Learning From Experience: Improving Early Tracheal Extubation Success After Congenital Cardiac Surgery*

Peter D. Winch, MD, MBA[1]; Anna M. Staudt, MD[2]; Roby Sebastian, MD[1]; Marco Corridore, MD[1]; Dmitry Tumin, PhD[1]; Janet Simsic, MD[3]; Mark Galantowicz, MD[4]; Aymen Naguib, MD[1]; Joseph D. Tobias, MD[1]

Objectives: The many advantages of early tracheal extubation following congenital cardiac surgery in young infants and children are now widely recognized. Benefits include avoiding the morbidity associated with prolonged intubation and the consequences of sedation and positive pressure ventilation in the setting of altered cardiopulmonary physiology. Our practice of tracheal extubation of young infants in the operating room following cardiac surgery has evolved and new challenges in the arena of postoperative sedation and pain management have appeared.

Design: Review our institutional outcomes associated with early tracheal extubation following congenital cardiac surgery.

Patients: Inclusion criteria included all children less than 1 year old who underwent congenital cardiac surgery between October 1, 2010, and October 24, 2013.

Measurements and Main Results: A total of 416 patients less than 1 year old were included. Of the 416 patients, 234 underwent tracheal extubation in the operating room (56%) with 25 requiring reintubation (10.7%), either immediately or following admission to the cardiothoracic ICU. Of the 25 patients extubated in the operating room who required reintubation, 22 failed within 24 hours of cardiothoracic ICU admission; 10 failures were directly related to narcotic doses that resulted in respiratory depression.

Conclusions: As a result of this review, we have instituted changes in our cardiothoracic ICU postoperative care plans. We have developed a neonatal delirium score, and have adopted the "Kangaroo Care" approach that was first popularized in neonatal ICUs. This provision allows for the early parental holding of infants following admission to the cardiothoracic ICU and allows for appropriately selected parents to sleep in the same beds alongside their postoperative children. (*Pediatr Crit Care Med* 2016; 17:630–637)

Key Words: airway extubation; analgesics, opioid; congenital cardiac surgery; hypnotics and sedatives; intensive care units; pain management; pain, postoperative

*See also p. 699.

[1]Department of Anesthesiology and Pain Medicine, Nationwide Children's Hospital, Ohio State University, Columbus, OH.

[2]Department of Anesthesiology and Perioperative Medicine, Kosair Children's Hospital, University of Louisville School of Medicine, Louisville, KY.

[3]Department of Pediatrics and Critical Care, Nationwide Children's Hospital, Columbus, OH.

[4]Department of Cardiothoracic Surgery, Nationwide Children's Hospital, Ohio State University, Columbus, OH.

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For information regarding this article, E-mail: peter.winch@nationwidechildrens.org

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The many advantages of early tracheal extubation following congenital cardiac surgery even in young infants and children are now widely recognized. Such benefits include not only avoiding the morbidity associated with prolonged intubation, but also the consequences of sedation and the effects of positive pressure ventilation in the setting of altered cardiopulmonary physiology. Authors have published review articles on the topic of early tracheal extubation, others have published based on their institutional experience, and others have editorialized on the theoretical advantages or disadvantages of such an approach (1–4).

In 2009, we published a article detailing predictors of successful early tracheal extubation following congenital cardiac surgery in neonates and infants (5). Based on a retrospective review of 391 patients less than 1 year old who underwent cardiopulmonary bypass (CPB) and surgery, we attempted to elicit which variables impacted successful early tracheal extubation. We defined such early extubation as occurring in the operating room (OR) immediately following skin closure. After analyzing a number of variables, we developed formulas that predicted the probability of successful tracheal extubation. The most significant variables identified in that analysis included patient weight, CPB time, and serum lactate concentrations (for patients between the ages of 0–3 mo).

As our practice of achieving tracheal extubation in young infants in the OR following cardiac surgery has continued to evolve, new challenges in the arena of postoperative sedation and pain management have appeared. In attempting to address these issues through the administration of sedative and analgesic agents, a certain number of patients have required reintubation following admission to the cardiothoracic ICU (CTICU). We reviewed recent data to assess our experience and understand the reasons for these failures. Specifically, we wanted to understand if there were patients on the anticipated early tracheal extubation pathway that failed based on our published predictors. Furthermore, we wanted to evaluate the factors that led to and the consequences of early tracheal extubation failure, especially in regards to prolonged hospital course and in-hospital mortality.

MATERIALS AND METHODS

As part of a quality improvement process, data were reviewed for all children less than 1 year old who underwent congenital cardiac or great vessel surgery between October 1, 2010, and October 24, 2013. The project was exempted from formal review by our institutional review board, which determined the project to consist of a quality improvement process. Retrospective data were collected on use of CPB, tracheal extubation in the OR versus tracheal extubation in the CTICU, age, weight, procedure, Special Tertiary Admissions Test (STAT) score, Risk Adjustment for Congenital Heart Surgery (RACHS) score, CPB time, and need for reintubation, in-hospital mortality and hospital length of stay (LOS) after surgery.

