Cardiology in the Young

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Evaluation of early extubation in the operating room for paediatric patients after congenital open-heart surgery

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Abstract

Background: Advances in surgical and perioperative care have reduced the need for prolonged mechanical ventilation in children following cardiac surgery. *Aim of the study:* To evaluate the feasibility and assess the clinical outcomes of an early extubation strategy in the operating room for children undergoing congenital heart surgery, including neonates (age < 28 days). *Methods:* This is a retrospective analysis including congenital open-heart surgery cases. We excluded patients who remained open chest postoperatively or patients with severe hemodynamic instability and high inotropic support from the study. Study variables include age, gender, weight, preoperative cardiac diagnosis, preoperative diagnosis of genetic or chromosomal abnormalities, prematurity, preoperative mechanical ventilation (invasive or non-invasive), cardiopulmonary bypass time, circulatory arrest time, postoperative use of inotropes, duration of mechanical ventilation, postoperative respiratory complication, sepsis, bleeding or other complications, paediatric cardiac ICU stay, total hospital stay, incidence of failed extubation, and operative or postoperative mortality. *Results:* This study included 163 patients who underwent congenital open cardiac surgery, out of these studied patients, 118 (72.4%) were extubated in the operating room. In total, 19.6% of studied patients had Down syndrome. Other genetic or chromosomal disorders were present among 8.6% of studied patients. There was a statistically significant difference between operating room extubation group and non-operating room extubation group regarding Risk Adjustment for Congenital Heart Surgery Score classification, postoperative paediatric ICU duration, postoperative hospital length of stay, vasoactive-inotrope score, duration of inotrope, open chest, and mortality. *Conclusion:* Extubation in the operating room after congenital open-heart surgery was successful in most of our patients, even following complex procedures.

Introduction

A common practice after congenital open-heart surgery at many institutions remains extubation in the ICU, despite the fact that extubation in the operating room is feasible.[1] Advances in surgical and perioperative care have reduced the need for prolonged mechanical ventilation in children with CHD following cardiac surgery.[2]

Early extubation has been implemented as a part of the management strategy for children undergoing cardiac surgery.[3] It has been associated with more efficient resource use for patients with CHD by reducing both paediatric cardiac ICU and hospital lengths of stay.[4,5]

This practice remains controversial in postoperative cardiac surgery because of the paucity of paediatric data as well as the heterogeneity in patient age, physiology, and anatomic complexity.[6,7,2].

Many studies have demonstrated the feasibility and practicality of this approach in infants and children. However, due to the selective nature of the populations studied, the number of patients included in these studies is often small.[2]

Despite the positive findings of these studies, early extubation strategies have not been rigorously evaluated when applied to paediatric patients undergoing congenital heart surgery.[8]

Aim of the study

To evaluate the feasibility and assess the clinical outcomes of an early extubation strategy in the operating room for paediatric patients undergoing congenital heart surgery.

Methods

This is a retrospective analysis including congenital open-heart surgery cases done at the heart centre of Al Qassimi Women's and Children's Hospital in the last 3 years from January 2021 till January 2024. The patients' ages ranged from neonatal age (2 days old) to 13 years.

We excluded patients from early extubation protocol in the operating room who remained open chest postoperatively or patients with severe haemodynamic instability and high inotropic support from the study.

Study variables include age, gender, weight, preoperative cardiac diagnosis, preoperative diagnosis of genetic or chromosomal abnormalities, prematurity, preoperative mechanical ventilation (invasive or non-invasive), cardiopulmonary bypass time, circulatory arrest time, postoperative use of inotropes, duration of mechanical ventilation, postoperative respiratory complication, sepsis, bleeding or other complications, paediatric cardiac ICU stay, total hospital stay, incidence of failed extubation, and operative or postoperative mortality.

Early extubation was defined as extubation in the operating room after the end of the open cardiac surgery and before shifting the patients to the paediatric cardiac ICU.

Extubation failure was defined as the need for reintubation 48 hours or less following the first extubation after surgery.

