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High Mortality Rate After Extubation Failure After Pediatric Cardiac Surgery

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Abstract. The objective of this study was to evaluate the different causes of extubation failure and the consequent mortality rates in a pediatric population after cardiac surgery. We studied 184 consecutive patients with a median age of 9 months (range, 0–165). In 158 patients, extubation was successful (group A). Nine patients were reintubated for upper airway obstruction and finally extubated successfully (group B). Seventeen patients were reintubated for cardiorespiratory failure, finally leading to death in 11 of 17 patients (65%) (group C). Group B patients were younger and had a longer intubation period compared to group A patients. Group C patients had more reoperations (30% vs 4% in group A patients, $p < 0.001$), a lower PaO_2 on admission at the intensive care unit as well as just prior to extubation, a lower base deficit before extubation, and needed more inotropic support during their stay in the intensive care unit. We conclude that extubation failure after pediatric cardiac surgery due to cardiorespiratory failure is a bad prognostic sign. Patients with high inotropic support and a low PaO_2 prior to extubation are especially at risk and probably need careful evaluation before final extubation.

Key words: Cardiac surgery — Pediatric — Reintubation — Cardiorespiratory failure — Upper airway obstruction

Weaning from mechanical ventilation and timing of endotracheal extubation are crucial components in the management of patients after cardiac surgery. Prolonged mechanical ventilation causes numerous complications, such as atelectasis, infection, tissue damage, postintubation stridor, and tube blockage [16]. Therefore, it is crucial to identify the time to start the weaning process and to identify the patients who are likely to fail the trial of weaning [16]. The usefulness of several parameters to predict extubation success and failure in infants and children has been investigated [6, 20]. Ventilatory parameters such as a low spontaneous tidal volume, a high FiO_2, or a high peak ventilatory inspiratory pressure [20], as well as other factors such as the presence of a congenital syndrome, preoperative pulmonary hypertension, and intraoperative circulatory arrest [6], have been described as risk factors for failed extubation. The outcomes after reintubation after cardiac surgery in an adult population provide conflicting results, with increased [3, 10, 15] or similar [14] mortality after reintubation. However, the outcome after extubation failure in a pediatric population after cardiac surgery has not been elucidated. We analyzed mortality rates among patient groups with different causes of extubation failure. We hypothesized that risk factors already present before extubation may at least partially predict the eventual reintubation rate.

Patients and Methods

We retrospectively reviewed medical records of 190 patients (age, <16 years) who were admitted after cardiac surgery in the pediatric intensive care unit (PICU) of the Leiden University Medical Center (LUMC) from January 1996 to May 1997. Six patients died before extubation could be attempted and were excluded from further analysis. Before leaving the operating room, transesophageal echocardiography was performed routinely to exclude residual defects. If significant, these residual defects were corrected.

The weaning process was started when the patients were hemodynamically stable and were assessed by the attending physician to be capable of sustaining spontaneous breathing. From the start of the weaning process, patients were ventilated in the synchronized intermittent mandatory ventilation mode with a maximum FiO_2 of 0.4. During the weaning process, the assisted mechanical breath

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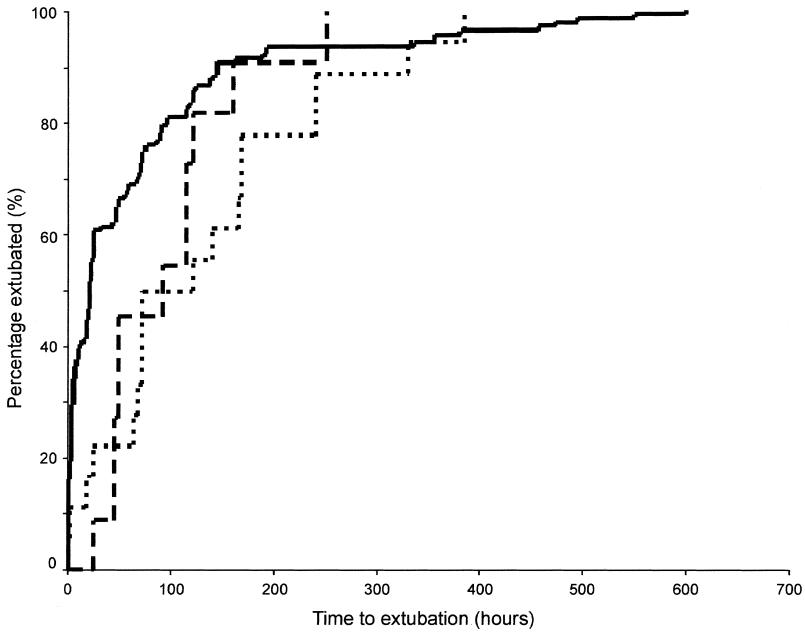