We have developed a standardized analgesic and anesthetic management strategy across our pediatric cardiac anesthesia group. Our approach regarding anesthetic technique, acute normovolemic hemodilution, heparin administration, crystalloid and blood product transfusion, and pH management on bypass have been previously published (6). In short, for patients that are planned for an OR extubation following surgery, fentanyl is dosed at an initial goal of 15–20 µg/kg, administered prior to surgical incision. This is supplemented with a dexmedetomidine infusion started at the rate of (0.5 µg/kg/hr) which is started after anesthetic induction, continued throughout the case during CPB, and discontinued just after weaning from CPB. Anesthesia is maintained with isoflurane and rocuronium is used for neuromuscular blockade. Intravenous acetaminophen is administered 30 minutes prior to tracheal extubation as an adjunct to postoperative analgesia. Additional narcotics are administered once the respiratory rate is reestablished at the conclusion of the surgery. Patients that present to the OR intubated and those who have comorbidities or other criteria that exclude them from an early extubation pathway are given fentanyl at an initial dose of 20–25 µg/kg, and additional fentanyl and midazolam prior to transport from the OR to the CTICU.

Categorical variables were presented as counts and continuous variables were presented as medians with interquartile ranges. Patient characteristics were compared using chi-square tests for categorical variables and Mann-Whitney *U* tests for continuous variables across four groups defined by timing of extubation and necessity of reintubation. Group 1 patients had tracheal extubation in the OR and remained extubated, group 2 patients had tracheal extubation in the OR, but required reintubation either immediately or in the CTICU, group 3 patients underwent tracheal extubation in the CTICU and remained extubated, and group 4 patients underwent tracheal extubation in the CTICU, but required reintubation (**Fig. 1**). Descriptive statistics were further stratified by the use of CPB. Among patients requiring reintubation, time to reintubation was coded as within 4 hours of CTICU arrival, within 4–24 hours of CTICU arrival, or within greater than 24 hours of CTICU arrival; and compared by extubation timing (in the OR [group 2] vs in the CTICU [group 4]). Survival analysis with in-hospital mortality as the endpoint was performed separately for early (OR) and late (CTICU) extubations using Kaplan-Meier

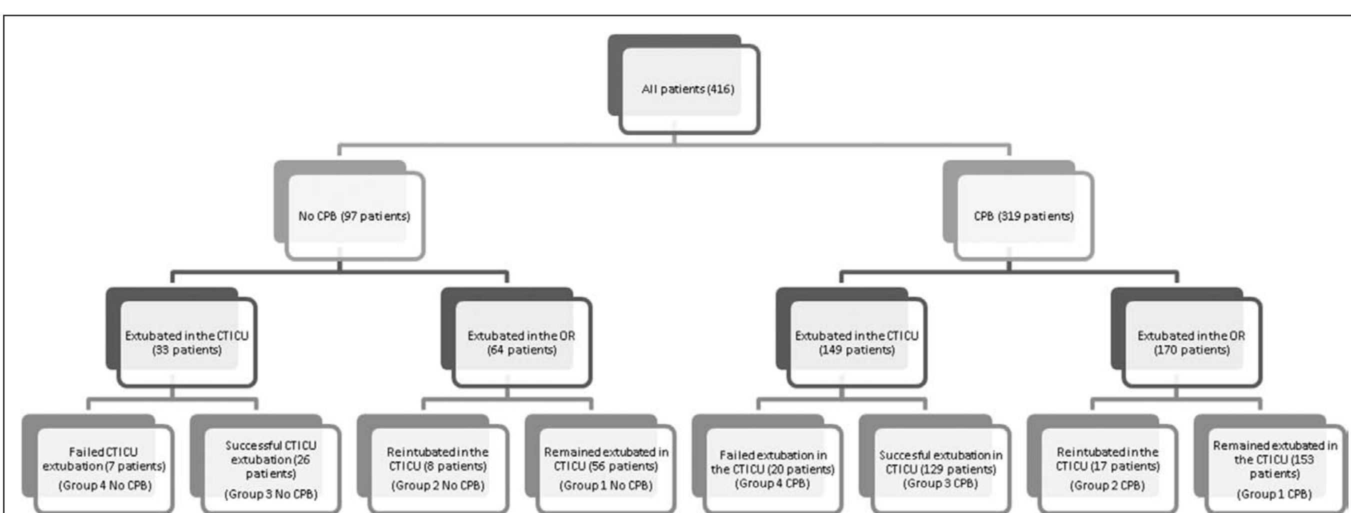

Figure 1. Graphic representation of patient groups.

curves with log-rank tests. The time metric for survival analysis was days from extubation to discharge, with patients surviving less than1 day excluded from this analysis. All analyses were performed in Stata/MP 13.1 (StataCorp LP, College Station, TX), and p value less than 0.05 was considered statistically significant. To elaborate on the statistical analysis, the hospital records were further scrutinized to determine if any patient data, including physical examination, laboratory data or observational data from parents, nurses or physicians, predicted respiratory failure.