The vasoactive-inotropic score was used to assess and evaluate cumulative catecholamine therapy.[10] The score was calculated as follows:

- Inotrope score = Dopamine dose (mcg/kg/min) + Dobutamine dose (mcg/kg/min) + 100 x Epinephrine dose (mcg/kg/min)
- Vasoactive-inotropic score = inotrope score + 10 x Milrinone dose (mcg/kg/min) + 10,000 x Vasopressin dose (units/kg/min) + 100 x Norepinephrine dose (mcg/kg/min).[10]

The complexity of each case was assessed using the Risk Adjustment for Congenital Heart Surgery Score published by Enkins et al in 2002 as shown below.[9]

Risk category 1

- Atrial septal defect surgery (including atrial septal defect secundum, sinus venosus atrial septal defect, patent foramen ovale closure)
- Aortopexy
- Patent ductus arteriosus surgery at age >30 d
- Coarctation repair at age >30 d
- Partially anomalous pulmonary venous connection surgery

Risk category 2

- Aortic valvotomy or valvuloplasty at age >30 d
- Subaortic stenosis resection
- Pulmonary valvotomy or valvuloplasty
- Pulmonary valve replacement
- Right ventricular infundibulectomy
- Pulmonary outflow tract augmentation
- Repair of coronary artery fistula
- Atrial septal defect and ventricular septal defect repair
- Atrial septal defect primum repair
- Ventricular septal defect repair
- Ventricular septal defect closure and pulmonary valvotomy or infundibular resection
- Ventricular septal defect closure and pulmonary artery band removal
- Repair of unspecified septal defect
- Total repair of tetralogy of Fallot
- Repair of total anomalous pulmonary veins at age >30 d
- Glenn shunt
- Vascular ring surgery
- Repair of aorta-pulmonary window
- Coarctation repair at age ≤30 d
- Repair of pulmonary artery stenosis
- Transection of pulmonary artery
- Repair of coarctation and ventricular septal defect closure
- Excision of intracardiac tumour

Risk category 3

- Aortic valve replacement
- Ross procedure
- Left ventricular outflow tract patch
- Ventriculomyotomy
- Aortoplasty
- Mitral valvotomy or valvuloplasty
- Mitral valve replacement
- Valvectomy of tricuspid valve
- Tricuspid valvotomy or valvuloplasty
- Tricuspid valve replacement
- Tricuspid valve repositioning for Ebstein anomaly at age >30 d
- Repair of anomalous coronary artery without intrapulmonary tunnel
- Repair of anomalous coronary artery with intrapulmonary tunnel (Takeuchi)
- Closure of semilunar valve, aortic or pulmonary
- Right ventricular to pulmonary artery conduit
- Left ventricular to pulmonary artery conduit
- Repair of double-outlet right ventricle with or without repair of right ventricular obstruction
- Fontan procedure
- Repair of transitional or complete atrioventricular canal with or without valve replacement
- Pulmonary artery banding
- Repair of tetralogy of Fallot with pulmonary atresia
- Repair of cor triatriatum
- Systemic to pulmonary artery shunt
- Atrial switch operation
- Arterial switch operation
- Reimplantation of anomalous pulmonary artery
- Annuloplasty
- Repair of coarctation and ventricular septal defect closure
- Excision of intracardiac tumour

Risk category 4

- Aortic valvotomy or valvuloplasty at age ≤30 d
- Konno procedure
- Repair of complex anomaly (single ventricle) by ventricular septal defect enlargement
- Repair of total anomalous pulmonary veins at age ≤30 d
- Atrial septectomy

- Repair of transposition, ventricular septal defect, and subpulmonary stenosis (Rastelli)
- Atrial switch operation with ventricular septal defect closure
- Atrial switch operation with repair of subpulmonary stenosis
- Arterial switch operation with pulmonary artery band removal
- Arterial switch operation with ventricular septal defect closure Arterial switch operation with repair of subpulmonary stenosis
- Repair of truncus arteriosus
- Repair of hypoplastic or interrupted arch without ventricular septal defect closure
- Repair of hypoplastic or interrupted aortic arch with ventricular septal defect closure
- Transverse arch graft
- Unifocalization for tetralogy of Fallot and pulmonary atresia
- Double switch