Fig. 1. Time to first extubation. *Solid line*, group A patients; *dashed line*, group B patients; *dotted line*, group C patients.

rate was gradually decreased to zero. A spontaneous breathing period of 15–30 minutes through the endotracheal tube with supplemental oxygen was performed prior to extubation. If there were no signs of respiratory distress or circulatory failure, the patient was extubated. After extubation, supplemental oxygen was administered by nasal tube. All patients remained in the ICU for at least 24 hours after extubation. Extubation failure was defined as the need for reintubation within 48 hours after extubation. Mortality after reintubation was defined as in-hospital death.

Preoperative data included demographics. Operative data included total cardiopulmonary bypass time and surgical procedure. Postoperative data included data on admission to the ICU, prior to extubation, and 1 hour after extubation (inotropic support, hemodynamic and respiratory parameters, and laboratory data). Maximal inotropic support, maximal FiO_2, the use of NO, and maximal creatinine levels were also noted. As overall estimates of morbidity, we used two additional scores—the modified sequential organ failure assessment score (mSOFA) [19] and the pediatric index of mortality (PIM) [13]. By definition, PIM was measured on admission to the ICU, whereas mSOFA was measured both on admission and immediately before extubation. The surgical procedures were categorized according to the risk-adjusted scheme for congenital heart surgery (RACHS-1) [8] and stratified into the six groups, with 1 indicating easy and 6 indicating difficult procedures.

In addition, we calculated an overall score for inotropic support (dopamine 1 μg/kg/min = 1, dobutamine 1 μg/kg/min = 1, adrenaline 0.01 μg/kg/min = 1, noradrenaline 0.01 μg/kg/min = 1, and enoximone 0.1 μg/kg/min = 1).

Statistical Analysis

All values are median and ranges unless otherwise stated. The Kruskall–Wallis test was used for comparison between groups. Categorical data were compared using the chi-squared test. A p value < 0.05 was considered statistically significant. All statistical analyses were performed using SPSS 10.0 for Windows (SPSS Inc., Chicago, IL, USA).

Results

The median age of the patients was 9 months (range, 0–165). In all patients, an extubation attempt was done 3 days (range, 1–23) after cardiac surgery (Fig. 1). In 158 patients (86%), extubation was successful, and all these patients left the hospital alive (group A). Twenty-six patients (14%) had to be reintubated. Reintubation was performed in 9 (35%) of these 26 patients for upper airway obstruction (group B) and in 17 (65%) because of cardiorespiratory failure (group C). The intubation period in group A patients was significantly shorter (20 hours; range, 1–100) compared to group B patients (92 hours; range, 25–250) and group C patients (120 hours; range, 1–384) ($p < 0.01$).

Median extracorporeal bypass time was 104 minutes (range, 0–520). Excluding patients who did not undergo extracorporeal circulation ($n = 11$), the median bypass time increases to 107 minutes (range, 35–520). There were no differences in extracorporeal bypass time between the different groups. On arrival to the PICU, all patients had an endotracheal tube and were mechanically ventilated (Bear 1000 ventilator). During the postoperative course, the maximum creatinine level was 52 μmol/L (range, 31–756) reference values; 25–50 μmol/L for infants, 40–70 μmol/L for children < 6 years, and 50–90 μmol/L for those > 6 years).

