Title: Incidence and Risk Factors for Upper Airway Obstruction after Pediatric Cardiac Surgery

Short Title: Upper Airway Obstruction after Pediatric Cardiac Surgery

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Abstract

Objective: To determine the incidence of and risk factors for extrathoracic upper airway obstruction after pediatric cardiac surgery.

Study Design: A retrospective chart review was performed on 213 patients less than 18 years of age who recovered from cardiac surgery in our multidisciplinary intensive care unit in 2012. Clinically significant upper airway obstruction was defined before performing the chart review as post-extubation stridor with at least one of the following: greater than two corticosteroid doses, receiving helium-oxygen therapy, or re-intubation. Multivariate logistic regression analysis was performed to determine independent risk factors for this complication.

Results: Thirty-five patients (16%) with extrathoracic upper airway obstruction were identified. On bivariate analysis, patients with upper airway obstruction had greater surgical complexity, higher vasoactive medication requirements, and longer postoperative durations of endotracheal intubation. They were also more difficult to calm while on mechanical ventilation, as indicated by higher narcotic infusion doses and greater likelihood to receive dexmedetomidine or vecuronium. On multivariable analysis, adjunctive use of dexmedetomedine or vecuronium (odds ratio: 4.4, 95% confidence intervals: 1.8-10.5) remained independently associated with upper airway obstruction.

Conclusion: Extrathoracic upper airway obstruction is relatively common following pediatric cardiac surgery, especially in children who are difficult to calm while endotracheally intubated. Postoperative upper airway obstruction could represent an important outcome measure in future studies of optimal sedation practices in this patient population.

Introduction

The outcomes of patients requiring pediatric cardiac surgery have steadily improved over the past quarter century. Despite these improvements, postoperative management remains challenging in certain patients, especially in infants and children with complex cardiac defects or those who experience postoperative complications. Extrathoracic upper airway obstruction is one such complication for which patients undergoing cardiac surgery are particularly at risk, resulting from either pre-existing underlying anatomic abnormalities, operative injury to the recurrent laryngeal nerve, or alterations to the airway associated with postoperative endotracheal intubation.[1-5] Upper airway obstruction can lead to increased work of breathing, derangements in gas exchange, and increased transmural ventricular wall stress, all of which are poorly tolerated by a recovering myocardium. Upper airway obstruction has also been implicated as important contributor to extubation failure, which has been associated with increased morbidity and mortality in this patient population.[6-8] In the most severe cases, tracheostomy is required to facilitate long-term recovery.[9-11]

Current literature cites wide-ranging incidences of upper airway obstruction in the non-cardiac pediatric ICU population from 5-40%.[12-14] Despite the fact that it is also a well-recognized postoperative sequela in children undergoing cardiac surgery, data on characteristics of patients at risk for extrathoracic upper airway obstruction and the frequency with which it occurs within this patient population are limited. We therefore aimed to determine the incidence of extrathoracic upper airway obstruction after pediatric cardiac surgery at our institution and identify risk factors for its occurrence. Moreover, from our anecdotal observations, we hypothesized that agitated patients requiring considerable escalation of their analgesic and

sedative requirements would more commonly have post-extubation upper airway obstruction due to airway trauma from their endotracheal tube.

Methods

The Institutional Review Boards of the Detroit Medical Center and Wayne State University approved this retrospective study. Children's Hospital of Michigan is a 260-bed tertiary care hospital where two pediatric cardiovascular surgeons perform approximately 300-350 operations per year on patients with congenital heart lesions in all of the complexity levels. The cardiac surgical patients recover in our 26-bed PICU, where a multidisciplinary team provides care led by cardiovascular surgeons and pediatric intensive care physicians. We reviewed all patients less than 18 years recovering from pediatric cardiothoracic surgery that arrived to our intensive care unit at our institution endotracheally intubated on mechanical ventilation between January 1, 2012 and December 31, 2012. Patients with tracheostomy tubes in place prior to cardiac surgery, patients who underwent cardiac surgery and were admitted to the intensive care unit before January 1, 2012 but underwent their first extubation attempt from mechanical ventilation after this date, and patients who expired without any extubation attempt were excluded. For patients who required multiple procedures during the calendar year, only hospital admission following the first procedure was reviewed. We reviewed 213 unique patients who met inclusion criteria, representing a wide variety of congenital heart defects (Table 1). Of these patients, 54 (25%) were neonates at the time of surgery (<30 days old).