RESULTS

A total of 416 patients less than 1 year old were included in this review. This cohort included 234 patients (56%) who underwent tracheal extubation in the OR, of who 25 subsequently required reintubation (11%), either immediately or following admission to the CTICU. The 209 patients who remained extubated comprised a wide spectrum of cases, with the majority of them being ventricular septal repairs (45 patients: 21%), followed by Tetralogy of Fallot repairs (30 patients: 14%), stage 1 hybrid procedure (24 patients: 12%), atrioventricular canal repairs (17 patients: 8%), and bidirectional Glenn (14 patients: 7%). The remaining 182 patients (44%) returned to the CTICU intubated, with 27 (15%) requiring reintubation following a trial of tracheal extubation. The difference in the proportion of failed extubations between patients first extubated in the OR and patients first extubated in the CTICU was not statistically significant (chi-square $p = 0.204$). Patients requiring reintubation were distinguished from patients successfully extubated (in the OR or CTICU) by lower body weight (reintubated median, 4.3 vs 4.9 kg; $p < 0.001$) and greater STAT score (reintubated median, 1.7 vs 0.8; $p < 0.001$). Median LOS was significantly longer among patients requiring reintubation (29 vs 14 d; $p < 0.001$), and there were 14 of 52 in-hospital deaths (27%) among reintubated patients, compared to 12 of 364 (3%) among successfully extubated patients ($p < 0.001$).

Table 1 compares patient characteristics by extubation timing (OR vs CTICU) and success among 319 patients who had CPB. Greater LOS and in-hospital mortality were observed among patients requiring reintubation whether the initial extubation was attempted in the OR or in the CTICU. Associations between reintubation and elevated STAT and RACHS scores, as well as prolonged CPB time, were observed only among patients initially extubated in the OR. In **Table 2**, similar comparisons are reported for 97 patients who did not undergo CPB. As above, this table demonstrates prolonged LOS and greater in-hospital mortality following failed extubation, whether in the OR or CTICU. Elevated STAT and RACHS scores were correlated with failed extubation in the OR, but not in the CTICU.

Weight less than 3.6 kg and CPB time more than 80 minutes were shown to predict failed extubation in our past experience (5), and we used the present data to compute extubation success rates for patients meeting one or both of these criteria. For nine patients with both risk factors, the success rate of early tracheal extubation was 89%. Patients weighing less than 3.6 kg had good

TABLE 1. Descriptive Statistics by Extubation Timing and Success Among Patients Who Had Cardiopulmonary Bypass ($n = 319$)

	Operating Room Extubation			Cardiothoracic ICU Extubation		
Variables	Remained Extubated (Group 1)	Reintubated (Group 2)	p^a	Remained Extubated (Group 3)	Reintubated (Group 4)	p^a
n	153	17		129	20	
Age (yr)[b]	0.47 (0.34/0.61)	0.45 (0.25/0.57)	0.299	0.16 (0.02/0.41)	0.19 (0.14/0.41)	0.253
Weight (kg)[b]	6.1 (5.0/7.1)	6 (4.7/6.8)	0.547	4.1 (3.3/5.4)	4.4 (2.7/4.9)	0.41
In house mortality	0	3	< 0.001	7	5	0.003
Society of Thoracic Surgeons - European Association for Cardio-Thoracic Surgery Congenital Heart Surgery Mortality Categories scores[b]	0.5 (0.2/0.8)	1.4 (0.8/2.1)	0.002	1.4 (0.5/2.1)	1.4 (0.8/1.8)	0.824
Risk Adjustment for Congenital Heart Surgery scores[b]	2 (2.0/3.0)	3 (3.0/4.0)	< 0.001	3 (2.0/4.0)	3 (2.5/4.0)	0.850
Length of stay (d)[b]	5 (3.7/7.0)	18 (8.7/38.0)	< 0.001	10 (6.0/20.0)	32.5 (21.8/63.3)	< 0.001
Cardiopulmonary bypass time (min)	114 (85/149)	171 (130/241)	0.004	170 (125/218)	203 (126/234)	0.515

[a] *p* values by chi-square test for categorical variables and Mann-Whitney *U* test for continuous variables.
[b] Data presented as median (interquartile range).