Risk category 5

- Tricuspid valve repositioning for neonatal Ebstein anomaly at age ≤30 d
- Repair of truncus arteriosus and interrupted arch

Risk category 6

- Stage 1 repair of hypoplastic left heart syndrome (Norwood operation)
- Stage 1 repair of non-hypoplastic left heart syndrome conditions Damus-Kaye-Stansel procedure

Anesthesia protocol

All children posted for paediatric cardiac surgery (including children with single ventricle physiology) were considered candidates for fast tracking with on-table extubation following paediatric cardiac surgery. These patients were anaesthetised using the same anaesthesia protocol to ensure uniformity of anaesthetic technique. Perioperative transesophageal echocardiography was conducted in all the patients.

Upon arrival in operating room, all patients were monitored with five leads electrocardiogram, systemic oxygen saturation (SPO2), end-tidal CO2, near infra-red spectroscopy, and rectal temperature monitoring.

Patients were sedated with intravenous Midazolam 0.05 mg/kg and induced with intravenous Ketamine 1–2 mg/kg. Intravenous fentanyl 1mcg/kg was administered at the time of induction. Neuromuscular paralysis was achieved and maintained with intravenous cisatracurium 0.1–0.15 mg/kg throughout the surgery. Sevoflurane, the minimum alveolar concentration, was used to maintain balanced anaesthesia in all cases. Single anaesthesia machine (Dräger Zeus® Infinity® Empowered Anesthesia Workstation, L FC; beck, Germany) was used for anaesthetic management. All patients were ventilated with pressure-controlled ventilation mode with a tidal volume of 8–10 ml/kg, FIO2 adjusted to maintain physiological SPO2 and the respiratory rate adjusted to maintain optimal PaCO2 levels.

After induction, appropriate invasive arterial lines and central lines were inserted to monitor continuous arterial blood pressure and central venous pressures. Caudal block was performed to supplement analgesia with dexmedetomidine 1 mcg/kg and morphine sulphate (preservative free) 0.1 mg/kg diluted up to a total volume of 1 ml/kg.

Intraoperative sedation during cardiopulmonary bypass was maintained with an intravenous infusion of dexmedetomidine at 0.2–1 mcg/kg/hr, adjusted according to the patient's hemodynamics. Analgesia was supplemented with intravenous fentanyl 1–2 mcg/kg as needed. Neuromuscular paralysis was maintained with intravenous cisatracurium 0.1–0.15 mg/kg as needed.

Heparin was administered in a dose of 400 IU/kg before establishing cardiopulmonary bypass to maintain activated clotting time > 400–480 secs.

In open-heart surgeries, following aortic and venous cannulation and establishment of full flows on cardiopulmonary bypass, anaesthesia was supplemented with fentanyl (1–2 μg/ kg), midazolam (5–10 μg/kg) and neuromuscular paralysis was supplemented with intravenous cisatracurium 0.1–0.15 mg/kg. Minimum ventilation with sevoflurane administration was continued in all patients on cardiopulmonary bypass.

After successful weaning from cardiopulmonary bypass, transesophageal echocardiography was performed to confirm absence of residual lesions. Anticoagulation was reversed with intravenous protamine. After decannulation, patients with stable hemodynamics, acceptable arterial blood gas values and respiratory parameters, were considered for on-table extubation, using the following mentioned criteria:

Extubation criteria

Stable hemodynamics

- Absence of haemodynamically significant arrhythmias
- Vasoactive-inotropic score ≤ 10

Echocardiographic parameters

Absence of severe ventricular dysfunction

Coagulation parameters

- Absence of ongoing significant bleeding

Respiratory parameters

- Uncomplicated intubation
- Adequate respiratory efforts
- Physiologically appropriate systemic saturation (SpO2) and end-tidal CO2

Other parameters

- Rectal temperature > 35.5°C
- Chest closed
- Acceptable arterial blood gas results.