Operative and Postoperative Management

All children undergoing cardiac surgery on cardiopulmonary bypass received one dose of intravenous methylprednisolone 30 mg/kg prior to initiation of cardiopulmonary bypass. All patients were admitted to the intensive care unit following cardiac surgery endotracheally intubated and were placed on synchronized intermittent mandatory ventilation. Postoperative

management including titration of vasoactive medication to maintain hemodynamic stability, adjustments in intravenous fluid management to prevent electrolyte derangements, and administration of analgesia and sedation to treat postoperative pain and anxiety were at the discretion of the surgical and intensive care team. For postoperative pain, most patients initially received intravenous morphine, either 0.05-0.1 mg/kg/dose intermittently or 10-20 mcg/kg/hour via continuous infusion. In patients with considerable hemodynamic instability, intravenous fentanyl 1 mcg/kg/dose intermittently or 1-2 mcg/kg/hour as a continuous infusion was occasionally used as an alternative to morphine. If patients continued to be agitated despite initiation and escalation of the dose of their narcotic infusion or if they exhibited excessive movement deemed hazardous to their postoperative stability, they then received either dexmedetomidine administered as a 1 mg/kg/dose bolus followed by continuous infusion at 0.2-1 mcg/kg/hour, midazolam as a continuous infusion at 0.05-0.1 mg/kg/hour, intermittent neuromuscular blockade with vecuronium 0.1 mg/kg/dose, or a combination of these three regimens. Continuous infusions of neuromuscular blockade are not used at our institution.

Extubation from mechanical ventilator support was attempted based on extubation readiness guidelines that have been adopted as a standard of practice at our institution. Specifically, extubation was attempted when patients were breathing comfortably with good gas exchange and without metabolic acidosis on the following settings: respiratory rate ≤ 5 breaths per minute, pressure support ≤ 10 cmH2O, positive end-expiratory pressure ≤ 5 cmH2O, and fraction of inspired oxygen concentration ≤ 0.4. The decision as to whether or not to provide peri-extubation corticosteroids as well as the timing of which this therapy was initiated was at the discretion of the ICU team. For patients who were given peri-extubation corticosteroids, intravenous dexamethasone 0.5 mg/kg was administered every 6 hours, and the number of doses received prior to extubation was dependent on when the first dose was ordered. Upon

extubation, patients were placed on oxygen via nasal cannula, the flow of which was also at the discretion of the ICU team.

Data Collection and Definitions

Preoperative data collected included age, gender, weight, weight-for age z-score (calculated based on Center for Disease Control / National Center for Health Statistics Weight-for-Age Percentiles, www.cdc.gov/growthcharts/zscore.htm), body surface area, history of prematurity (defined as less than 37 weeks gestation), presence of genetic abnormalities, preoperative cardiac diagnosis, preoperative surgical procedure, and basic and comprehensive Aristotle scores.[15] The Aristotle score is a risk stratification tool used to stratify pediatric cardiac surgical procedures based upon complexity. Peri-operative data recorded included endotracheal tube size, number of intraoperative intubation attempts, duration of cardiopulmonary bypass, aortic cross clamp time, and deep hypothermic circulatory arrest time. Postoperative variables recorded included maximum positive end-expiratory pressure and positive inspiratory pressure provided via mechanical ventilation, inhaled nitric oxide use, number of doses of dexamethasone pre- and post-extubation from mechanical ventilation, duration of endotracheal intubation from the date of surgery to the first extubation attempt, presence of stridor post-extubation, use of helium-oxygen therapy or racemic epinephrine post-extubation, and need for re-intubation. Postoperative vasoactive inotrope requirements were quantitated by using the vasoactive-inotropic score (VIS) at 48 hours postoperatively, the postoperative time point at which the VIS has been shown to best correlate with postoperative outcomes.[16] This score is calculated according to the following formula: VIS = Dopamine (μg/kg/min) + dobutamine (μg/kg/min) + 100 X epinephrine (μg/kg/min) + 10 X milrinone (μg/kg/min) + 10,000 X vasopressin (U/kg/min) + 100 X norepinephrine (μg/kg/min). We also recorded maximum dose of narcotic infusion in morphine equivalents, dexmedetomidine infusion, and midazolam infusions if implemented. Fentanyl infusions were converted to morphine equivalents by

multiplying the fentanyl dose by 80.[17] We also recorded cumulative dose of vecuronium in patients in whom it was administered. Lastly, we recorded outcome variables including postoperative duration of mechanical ventilation, intensive care unit length of stay, and mortality.