TABLE 2. Descriptive Statistics by Extubation Timing and Success Among Patients Who Had Cardiopulmonary Bypass ($n = 97$)

Variables	Operating Room Extubation			Cardiothoracic ICU Extubation		
	Remained Extubated (Group 1)	Reintubated (Group 2)	p[a]	Remained Extubated (Group 3)	Reintubated (Group 4)	p[a]
n	56	8		26	7	
Age (yr)[b]	0.03 (0.02/0.48)	0.02 (0.01/0.04)	0.173	0.02 (0.01/0.13)	0.03 (0.02/0.03)	0.857
Weight (kg)[b]	3.5 (3.0/6.3)	3.5 (3.0/3.8)	0.434	3.1 (2.8/3.6)	2.5 (2.3/3.3)	0.27
In house mortality	1	2	0.004	4	4	0.022
Society of Thoracic Surgeons - European Association for Cardio-Thoracic Surgery Congenital Heart Surgery Mortality Categories scores[b]	1.7 (0.5/3.1)	3.1 (2.6/3.1)	0.035	2.1 (0.5/3.1)	2.2 (1.5/3.1)	0.75
Risk Adjustment for Congenital Heart Surgery scores[b]	2 (2.0/3.0)	3 (3.0/3.0)	0.038	3 (2.0/4.0)	3 (3.0/3.0)	0.54
Length of stay (d)[b]	5.8 (3.0/16.8)	45.8 (23.3/126.5)	< 0.001	13.8 (7.0/20.6)	56.7 (27/90.0)	0.005

[a]*p* values by chi-square test for categorical variables and Mann-Whitney *U* test for continuous variables.
[b]Data presented as median (interquartile range).

success (33/44; 86%) with early (OR) tracheal extubation, while prolonged CPB time (> 80 min) was more of an obstacle to successful early extubation, with success demonstrated in 31 of 47 patients (66%) in the CPB group who were extubated in the OR.

The consequences of reintubation for in-hospital mortality were further investigated using survival analysis of 407 patients who survived at least 1 day after tracheal extubation. A log-rank test confirmed statistically significant difference in survival from extubation until discharge by the need for reintubation ($p = 0.006$). Kaplan-Meier curves stratified by extubation timing (in the OR vs in the CTICU) and need for reintubation are presented in **Figure 2**. The log-rank tests assessed separately for early and late extubation indicate that in-hospital mortality was correlated with reintubation among patients extubated in the CTICU ($n = 173$; $p = 0.018$) but not among patients extubated in the OR ($n = 234$; $p = 0.098$).

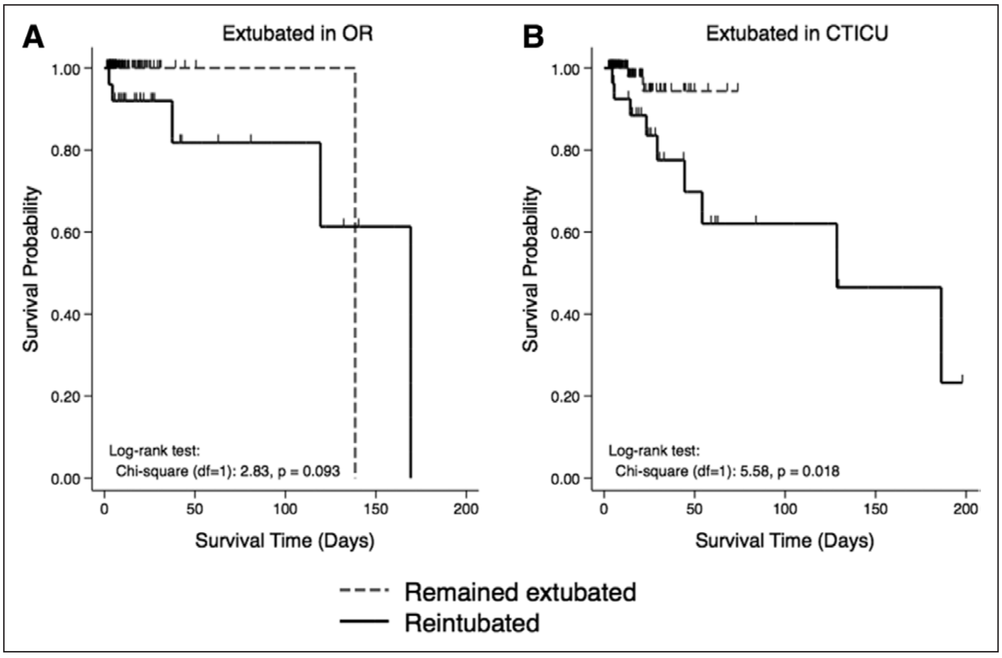

Figure 2. Kaplan-Meier curves depicting extubation timing, reintubation, and mortality. CTICU = cardiothoracic ICU, OR = operating room.