There were no differences between the groups for age at operation, maximum postoperative creatinine level, and cardiopulmonary bypass time. There were also no differences in the types of operations performed (Table 1). The single largest group consisted

Table 1. Surgical procedures

	Group		
Procedure	A	B	C
Art switch	14 (9%)	1 (11%)	1 (6%)
ASD	8 (5%)	0	0
AVSD	24 (15%)	3 (33%)	5 (29%)
BT	7 (4%)	0	1 (6%)
Fallot	22 (14%)	0	0
Fontan	5 (3%)	0	0
Glenn	6 (4%)	0	0
Ross	9 (6%)	0	0
TAPVC	6 (4%)	0	1 (6%)
Truncus	2 (1%)	1 (11%)	1 (6%)
VSD	22 (14%)	2 (22%)	3 (18%)
Others	33 (21%)	2 (22%)	5(29%)
Total	158 (100%)	9 (100%)	17 (100%)

Art switch, arterial switch operation for transposition of the great arteries; ASD, surgical closure of atrial septal defect; AVSD, surgical correction of an atrioventricular septal defect; BT, placement of a modified Blalock–Taussig shunt; Fallot, correction of tetralogy of Fallot; Fontan, completion of Fontan circulation; Glenn, creation of bidirectional Glenn anastomosis; Ross, performing Ross procedure for aortic stenosis; TAPVC, correction of total anomalous pulmonary venous connection; Truncus, correction of truncus arteriosus; VSD, surgical closure of ventricular septal defect.

of patients after atrioventricular septal defect (AVSD) correction. The number of AVSD patients did not differ between groups. Defining procedures according to the RACHS-1 list [8], group A consisted of 12 risk category 1 patients (8%), 65 risk category 2 patients (41%), 72 risk category 3 patients (45%), and 9 risk category 4 patients (6%). Group B consisted of 3 risk category 2 patients (33%), 5 risk category 3 patients (56%), and 1 risk category 4 patient (11%). Group C consisted of 6 risk category 2 patients (35%), 9 risk category 2 patients (53%), and 2 risk category 4 patients (12%) (NS). Group B patients were younger compared to group A patients (median age, 4 months compared to 9 months for group A and C patients). All group A patients left the hospital alive. All patients in group B were successfully extubated 3–5 days after reintubation. There was no mortality in this group as well. Eleven (65%) of the 17 patients in group C eventually died as a result of cardiorespiratory failure ($p < 0.001$ compared to mortality in groups A and B).

On admission to the ICU, group A had higher systolic blood pressure, needed less inotropic support, and had a higher PaO_2 (Table 2). Before extubation, the base excess differed between groups A and C (−4 vs 0, respectively $p < 0.001$). This difference remained after extubation. There was no difference in newly developed base excess between the groups. The PaO_2 before extubation was lower in group C than in group A ($p < 0.01$) (Tables 3 and 4). By multifactor analysis, the inotropic support on admission and the base excess before extubation remained significantly different between groups A and C ($p < 0.001$).

After excluding patients with persistent intracardiac shunts (Blalock-Taussig shunt, bidirectional Glenn anastomosis, and pulmonary artery banding; 16 group A patients and 1 group C patient), all analyses were repeated, but statistical significances did not change.

NO inhalation was used in 11 patients (6%): 8 group A patients (5%), 1 group B patient (11%), and 2 group C patients (12%) (NS).

During their stay in the ICU, 11 patients were reoperated: 6 patients in group A (4%) and 5 patients in group C (30%) ($p < 0.001$). In group A, 4 patients were reoperated because of persistent blood loss, 1 patient because of patch dehiscence after AVSD correction, and in 1 patient correction of tetralogy of Fallot was eventually followed by closure of a residual VSD and placement of a pulmonary homograft. The reoperations in group C patients consisted of surgical relief of pulmonary vein stenosis after total anomalous pulmonary venous connection correction, mitral valve replacement after correction of partial AVSD, enlargement of the pulmonary arteries and closure of residual VSD after Rastelli-like operation, rebanding of the pulmonary artery in a patient with VSD and coarctation after coarctectomy and banding of the pulmonary artery, enlargement of the pulmonary artery, and closure of residual VSD and surgical relief of pulmonary vein stenosis in a patient with coarctation and multiple VSDs. All patients in group A survived after the reoperation, whereas 3 of the 5 group C patients eventually died.