Patients were defined, before performing the chart review, as having clinically significant extrathoracic upper airway obstruction if stridor was present *and* documentation of one or more of the following was noted in the medical record following their first extubation attempts: greater than two corticosteroid doses, need for helium-oxygen (heliox) therapy, or need for re-intubation. Patients without stridor who required re-intubation for other causes (e.g. cardiovascular insufficiency) were analyzed as part of the group of patients without clinically significant upper airway obstruction. Patients in whom stridor resolved easily with racemic epinephrine alone were also not considered to have clinically significant upper airway obstruction. Further, patients who received only 1-2 doses of post-extubation corticosteroids were receiving these doses as part of their 24-hour peri-extubation prophylaxis regimen typically employed at our institution, most often started at 12AM prior to extubation attempt planned for later that day - these patients were also not included as having clinically significant upper airway obstruction. Clinicians at our institution who employ dexamethasone to treat post-extubation upper airway obstruction provide in most cases at least 3-4 doses of post-extubation therapy.

Statistical Analysis

Data were represented as median (intraquartile range) or absolute count (percentage) unless otherwise noted. Bivariate analysis was performed by comparing variables in those patients with upper airway obstruction to those without using Mann-Whitney U or χ-square tests as appropriate. Variables with $P<0.1$ on bivariate analysis were considered for inclusion in the multivariable analysis. Multivariable logistic regression analysis was performed to determine independent risk factors for upper airway obstruction. Non-significant variables remained in the

model as potential confounders if odds ratios were appreciably altered (>5%) after backward elimination.

Results

Thirty-five patients (16%) developed clinically significant extrathoracic upper airway obstruction following extubation from mechanical ventilation. Twenty-two additional patients were noted to have stridor that resolved quickly with nebulized racemic epinephrine administration. None of these patients were noted to have extrathoracic upper airway obstruction prior to surgery. The use of post-extubation corticosteroids and helium-oxygen therapy to manage clinically significant postoperative upper airway obstruction, and the need for re-intubation secondary to upper airway obstruction are illustrated in Figure 1. Of note, use of peri-extubation corticosteroids in an effort to prevent post-extubation upper airway obstruction was not statistically different in patients who ultimately developed clinically significant upper airway obstruction and those who did not, 43% vs 53%, respectively, P=0.42.

Patient characteristics of those children with clinically significant upper airway obstruction following extubation from mechanical ventilation are further compared to those without upper airway obstruction in Table 2. Patients with clinically significant upper airway obstruction were significantly more complex (greater Aristotle scores), required greater hemodynamic support postoperatively (greater 48-hour VIS), and were intubated significantly longer prior to their first extubation attempt as compared to patients without upper airway obstruction. Patients with upper airway obstruction also received greater escalation of the dose of their narcotic infusion, and were significantly more likely to have received dexmedetomidine infusion or intermittent vecuronium. Six patients in the study were endotracheally intubated in the neonatal intensive care unit prior to surgery, four of which remained endotracheally intubated on the day of

surgery. None of these four patients developed clinically significant upper airway obstruction following extubation postoperatively.

We also found that significantly *smaller* endotracheal tubes were placed in patients with upper airway obstruction, 4 mm (range: 3-5.5) versus 4 mm (range: 3-7), *P*=0.008. This somewhat counterintuitive finding is likely explained by the trends observed toward smaller weight and body surface area in patients with upper airway obstruction. Indeed, weight and endotracheal tube size were highly correlated (Spearman rho = 0.8793, *P*<0.001). We therefore indexed endotracheal tube size to body surface area and found that there was a non-significant trend toward *greater* endotracheal tube size per m^2 in patients with upper airway obstruction, 12.5 mm/m^2 (range: 5.9-20.6) versus 11.8 mm/m^2 (range: 3.2-21.4), *P*=0.14.