Table 3 further describes the patients who required reintubation (groups 2 and 4), dividing them into groups according to the time elapsed from the initial tracheal extubation until reintubation. Following extubation in the OR, five patients were reintubated within 4 hours, 16 patients were reintubated in 4–24 hours, and four patients were reintubated in more than 24 hours; among patients extubated in the CTICU, six were reintubated within 4 hours, 12

TABLE 3. Time From Tracheal Extubation to Reintubation, by Use of Cardiopulmonary Bypass and Extubation Attempt Timing ($n = 52$)

	CPB			Non-CPB		
	Reintubated After OR Extubation (Group 2)	Reintubated After CTICU Extubation (Group 4)		Reintubated After OR Extubation (Group 2)	Reintubated After CTICU Extubation (Group 4)	
Variables	$n = 17$	$n = 20$	p[a]	$n = 8$	$n = 7$	p[a]
Time to reintubation, hr			0.420			0.181
< 4	2	5		3	1	
4–24	12	10		4	2	
> 24	3	5		1	4	

CPB = cardiopulmonary bypass, OR = operating room, CTICU = cardiothoracic ICU.
[a]p values by chi-square test.

were reintubated in 4–24 hours, and nine were reintubated in more than 24 hours. The overall difference in time to reintubation (categorized as above) was not statistically significant when combining CPB and non-CPB patients ($p = 0.285$) or when analyzing CPB and non-CPB patients separately (Table 3).

To identify intraoperative factors possibly contributing to reintubation within 24 hours, we identified 22 patients who were extubated in the OR but required reintubation (group 2) within less than 24 hours, and compared intraoperative data from those patients against data from patients with similar characteristics (diagnosis, procedure, STAT, and RACHS scores) in the other three groups. The reintubated patients were similar to the comparison group in age, weight, CPB time, aortic cross-clamp time, last operative arterial blood gas analysis and temperature on arrival to the CTICU. Furthermore, for each of the 22 infants who failed the early tracheal extubation strategy within the first 24 hours (seven within < 4 hr and 15 between 4 and 24 hr), we examined their entire inpatient record, seeking the reason for reintubation and any preceding events (**Table 4**). Ten of the 22 patients (45%) had agitation that led to an escalation of their pain management regimen, resulting in sedation that ultimately led to respiratory depression and reintubation. Of the remaining 12 cases, 4 (18%) were reintubated for bleeding, 3 (14%) for junctional ectopic tachycardia, 1 (5%) for stridor with increased work of breathing and hypoxemia, 1 (5%) for immediate respiratory failure upon tracheal extubation in the OR, and 1 (5%) for cardiogenic shock.

DISCUSSION

Our data again demonstrate that early tracheal extubation is achievable in small infants undergoing cardiovascular surgery. Successful early tracheal extubation avoids the potential complications and associated morbidity of prolonged tracheal intubation in the CTICU and thus results in a shorter length of hospitalization. Over the last decade, there have been tremendous changes in the overall intraoperative management of pediatric cardiac surgical patients. Not only have we seen improved surgical techniques, but also better CPB management such as reduced circuit sizes for pediatric patients and low-flow bypass techniques to avoid circulatory arrest. With regards to the anesthetic management, the evolution of inhaled volatile anesthetic agents along with shorter-acting analgesics and sedatives has also changed management strategies. This has also led to a smoother and more stable emergence and recovery in these patients. All of these factors have considerably contributed to the practice of successful early tracheal extubation.

The early tracheal extubation strategy returns the patient to a physiology of negative pressure ventilation sooner, a physiology particularly important in those patients with Blalock-Taussig shunts and Glenn or Fontan anatomy. It also minimizes the need for pharmacologic sedation and its attendant impact on cardiovascular physiology. While there are clear advantages of the early tracheal extubation, both physiologic and in terms of parental satisfaction, it is of paramount importance to be able to identify those patients who are and are not candidates for early tracheal extubation and continuously improve their management. Early tracheal extubation failure that either directly causes morbidity or prolongs hospital stay does far more harm than benefit. In a large study looking at extubation failure in a multi-institutional cohort of CTICU patients, the duration of ventilation prior to extubation was an important independent risk factor predictive of extubation failure, with the rate of failure increasing two-fold after only 24 hours of ventilation (7). In this analysis and in our study, extubation failure was correlated with increased in-hospital mortality and prolonged LOS, confirming these as risks to consider when planning the extubation strategy. Thus, it is imperative that we monitor our results with this strategy and continue to attempt to identify challenges that arise from this approach.