Discussion

Early extubation can be performed safely in many patients undergoing repair of congenital heart defects [7] as well as in adults after cardiac surgery [18]. However, failed extubation remains a significant problem, and it is important to identify patients who are likely to fail an extubation beforehand since failed extubation due to progressive cardiorespiratory failure is correlated with a high mortality rate [10].

In this study, we evaluated extubation failure in a pediatric population after cardiac surgery. Extubation failure occurred in 14% of the patients. The main reasons for extubation failure were upper airway obstruction (5%) and cardiorespiratory failure (9%). In other studies, the extubation failure rate in a pediatric population ranges from 4.9% [2] to 16.3% [20]. Stridor accounts for approximately 25% of the total failures in the study by Edmunds et al. [2], which is similar to the 30% stridor found in our study. The main factors associated with inspiratory stridor and

Table 2. Hemodynamic and biochemical markers on admission to the intensive care unit

Marker	Group				
	A	B	C	A vs B	A vs C
Sys (mmHg)	85 (50–150)	70 (60–85)	75 (50–115)	< 0.05	NS
FiO_2 (%)	40 (35–100)	60 (40–80)	50 (40–100)	< 0.05	NS
PaO_2 (kPa)	19 (4–40)	16.8 (7.7–37.4)	11.7 (4.1–25)	NS	< 0.001
Dobutamine (μg/kg/min)	0 (0–15)	2.5 (0–15)	0 (0–18)	< 0.05	< 0.05
Adm inotropes	5 (0–226)	9 (3–25)	6 (0–365)	< 0.05	NS
PIM score	19 (3–45)	7 (4–32)	9 (4–34)	NS	< 0.05
mSOFA score	4 (0–8)	6 (3–7)	4 (1–8)	< 0.05	NS

FiO_2, inspiratory oxygen fraction during ventilation; inotropes, inotropic support score; mSOFA, modified sequential organ failure assessment; NS, not significant; PaO_2, arterial oxygen content; PIM, pediatric index of mortality; Sys, systolic blood pressure.

Table 3. Hemodynamic and biochemical markers before and after extubation

	Group				
Marker	A	B	C	A vs B	A vs C
BE before (mmcl/L)	−4 (−15–7)	−1 (−9–7)	0 (−6–8)	NS	0.001
PaO_2 before (kPa)	18.4 (4.3–40.2)	16.8 (10.5–27)	13.5 (5.5–23.8)	NS	< 0.01
BE after (mmcl/L)	−5 (−14–5)	−3 (−5–3)	−2 (−9–7)	NS	< 0.01

BE after, base excess after ectubation; BE before, base excess before ectubation; NS, not significant; PaO_2 before, arterial oxygen content before ectubation.

Table 4. Maximal respiratory and inotropic support during intensive care treatment

	Group				
	A	B	C	A vs B	A vs C
Dobu max (μg/kg/min)	0 (0–20)	5 (0–15)	5 (0–20)	< 0.05	< 0.05
Inotropes max	5 (0–431)	20 (3–40)	14 (10–370)	< 0.05	< 0.001

Dobumax, maximal amount of dobutamine; Inotropes max, maximal inotropic support score.

reintubation were longer intubation periods (92 vs 20 hours in group A) and a younger age (4 vs 9 months in groups A and C). It is therefore important, especially for young patients, to be extubated as early as possible. To further reduce the incidence of upper airway obstruction, the use of corticosteroids has been advocated, but its efficacy is controversial. However, high-risk patients, such as young infants and those intubated for longer time periods, may benefit from its prophylactic use. In an adult population, extubation failure was strongly correlated with adverse outcome and increased risk of death [4]. However, in our study, this negative effect was not found in patients with extubation failure due to upper airway obstruction. Although these patients had a longer stay in the ICU, their hospital course was uneventful, and all left the hospital alive. No residual airway problems were noted.