At the time of sternal closure, all patients received intravenous paracetamol 15mg/kg as additional analgesia and intravenous dexamethasone to prevent any postop stridor. In patients who decided to extubation, neuromuscular blockade was reversed with neostigmine and glycopyrrolate and ventilation was weaned to synchronised intermittent mandatory pressure controlled ventilation after sternal closure. With adequate respiratory efforts, pressure support ventilation mode was established at the time of skin closure. After application of surgical dressing, patients were allowed to breathe spontaneously. Those fulfilling the extubation criteria with adequate respiratory efforts, generating a tidal volume > 6 ml/kg with physiologically appropriate systemic saturation

Table 1. Demographic and operative data of studied patients ($n = 163$)

Variable	Operating room extubation (n = 118) No.	%	Non-operating room extubation (n = 45) No.	%	Total (n = 163) No.	%	Test of significance	p-value
Sex							$\chi^2 = 0.56$	0.454
Male	68	57.6	23	51.1	91	55.8		
Female	50	42.4	22	48.9	72	44.2		
Age							$\chi^2 = 2.77$	0.096
<1 year	51	43.2	26	57.8	77	47.2		
≥1 year	67	56.8	19	42.2	86	52.8		
Body weight (Kg)							$U = 3.34$	**0.001***
Median (IQR)	9.2 (5.8–14)		5.3 (3.7–10.8)		8.2 (5–13.3)			
Range	2.7–59		1.8–70		1.8–70			
Down syndrome	22	18.6	10	22.2	32	19.6	$\chi^2 = 0.60$	0.437
Other genetic and chromosomal disorders	10	8.5	4	8.9	14	8.6	FE = 0.01	1.000
Type of repair							FE = 0.06	1.000
Single ventricle	12	10.2	4	8.9	16	9.8		
Biventricular	106	89.8	41	91.1	147	90.2		
Redo sternotomy	3	2.5	7	15.6	10	6.1	FE = 9.58	**0.005***

*: Statistically significant, IQR: Interquartile range, χ2: Chi-squared test, U: Mann-Whitney *U* test, FE: Fisher exact test.

(SpO2) and end-tidal CO2 were planned to extubate. Those deemed not fit for extubation were paralysed with intravenous cisatracurium 0.1–0.15 mg/kg and transferred to mechanical ventilator.

All patients were then transferred to the paediatric cardiac ICU where intensive care was provided by a dedicated paediatric cardiac intensivist and an experienced team of nurses with a 1:1 nurse-to-patient ratio. Postoperative pain was managed with intravenous paracetamol and intermittent boluses of 0.1 mg/kg morphine given intravenously. Patients were kept sedated post-operatively with ongoing intravenous dexmedetomidine infusion of 0.2–1 mcg/kg/hr depending on patient's respiratory efforts and haemodynamics.

Statistical analysis

The data collected were tabulated and analysed by SPSS (statistical package for the social science software) statistical package version 26 on IBM-compatible computer. Data were expressed as number and percentage (No & %) for qualitative data, median & interquartile range, and range for quantitative not normally distributed data. Pearson Chi-squared test (χ2) was used to study association between two qualitative variables. Fisher exact test was used to study association between two qualitative variables if any of expected cells were less than five. Mann-Whitney *U* test (U) was used to study association between two quantitative not normally distributed variables. A logistic regression was performed to detect predictors for non-OR Exubation. *P*-value < 0.05 was set to be statistically significant.

Results

This study included 163 patients who underwent congenital open cardiac surgery, out of these studied patients, 118 (72.4%) were extubated in the operating room, 55.8% of studied patients were males and 44.2% were females, aged between 2 days to 13 years, 47.2% were less than 1 year and 52.8% were more than 1 year with median value of body weight of 8.2 (5–13.3) ranged between 1.8 and 70 kilograms.

In the current study, 19.6% of studied patients had Down syndrome. Other genetic or chromosomal disorders were present among 8.6% of studied patients, including hypothyroidism, chondroectodermal dysplasia, Cornelia de Lange syndrome, Hirschsprung's disease, Noonan's syndrome, sickle cell trait, and thalassaemia trait. In total, 90.2% of studied patients underwent biventricular repair representing. Only 6.1% of studied patients underwent redo sternotomy. There was a statistically significant higher body weight in the operating room extubation group when compared to non-operating room extubation group. Redo sternotomy was significantly more prevalent in the non-operating room extubation patients (*p*-value < 0.05) (Table 1).