To this point, it is important to consider how our practice has progressed since our last report in 2009. In 2009, we detailed predictors of successful early tracheal extubation following congenital cardiac surgery in neonates and infants. We concluded, "in order to obtain a probability of extubation of at least 50%, 0–3 month-old patients need a weight at or above 3.6 kg and a CPB time of less than 80 minutes" (5). However, in our recent experience, the success rate for patients with both

TABLE 4. Data for Patients Who Failed Operating Room Extubation Within 24 Hours in the Cardiothoracic ICU

Patient	Weight (Kg)	Age	Hours to Reintubation	Procedure	Comorbidities	Diagnosis	Length of Admission (D)	Reintubation Reason
1	3.9	4 d	3	Arterial switch	0	Transposition of great arteries	5.7	Bleeding
2[a]	3.1	18.5 d	0	Palliative shunt (systemic to PA)	Cleft lip/palate	TOF	28.7	Respiratory failure (operating room reintubation)
3[a]	3.8	3.7 d	6	Hybrid 1	0	HLHS	63	Cardiogenic sock
4[a]	2.9	12 d	3	Hybrid 1	0	HLHS	133	Respiratory failure
5[a]	2.9	3.7 d	3	Hybrid 1	0	HLHS	133	NCA escalation
6[a]	3.8	7.3 d	10	Hybrid 1	0	HLHS	120	NCA escalation
7[a]	3.4	3.7 d	2	Hybrid 1	0	HLHS	11.7	NCA escalation
8[a]	2.75	11 d	18	Hybrid 1	Heterotaxy/asplenia Anomalous pulmonary valve replacement Aorta coarctation of the aorta	HLHS	19.7	NCA escalation
9	7	7.8 mo	13	Central shunt	Small PAs	PA/VSD MAPCAs	3	NCA escalation
10	6	5.3 mo	11	Patch augmentation RVOT	Right ventricular hypertrophy	Critical Pulmonary stenosis	80.7	NCA escalation
11	6.8	8 mo	16	RVOT reconstruction	FTT	PA and MAPCAs	18	NCA escalation
12	4.5	4.2 mo	21	AVSD Repair	Trisomy 21	AVSD	11.7	NCA escalation
13	6.3	5.7 mo	16	Comp 2	Right lung hypoplasia	HLHS	8.7	NCA escalation
14	5.3	5.8 mo	4	Comp 2	FTT	HLHS	17	NCA escalation
15	7.9	8.2 mo	3	Comp 2	Rhinovirus+	HLHS	21.7	Respiratory failure with stridor
16	6.5	5.4 mo	10	Comp 2	Mitral valve stenosis/ aortic valve stenosis	HLHS	43	Bleeding
17	5.6	2.2 mo	5	Aorta arch repair	Reoperation	Arch small	5	Bleeding
18	4.2 mo	5.5	10	VSD repair	Trisomy 21 Prematurity	ASD and VSD	25.7	Bleeding
19	2.85	3.1 mo	21	VSD repair	Trisomy 21	ASD and VSD	8	JET
20	6.2	4.5 mo	5	AVSD repair	Trisomy 21	AVSD	141	JET
21	4.7	1.7 mo	7	TOF repair	Upper respiratory infection	TOF	38	JET
22	2.9	12 d	3	Hybrid 1	0	HLHS	133	Respiratory failure

ASD = atrial septal defect, AVSD = atrioventricular septal defect, FTT = failure to thrive, HLHS = hypoplastic left heart syndrome, JET = junctional ectopic tachycardia, MAPCAs = major aortopulmonary collateral arteries, NCA = nurse controlled analgesia, PA = pulmonary atresia, RVOT = right ventricular outflow tract, TOF = Tetralogy of Fallot, VSD = ventricular septal defect.

[a]Data with no cardiopulmonary bypass.

of these risk factors was 89%, with similarly high success rates observed among non-CPB patients weighing less than 3.6 kg. These updated data demonstrate considerable improvement in early extubation success rates over the predicted probability of 50% computed from a past cohort (5). Since 2009, we have developed a small cohesive group of cardiac anesthesia practitioners, which has enabled us to pursue a practice guideline that uses a standardized anesthetic. Such practice guidelines have been demonstrated to improve outcomes throughout all areas of medical practice.

Preoperative pulmonary hypertension is perceived to be one of the major contraindications to early tracheal extubation (8–11). Many institutions often keep these patients sedated and chemically paralyzed due to the fear of a pulmonary hypertensive crisis which remains a major cause of morbidity and mortality (12). On the other hand, positive intrapulmonary pressure and alveolar over-distention caused by prolonged mechanical ventilation might increase pulmonary vascular resistance (13). Suctioning through the endotracheal tube has been shown to be a potent trigger for pulmonary hypertensive crisis in patients with preoperative pulmonary hypertension (PAH) (13, 14). PAH in itself does not seem to contraindicate early tracheal extubation, which remains a feasible way to decrease postoperative ICU stay and hospital costs (15). Early tracheal extubation also maintains stable hemodynamic parameters in the immediate postoperative period. Changes that may occur with alterations in arterial blood values are often transient without a major impact on the overall outcome (16, 17).