The results of our multivariable analysis are provided in Table 3. Our multivariable model included weight, presence of genetic abnormalities, Basic Aristotle Score, 48-hour vasoactive inotrope score, use of either dexmedetomidine or vecuronium as a dichotomous variable, and duration of mechanical ventilation. Rather than include all variables related to postoperative analgesia, sedation, and neuromuscular blockade, in which there was frequent overlap, use of either dexmedetomidine or vecuronium (or both) as a dichotomous variable was chosen to more simply represent the need for a more aggressive pharmacologic means of quelling postoperative agitation or potentially harmful patient movement. We also included endotracheal tube indexed to BSA in the model in order to be confident that our results were not confounded by this important variable. Intraoperative deep hypothermic circulatory arrest, which approached statistical significance on bivariate analysis, had minimal effect on the model and was not included in the final analysis. In our model, only adjunctive use of dexmedetomidine or vecuronium while endotracheally intubated was independently associated with postoperative upper airway obstruction (odds ratio: 3.4, 95% confidence intervals: 1.4-8.0). In another model

that differed only from the previous model in that use of dexmedetomidine and use of vecuronium are in the model as two separate dichotomous variables, use of both of these agents remained independently associated with upper airway obstruction while the relationship between upper airway obstruction and the other six variables remained insignificant (data not shown).

In regards to outcomes, patients with clinically significant extrathoracic upper airway obstruction had significant longer median total ICU length of stay [8.1 days (intraquartile range: 5.1-14.5) versus 4.2 days (intraquartile range: 2.5-9.3), $P<0.001$] and ICU length of stay following the initial extubation attempt [6.3 days (intraquartile range: 3.6-13.8) versus 3.2 days (intraquartile range: 1.8-6.5), $P<0.001$]. Flexible bronchoscopy was performed in 13 of the 35 patients with upper airway obstructions, which provided the following diagnoses: vocal cord paralysis (n=5), subglottic stenosis (n=4), subglottic granulation tissue n=3), and airway mucositis (n=1). Upper airway obstruction resolved in the other 22 patients without the need for further diagnostic procedures. The etiology of the extrathoracic upper airway obstruction in the patients with vocal cord paralysis (i.e. damage to the recurrent laryngeal nerve) very likely differs from that of the other patients (e.g. airway trauma) in our study. Hence, we repeated the multivariable regression analysis with the five patients with vocal cord paralysis excluded. In this analysis, adjunctive use of dexmedetomidine or vecuronium while endotracheally intubated remained the only risk factor found to be independently associated with postoperative upper airway obstruction (odds ratio: 4.6, 95% confidence intervals. 1.8-11.8). Lastly, only one patient in the study ultimately required tracheostomy (related to unilateral vocal cord paralysis), and of all patients in the study, there were two mortalities, neither of which could be attributed to post-extubation upper airway obstruction.

Discussion

In 1977, Battersby and colleagues, in an early study looking at postoperative respiratory complications following pediatric cardiac surgery, reported the incidence of postoperative stridor to be 4.8% in their patient population.[1] Nearly forty years later, during which the field of pediatric cardiac surgery has undergone dramatic evolution, extrathoracic upper airway obstruction remains a well-recognized and potentially life-threatening postoperative complication. Most studies of upper airway obstruction in this patient population since this early report however have focused on the more severe cases that lead to extubation failure or tracheostomy. For example, upper airway obstruction leading to extubation failure has been implicated in 2-4% of patients in studies focused on children recovering from cardiac surgery.[6-8] Interestingly, one of these studies, 4 of 7 patients who failed extubation did so in the operating room secondary to extrathoracic upper airway obstruction,[8] indicating, as also demonstrated in our report, that patients need not be endotracheally intubated for prolonged periods of time to experience post-extubation stridor. In two studies of patients requiring tracheostomy following cardiac surgery, extrathoracic upper airway obstruction followed by tracheostomy placement occurred in 0.2% and 0.5% of patients.[9-10] Vocal cord paralysis or subglottic stenosis as the cause of upper airway obstruction leading to tracheostomy accounted for most of these cases. Thus, though these studies focused on the most severe sequelae of extrathoracic upper airway obstruction have provided important and useful information, they have likely underestimated the incidence of this postoperative complication in this patient population.

