTE, EE, and DE groups were 1.5%, 2.5%, and 3%, respectively. The highest median blood gas lactate concentrations within the first 24 h after surgery in the FTE, EE, and DE groups were 4.1 (range, 2.8 to 6.1), 4.3 (range, 3.1 to 5.8), and 5.2 (range, 4.2 to 7.5) mmol/L, respectively, and did not significantly differ among the groups. The VIS score, infection rate, and acute kidney injury (AKI) rate were significantly higher in the DE group (p<0.05). No significant difference was observed among the groups regarding arrhythmia frequency (p>0.05). Median lengths of stay in the ICU in the FTE, EE, and DE groups were 3 (range, 2 to 4), 5 (range, 3 to 7), and 10 (range, 8 to 12) days, respectively, whereas the median lengths of hospitalization in the FTE, EE, and DE groups were 6 (range, 5 to 7), 7 (range, 5 to 10), and 13 (range, 10 to 21) days, respectively (p<0.05). There was no mortality in the FTE group, whereas there were three (2.4%) mortalities in the EE group and 34 (10.2%) mortalities in the DE group.

The factors with a p value of <0.05 as indicated by the univariate analysis from among the preoperative, operative, and ICU data were further analyzed using the multivariate regression analysis to identify the independent risk factors that caused DE. The independent risk factors are shown in Table 3. Accordingly, the RACHS-1 score >4 (OR: 3.7, 95% CI: 2.1-8, p=0.010), STAT level >3 (OR: 2.8, 95% CI: 0.9-7.4, p=0.004), AKI >2 (OR: 2.1, 95% CI: 1.4-6, p=0.007), neonatal age group (OR: 1.2, 95% CI: 0.7-1.5, p=0.02, CPB >100/min (OR: 4.4, 95% CI: 3.1-12,

p=0.008), VIS >8 (OR: 2.7, 95% CI: 1.8-5.1, p=0.001) and low body weight during operation (OR: 0.8, 95% CI: 0.6-1.1, p=0.03) were identified as the independent risk factors.

DISCUSSION

As one of the few studies conducted on the subject matter in Türkiye, in the present study, we investigated the clinical effects of FTE or EE in pediatric patients who underwent congenital heart surgery. According to our study results, FTE or EE can be performed with low reintubation rates in eligible cases and being in the neonatal age group, presence of syndrome, being in the high-risk category, and the duration of CPB are the determinant factors for delayed extubation period.

Congenital heart diseases are a heterogeneous group which includes different anatomical and physiological features such as cyanotic/acyanotic, or single ventricle/double ventricle. In some studies, the primary cardiac diagnosis of the patients was associated with extubation. In one of these studies, Ödek et al.[9] reported that cases with atrial septal defect and ventricular septal defect were extubated earlier than those diagnosed with hypoplastic left heart syndrome and transposition of the great arteries. Similarly, it was reported in the case series of Tirotta et al.[2] that patients who were extubated early had different diagnoses, with atrial septal defect, ventricular septal defect, and tetralogy of Fallot being the most common. Likewise, in the current study, the most common EE cases had a diagnosis of atrial septal defect and ventricular septal defect or tetralogy of Fallot.

Early extubation rates reported in the literature vary significantly between 27 and 82%,[10,11] which can be attributed to different cut-off periods used to define EE. In some cases, EE is considered the extubation performed in the operating room, whereas in others, it is considered the extubation performed at 1 h, first 6 h, first 12 h, or first 24 h of the operation. A prospective study showed that 40% of the cases were extubated in the first 12 h, and 64% of the cases were extubated in the first 24 h of the operation.[9] Additionally, in a case series by Alam et al.,[12] 33.8% of the cases were extubated in the first 6 h of the operation. In comparison, in this study, 36.5% of the cases were extubated in the first 6 h of the operation.

The main reason for refraining from EE in congenital heart surgery is the frequent emergence of the need for reintubation. The reintubation rate reported in a multi-center pediatric cardiac intensive care study in newborns after cardiac surgery was 11% (range, 5 to 22%).[13] In another study, this rate was reported as 2.7% for all cases (1.5% in the operating room, 3.8% in the first 6 h, and 4% in the DE group), and there was no statistically significant difference between the EE and DE cases in terms of reintubation frequency.[2] In our study, the overall reintubation rate was 6.4%. The reintubation rates in the FTE, EE, and DE groups were 1.5%, 2.5%, and 9%, respectively ($p<0.05$). A higher reintubation rate in the DE group can be attributed to the fact that the patients in the DE group were younger and in the high-risk category.

In several studies, length of stay in the ICU and length of hospitalization have been related to EE.[14] Additionally, it has also been reported that the mortality rate varies between 0-5% in cases who are extubated early.[15,16] Similarly, in this study, the length of stay in the ICU and length of hospitalization were significantly lower in patients who were extubated early. Moreover, there was no mortality among the patients who were extubated early.

Many different preoperative, intraoperative, and postoperative factors may affect EE. In a study conducted by Wu et al.,[4] age, bodyweight at the time of operation, whether the lungs were pneumonic in the preoperative stage, type and duration of CPB, presence of deep hypothermic circulatory arrest, whether ultrafiltration was used, and STAT categories were found to be independent risk factors associated with EE. In the studies of Simeonov et al.,[14] malnutrition and extended CPB duration adversely affected extubation success. In a case series of Tirotta et al.[2] including 338 cases, low flow perfusion, presence of deep hypothermia, presence of red sternotomy, use of medications such as furosemide, epinephrine, and vasopressin, provision of cardiopulmonary support, history of pulmonary edema, presence of syndrome and difficult intubation were found to be significantly associated with DE. In our study, preoperative, operative, and postoperative risk factors that could affect DE were evaluated extensively. Consistent with the results of the aforementioned studies, factors such as being newborn, presence of syndrome, being in the high-risk category, long CPB time, and high VIS score were identified as independent risk factors causing DE.

The single-center, retrospective design with a relatively short-term results is the main limitation to this study. Further large-scale, prospective studies are needed to confirm these findings.

In conclusion, fast-track and early extubation can be successfully applied with low reintubation rates in selected cases with congenital heart surgery. Age more than 30 days, less complex procedures (RACSH-1 <4), absence of a genetic syndrome, shorter cardiopulmonary bypass time, and lower vasoactive inotrope score (<8) may predict fast-track and early extubation.

Ethics Committee Approval: The study protocol was approved by the University of Health Sciences, Başakşehir Çam and Sakura City Hospital Local Ethics (date: 29.12.2021, no: 300). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from the parents and/or legal guardians of the patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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