As demonstrated in Table 3, there was no meaningful difference between the tracheal extubation failure rate for the early (group 2) (11%) or late (group 4) patients (15%). Arterial blood gas analyses from the OR through the CTICU stay until the time of reintubation were examined for potential predictors of deterioration in cardiac output or respiratory drive, such as lactic acidosis, hypercapnia, or anemia. Unfortunately, there was nothing in the laboratory data that predicted the need for reintubation in these 10 patients. Of the 22 patients who required reintubation within 24 hours of arrival in the CTICU, 45% failed because of excessive agitation. This agitation resulted in escalation or change to the standard nurse controlled analgesia (NCA) used for nearly all postoperative patients (< 1 yr old): fentanyl 0.5 µg/kg basal rate with 0.5 µg/kg bolus every 10 minutes as needed. In these 10 patients, there was an increase in pain medication administration, additional sedative agents, or a variation from the normal NCA order that appeared to contribute to respiratory depression and failure, requiring reintubation. Delirium may have also been a contributing factor, as the escalation of the sedative and analgesic agents did not result in control of the symptoms, but rather a further escalation.

Our success in early tracheal extubation has resulted in the emergence of a new challenge related to postoperative pain management and sedation for this unique population of patients, particularly during the first 24 hours. Clearly, not all agitation in the CTICU is caused by pain. Hunger, the unfamiliar environment of the CTICU with its attendant noises and lighting, the inability or permissibility of parents holding their infant, and the uncertainty and anxiety transferred by parents to their children are all possible contributors. Additionally, delirium in the ICU setting in the adult population is well documented and is felt, in part, to arise from a disruption of the circadian rhythm by routine ICU operating procedures. Infants may be particularly susceptible to this phenomenon (18–20).

We loosely use the pediatric anesthesia emergence delirium scale as detailed by Sikich et al (21) at bedside in the CTICU when attempting to decide which patients will benefit from the escalation of pain medications. This scale awards points (from 1 to 4) based on the applicability of a series of statements; if the child makes eye contact with the caregiver, if the child's actions are purposeful, if the child is aware of their surroundings, and if the child is restless or inconsolable.

As a result of our analysis, we have embarked on an effort in our CTICU to provide non-pharmacologic interventions to decrease patient agitation. Appropriately selected patients may be placed in adult size beds to allow for parental presence (holding and comforting). In our experience, it has been possible to reduce agitation and avoid further escalation of opioid administration through this approach. There is a wide range of evidence to support the use of nonpharmacologic methods to provide complementary pain relief in children which may include cognitive-behavioral methods (22, 23). It is also important to assess the needs of patients on an individual basis. This may be based on various factors such as age, type of surgery, or preoperative status, with the intervention planned accordingly.

As our youngest patients cannot tell us why they are agitated, we, as creative, educated providers must seek better, perhaps more imaginative and holistic ways to treat the agitated infant. The "Kangaroo Care" model has been embraced in the neonatal ICU setting as a benefit in the care of the smallest patients. Perhaps a similar benefit may be realized for the population of patients included in our study. Realizing that not all patients are the same, nor are all parents appropriate candidates for this approach, careful selection will be needed in order to best utilize this method. Whether it is reducing the noise and light level in the wards at night or placing infants in larger beds to allow parental access, we must remain open to such changes. Pain and agitation often coexist and hence our management plan should be multimodal with the safe combination of medications and nonpharmacologic means such as cognitive-behavioral and emotional support and strategies to create a comfortable environment.

CONCLUSION

Our past experience reflected in a previous publication documented our success with the early tracheal extubation strategy, but as demonstrated herein, it also left room for further improvement. This most recent retrospective examination has not only demonstrated ongoing success of early tracheal extubation following surgery for congenital heart disease, but more importantly has identified that agitation and delirium may be important risk factors for failure of early tracheal extubation. This may provide an opportunity to further improve upon our care by modifying our postoperative approach to analgesia. By incorporating a more holistic parental presence in the CTICU, we might be able to further improve outcomes of early tracheal extubation, and, in the process, improve our patient care.

Using information from both this study and our prior publication, we continue our endeavor to improve our practice of early tracheal extubation. We have improved our success rate of early tracheal extubation in small infants, which is demonstrated to be safe and achievable for patients undergoing both CPB and non-CPB procedures. Additional characteristics predicting failed tracheal extubation were not identified, although the small number of failures limited analyses further differentiating patients who required reintubation. However, we believe that agitation or delirium is unique in this population of infants and may lead to failure of tracheal extubation during the first 24 hours. As data collection and review continue, more robust predictive indicators may become apparent. As a result of this review, which involved critically evaluating patients who failed early tracheal extubation, we are now reevaluating our approach to postoperative analgesia and sedation in the CTICU setting.