The most common cardiac disorder, as well as the most prevalent cardiac surgery procedure among studied patients, was ventricular septal defect representing about 22.7% followed by tetralogy of Fallot representing about 14.7% (Table 2).

Among studied patients, 45 (27.6%) patients were excluded from operating room extubation group. Causes for exclusion from early extubation included difficult intubation, delayed awakening, delayed sternal closure, serious bleeding, high dose of catecholamines, significant abdominal distension, cardiac tamponade, left ventricular dysfunction, reperfusion lung injury, an episode of cardiac arrest in the operating room before extubation, and the need for extracorporeal membrane oxygenation (Table 3).

There was a statistically significant difference between operating room extubation group and non-operating room extubation group regarding Risk Adjustment for Congenital Heart Surgery Score classification as the most prevalent category in operating

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Table 2. Diagnosis of studied patients ($n = 163$)

Diagnosis	No. of studied patients = 163		Operating room extubation = 118	
	No.	%	No.	%
VSD	37	22.7	31	26.3
TOF	24	14.7	22	18.6
AVSD	19	11.7	13	11.0
Single ventricle	16	9.8	12	10.2
ASD	14	8.5	10	8.5
Coarctation	7	4.3	4	3.4
ASD with PAPVD	7	4.3	6	5.1
dTGA	7	4.3	1	0.8
VSD, PDA	6	3.7	4	3.4
TAPVD	4	2.5	2	1.7
Pacemaker impanation	4	2.5	4	3.4
Sub aortic membrane	4	2.5	1	0.8
Cortriatriatum	2	1.2	2	1.7
Ebstein anomaly	2	1.2	1	0.8
HOCM	2	1.2	0	0
MR	2	1.2	2	1.7
ASD and PS	2	1.2	2	1.6
Coarctation, VSD, ASD	1	0.6	1	0.8
Severe MR, Severe AI	1	0.6	0	0
Severe AI	1	0.6	0	0
VSD, pulmonary atresia, MAPCS	1	0.6	0	0

Table 3. Causes of exclusion from early extubation

Cause	No. of studied patients = 163	
	No.	%
High dose of catecholamine	18	11.1
Delayed sternal closure	9	5.5
Serious bleeding	6	3.7
Delayed awakening	3	1.8
Left ventricular dysfunction	2	1.2
ECMO	2	1.2
Significant abdominal distension	1	0.6
Cardiac arrest	1	0.6
Cardiac tamponade	1	0.6
Difficult intubation	1	0.6
Reperfusion lung injury	1	0.6
Total	45	27.6

room extubation group and non-operating room extubation group was category 2 and category 3, respectively. Also, there was a statistically significant increase in postoperative ICU duration, postoperative hospital length of stay, vasoactive-inotrope score, duration of inotrope, open chest, pulmonary oedema and mortality in non-operating room extubation group when compared to operating room extubation group (p-value < 0.05) (Table 4).

Binary logistic regression analysis was performed to detect the effects of body weight, redo sternotomy, Risk Adjustment for Congenital Heart Surgery Score classification and vasoactive-inotrope score on the likelihood of non-operating room extubation group in the studied patients. On univariable analysis, all predictor variables were statistically significant except body weight. Accordingly, all statistically significant predictors entered a regression model. Of predictor variables, Risk Adjustment for Congenital Heart Surgery Score classification and vasoactive-inotrope score were statistically significant independent predictors of non-operating room extubation group (Table 5).

Discussion

Our study aimed to evaluate the feasibility of early extubation in the operating room for children undergoing congenital heart surgery, including neonates. The decision to extubate patients in the operating room was often influenced by several factors, including stable hemodynamics, adequate respiratory efforts, generating a tidal volume > 6 ml/kg with physiologically appropriate SpO2 and end tidal CO2, chest closed, no significant bleeding, no significant abdominal distension, no cardiac arrest during surgery and appropriate results of arterial blood gases after surgery. In addition to good ventricular function and no significant residual cardiac lesion evaluated by echocardiography in the operating room.