This uncomplicated course is in contrast to that of patients who were reintubated due to cardiorespiratory failure. These group C patients had showed a high mortality rate, a high rate of reoperations, a lower PaO_2, and an increased need for inotropic support (Tables 2–4).

The rate of reoperation in group C patients was 30%, whereas it was only 4% in group A patients. This difference is even more striking since the reoperations in group A consisted of rethoracotomy in four of six patients due to persistent blood loss, whereas the reoperations in group C were all structural corrections with use of cardiopulmonary bypass. Two of the five group C patients who were reoperated had a residual pulmonary vein stenosis, which was shown to be progressive. In patients with total abnormal pulmonary venous return, reinterventions due to pulmonary vein stenosis are often difficult [11] and carry a high operative risk, increasing to as much as 66% in patients with intrinsic obstruction of the pulmonary veins [12].

The high mortality rate in group C patients partially reflects the high degree of residual defects as indicated by the number of reoperations. These residual defects were present despite postoperative transesophageal echocardiography. However, pro-

gressive pulmonary vein stenosis and rebanding of a pulmonary artery cannot be prevented by transesophageal echocardiography, whereas a certain amount of atrioventricular valve regurgitation was accepted to prevent mitral valve replacement. It is well-known that residual defects after correction for congenital heart disease may lead to a more difficult postoperative course. This difficult postoperative course in group C patients was also reflected by the higher need for inotropic support. When comparing maximal inotropic support during the intensive care stay, there was a highly significant difference between groups A and C ($p < 0.001$). This increased need for inotropic support in patients who need reintubation for cardiorespiratory failure has been attributed to poor heart function [6], which may eventually lead to an adverse outcome.

In patients recovering from correction of their congenital heart lesion, cardiorespiratory function plays an important role. Several studies have emphasized the role of oxygen transport [17], ventilator-associated pneumonia [5], pulmonary hypertension [9], and other pulmonary complications [1]. We found a lower PaO_2 in group C patients, both on admission to the ICU and just prior to extubation. Rossi et al. [17] found significant derangements of oxygen transport in infants who eventually died after cardiac operations. Although we did not measure mixed venous oxygen content and were therefore not able to assess oxygen consumption and oxygen extraction ratio, we hypothesize that the lower PaO_2 found in group C patients who eventually were reintubated because of cardiorespiratory failure reflects their low cardiovascular reserve. Another factor that may reflect a poor cardiopulmonary reserve is an increased base deficit. However, this was more prevalent in group A patients. This unexpected finding may be due to the longer time period before extubation in group C (120 vs 20 hours) and the use of diuretics such as furosemide, which eventually may lead to metabolic alkalosis. On admission to the ICU, the base excess did not differ between groups. Postoperative pulmonary hypertension has been recognized as a severe complication after correction for congenital heart defects [9]. Since we did not measure pulmonary artery pressure, incidence of pulmonary arterial hypertension could not be assessed. However, using NO inhalation as a sign of severe pulmonary hypertension, we did not find any difference between the groups.

The limitations of this study are mainly related to its retrospective nature. Because we measured only arterial oxygen content and not mixed venous oxygen content, we were not able to measure oxygen consumption, which is a more reliable indicator of cardiorespiratory function. However, this study clearly identifies significant differences in arterial oxygen content between patients successfully extubated and those with extubation failure due to cardiorespiratory failure.

In conclusion, the need for reintubation in pediatric patients after cardiac surgery for cardiorespiratory failure is a bad prognostic sign since we observed a mortality rate of 65%. These patients already had a more difficult postoperative course, as indicated by a longer intubation period, increased need for inotropic support, lower PaO_2, and more reoperations. This contrasts with the good result of reintubation for upper airway obstruction. Failed extubation for cardiorespiratory failure needs to be followed by careful hemodynamic evaluation of the patient in order to optimize hemodynamic condition and increase the success of a second extubation attempt. Special attention needs to be given to patients with high inotropic support and low arterial oxygen content, and some of them may benefit from a final echocardiographic assessment of heart function on minimal ventilatory support just prior to extubation [17].

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