REFERENCES

1. Miller JW, Vu D, Chai PJ, et al: Patient and procedural characteristics for successful and failed immediate tracheal extubation in the operating room following cardiac surgery in infancy. *Paediatr Anaesth* 2014; 24:830–839
2. Alghamdi AA, Singh SK, Hamilton BC, et al: Early extubation after pediatric cardiac surgery: Systematic review, meta-analysis, and evidence-based recommendations. *J Card Surg* 2010; 25:586–595
3. DiNardo JA: Con: Extubation in the operating room following pediatric cardiac surgery. *J Cardiothorac Vasc Anesth* 2011; 25:877–879
4. Mittnacht AJ, Thanjan M, Srivastava S, et al: Extubation in the operating room after congenital heart surgery in children. *J Thorac Cardiovasc Surg* 2008; 136:88–93
5. Winch PD, Nicholson L, Isaacs J, et al: Predictors of successful early extubation following congenital cardiac surgery in neonates and infants. *Heart Lung Circ* 2009; 18:271–276
6. Naguib AN, Winch PD, Tobias JD, et al: A single-center strategy to minimize blood transfusion in neonates and children undergoing cardiac surgery. *Paediatr Anaesth* 2015; 25:477–486
7. Gaies M, Tabbutt S, Schwartz SM, et al: Clinical epidemiology of extubation failure in the pediatric cardiac ICU: A report from the pediatric cardiac critical care consortium. *Pediatr Crit Care Med* 2015; 16:837–845
8. Davis S, Worley S, Mee RB, et al: Factors associated with early extubation after cardiac surgery in young children. *Pediatr Crit Care Med* 2004; 5:63–68
9. Harrison AM, Cox AC, Davis S, et al: Failed extubation after cardiac surgery in young children: Prevalence, pathogenesis, and risk factors. *Pediatr Crit Care Med* 2002; 3:148–152
10. Ip P, Chiu CS, Cheung YF: Risk factors prolonging ventilation in young children after cardiac surgery: Impact of noninfectious pulmonary complications. *Pediatr Crit Care Med* 2002; 3: 269–274
11. Bandla HP, Hopkins RL, Beckerman RC, et al: Pulmonary risk factors compromising postoperative recovery after surgical repair for congenital heart disease. *Chest* 1999; 116:740–747
12. Miller OI, Tang SF, Keech A, et al: Inhaled nitric oxide and prevention of pulmonary hypertension after congenital heart surgery: A randomised double-blind study. *Lancet* 2000; 356:1464–1469
13. DiCarlo JV, Steven JM: Respiratory failure in congenital heart disease. *Pediatr Clin North Am* 1994; 41:525–542
14. Hansen TN, Gest AL: Oxygen toxicity and other ventilatory complications of treatment of infants with persistent pulmonary hypertension. *Clin Perinatol* 1984; 11:653–672
15. Vida VL, Leon-Wyss J, Rojas M, et al: Pulmonary artery hypertension: Is it really a contraindicating factor for early extubation in children after cardiac surgery? *Ann Thorac Surg* 2006; 81:1460–1465
16. Heinle JS, Diaz LK, Fox LS: Early extubation after cardiac operations in neonates and young infants. *J Thorac Cardiovasc Surg* 1997; 114:413–418
17. Meissner U, Scharf J, Dötsch J, et al: Very early extubation after open-heart surgery in children does not influence cardiac function. *Pediatr Cardiol* 2008; 29:317–320
18. Traube C, Silver G, Kearney J, et al: Cornell Assessment of Pediatric Delirium: A valid, rapid, observational tool for screening delirium in the PICU. *Crit Care Med* 2014; 42:656–663
19. Madden K, Turkel S, Jacobson J, et al: Recurrent delirium after surgery for congenital heart disease in an infant. *Pediatr Crit Care Med* 2011; 12:e413–e415
20. Silver GH, Kearney JA, Kutko MC, et al: Infant delirium in pediatric critical care settings. *Am J Psychiatry* 2010; 167:1172–1177
21. Sikich N, Lerman J: Development and psychometric evaluation of the pediatric anesthesia emergence delirium scale. *Anesthesiology* 2004; 100:1138–1145
22. Huth MM, Broome ME, Good M: Imagery reduces children's post-operative pain. *Pain* 2004; 110:439–448
23. Schaffer SD, Yucha CB: Relaxation & pain management: The relaxation response can play a role in managing chronic and acute pain. *Am J Nurs* 2004; 104:75–76, 78–79, 81–82