The management of congenital open-heart surgery has significantly improved over the past few decades because of developments in surgical skills, perfusion techniques, anaesthetic management, and postoperative care. However, extubation in the operating room following surgery is not a common practice at many institutes.[11,12]

Early extubation was a common practice after cardiac surgery in the 1960s due to a lack of the availability of ventilators. However, this practice lost favour in the latter due to the use of high-dose opioid analgesia.[13]

The use of high-dose opioids is a common, time honoured technique for cardiac anaesthesia complicated by the imposition of postoperative mechanical ventilation with a relatively high incidence of respiratory complications.[14]

With the increasing use of opioid-sparing techniques to anaesthetise cardiac surgical patients, early and immediate extubation practices have become more frequent.[15]

In 2000, Vricella and colleagues reported that of 201 congenital open-heart surgery cases, 175 (87.1%) were extubated in the operating room.[16] In 2008, Mittnacht and colleagues reported that operating room extubation was successful in 79% of their paediatric patients (178/224), even in cases where complex procedures were involved.[8]

Down syndrome and patients are frequently associated with increased perioperative morbidity.[17] However, it is confirmed that in our study, patients with trisomy 21 or other genetic or metabolic syndromes after cardiac surgery are not necessarily excluded from candidates for early extubation in the operating room (table 1).

The study demonstrated that most infants and paediatric congenital heart surgery patients can be successfully extubated in the operating room after postoperative cardiac surgery. The reintubation rate was four cases (3.4%) out of 118 cases extubated in the operating room. This is much better than the reported 11%

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Table 4. Comparison between operating extubation and non-operating extubation patients ($n = 163$)

Variable	Operating room extubation (n = 118) No.	Operating room extubation (n = 118) %	Non-operating room extubation (n = 45) No.	Non-operating room extubation (n = 45) %	Test of significance	*p*-value
RACHS classification					$\chi^2 = 38.18$	**<0.001***
Category 1	10	8.6	3	6.7		
Category 2	78	67.2	9	20		
Category 3	27	23.3	27	60		
Category 4	1	0.9	6	13.3		
Preoperative ventilation	2	1.7	4	8.9	FE = 4.76	0.050
Difficult intubation	0	0	1	0.8	FE = 0.38	1.000
Cardiopulmonary bypass (CPB) time (Minutes)					U = 0.43	0.671
Median (IQR)	160 (120–226)		130 (93.5–159.75)			
Range	69–404		45–553			
Cross clamp time (Minutes)					U = 0.09	0.921
Median (IQR)	99 (66–149.5)		83.5 (56.25–100.25)			
Range	14–245		21–262			
Deep hypothermia circulatory arrest	1	0.8	2	4.4	FE = 2.33	0.185
Post operative ICU Duration (days)					U = 5.45	**<0.001***
Median (IQR)	1 (1–2)		3 (2–7.75)			
Range	1–10		1–196			
Post operative hospital length of stay (days)					U = 6.18	**<0.001***
Median (IQR)	3 (3–4)		8 (4–16)			
Range	3–13		3–196			
Vasoactive inotrope Score (VIS)					U = 3.19	**0.001***
Median (IQR)	8 (6.5–10)		10 (7–10.75)			
Range	0–12		4–23			
Milrinone infusion	105	89	42	93.3	FE = 0.70	0.560
Epinephrine infusion	12	10.2	41	91.1	$\chi^2 = 31.26$	**<0.001***
Duration Of Inotrope (hours)					U = 2.96	**0.003***
Median (IQR)	22 (18–32)		32 (18.5–47.5)			
Range	0–80		4–384			
Open chest	0	0	9	20	FE = 22.06	**<0.001***
Reperfusion lung injury	0	0	11	24.4	FE = 30.93	**<0.001***
Intubation time (hours)					U = 0.38	0.704
Median (IQR)	6 (5–6)		6.5 (2–39)			
Range	3–62		0.5–1152			
Re-intubation within 24 hours	4	3.4	0	0	FE = 1.56	0.576
Mortality	0	0	5	11.1	FE = 13.53	**<0.001***

*: Statistically significant, IQR: Interquartile range, $\chi 2$: Chi-squared test, U: Mann-Whitney *U* test, FE: Fisher exact test.

(range 5 to 22%) reintubation rate in the paediatric cardiac critical care consortium multicenter study of neonates after cardiac surgery[18] who were extubated in the ICU hours or days later. However, our results could be better as the age of our patients ranged from 28 days to 13 years, not only in neonates.

In the current study, there was no difference between the two studied groups in cardiopulmonary bypass time, cross-clamp time and deep hypothermia. In study done by Takuma et al, 2018, cardiopulmonary bypass time duration was an independent factor correlated with the success rate of early extubation. In their study, a

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Table 5. Predictors for non-operating room extubation

Predictor	Univariable			Multivariable		
	cOR	95% CI	*p*-value	aOR	95% CI	*p*-value
Body weight (kg)	0.985	0.951–1.020	0.383	–	–	–
Redo sternotomy		1.739–28.674	**0.006***		0.602–22.988	0.158
Yes	1.0			1.0		
No	7.061			3.719		
RACHS classification		3.939–18.963	<**0.001***		2.778–14.819	<**0.001***
Category 1 & 2	1.0			1.0		
Category 3 & 4	8.643			6.416		
Duration Of Inotrope (hours)	1.314	1.131–1.525	<**0.001***	1.248	1.072–1.453	**0.004***

*: Statistically significant, cOR: Crude odds ratio, aOR: Adjusted odds ratio, CI: Confidence interval, *r* (1.0): Reference category.

long cardiopulmonary bypass time time was associated with prolonged mechanical ventilation and serious bleeding after open-heart surgery. In addition, this was associated with an increased risk of inflammatory response syndrome and cardiac oedema, resulting in delayed sternal closure, decreased respiratory compliance, acute lung injury, and coagulopathy or serious bleeding.[1] The same observations were reported by Christopher et al, 2020 who reported that the length of cardiopulmonary bypass, aortic cross-clamp time, use of deep hypothermia, and length of regional low flow perfusion were inversely correlated with the incidence of immediate extubation.[19]

In the current study, there was also a strong inverse relationship between need for postoperative epinephrine infusion, the vasoactive-inotropic score, the duration of postoperative inotrope infusions, and the ability to achieve early extubation in the operating room (Table 4). These variables might be considered as markers for more complex repairs, which are more likely to lead to inadequate hemostasis or haemodynamic instability.

The mortality rate in the early operating room extubation group was 0%, while it was 11.1% in the non-operating room extubation group. In the non-operating room extubation group, nine patients (20%) were transferred to the paediatric cardiac ICU with open chest. Eleven patients (24%) developed postoperative reperfusion lung injury, which may explain the higher mortality in this group. However, this also supports our strategy for early extubation in the operating room and suggests that it is a safe approach.

Other relevant clinical studies have shown that most children undergoing congenital heart surgery can be extubated in the operating room. Many neonates, including those undergoing complex procedures, can be extubated within the first 24 h after surgery. Early extubation has been associated with low morbidity rates and shorter lengths of ICU and hospital stays.[2]

In the current study, immediate extubation was associated with a shorter postoperative ICU length of stay and lower postoperative ICU costs without an increase in reintubation rates (table 4). Even though costs were not analysed in this study, our data also demonstrated reduced length of stay in the paediatric ICU and the total hospital stay without an increase in reintubation rates.

Conclusion

Extubation in the operating room after congenital open-heart surgery was successful in most of our patients, even following complex procedures. Implementation of an early extubation strategy for children with CHD is safe, feasible, and associated with good outcomes. Further investigation is necessary to evaluate the cost-reduction benefits associated with early extubation.

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Ethical standard. The authors declare review and approval of the study by Emirates Health Care Sevice research ethical committee.

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