To our knowledge, our study is the first to date to focus exclusively on this postoperative extrathoracic upper airway obstruction in patients recovering from pediatric cardiac surgery, describe its incidence (16%), identify risk factors for its occurrence (marked agitation requiring escalation of pharmacologic analgesia, sedation, and neuromuscular blockade), and determine what percentage of the patients with UAO go on to develop extubation failure or tracheostomy (40% and 3%, respectively). Our study has several implications. Patients with postoperative

extrathoracic upper airway obstruction were found to have significantly longer intensive care unit stays than those patients without upper airway obstruction. We acknowledge that the contribution of upper airway obstruction to these prolonged stays is unclear, considering these patients also required more complex surgical procedures and greater postoperative hemodynamic support. Nevertheless, many of these patients received helium-oxygen therapy or were re-intubated, two interventions that undoubtedly increased the duration of intensive care management. Perhaps more importantly, we hypothesized based on anecdotal observations that patients with considerable agitation postoperatively would be more likely to develop extrathoracic upper airway obstruction, and our results support this hypothesis. Patients who received dexmedetomidine or vecuronium, which are used at our institution as second or third-line agents to manage postoperative sedation or quell potentially hazardous postoperative movements, had a four-fold greater adjusted odds of developing upper airway obstruction. This finding likely reflects the cautious approach to postoperative analgesia and sedation that is standard at our institution, with the goal of preventing over-sedation and sparing patients excessive exposure to narcotics and sedatives. This management style, while appropriate for many patients, can at times be associated with numerous periods of agitation and excessive movement as doses of narcotic infusions are carefully escalated and additional adjunctive agents are gradually implemented. Patients receiving dexmedetomidine or vecuronium likely experienced these types of episodes more often, and the airway trauma resulting from these episodes seemed to have contributed more to the development of post-extubation upper airway obstruction than any other variables included in the study. Intensive care unit regimens for narcotic and sedative administration vary widely across different institutions, and optimal practice is the subject of much debate among pediatric critical care physicians.[17-18] We speculate that centers with a more aggressive initial approach to postoperative analgesia and sedation, or have lower thresholds for neuromuscular blockade, may have lower incidences of post-extubation upper airway obstruction (but also, possibly, higher incidences of over-

sedation). We therefore suggest that postoperative extrathoracic upper airway obstruction has potential as an outcome variable in future studies of optimal sedation practices in pediatric patients undergoing cardiac surgery.

Incidentally, we found that prophylactic peri-extubation dexamethasone was not statistically different between children with and with clinically significant stridor in this study. We acknowledge that the use of peri-extubation corticosteroids was not protocolized and interpretation of this result is therefore difficult. We cannot discount the possibility that we would have found a higher rate of upper airway obstruction had this practice been less readily employed. In light of our current findings, the conflicting nature of the data on dexamethasone use to prevent re-intubation in neonates and children,[19] and more recent data linking peri-operative and postoperative corticosteroid use in pediatric cardiac surgical patients to postoperative infection,[20-21] further studies are needed before this practice can be readily promoted.

Several limitations to our data should be noted. First, the retrospective nature of the study required us to define clinically significant extrathoracic upper airway obstruction based on the presence of stridor *and* documentation of one or more of our institutional practices indicative of treatment of a clinically significant upper airway obstruction. We did however develop this definition before performing the chart review, with the aim of limiting the bias inherent to a retrospective review. Secondly, we reiterate that our findings are that of a single center and may therefore not be generalizable to other centers, especially those with differing sedation practices. At other centers, especially those with contrasting sedation practices, certain patient characteristics could prove to be important risk factors, such as weight and surgical complexity, which, in theory, could contribute to the development of upper airway obstruction. Lastly, we also acknowledge that there could be other variables not considered in this report that could

have confounded our results. Despite these limitations, our study provides useful data that describe upper airway obstruction as a relatively common and important cause of postoperative morbidity in children undergoing cardiac surgery, and its occurrence could potentially be tempered by limiting agitation while endotracheally intubated.

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Table 1. Primary Diagnoses and Surgeries Organized by Aristotle Complexity Level

Aristotle Complexity Level	Cardiac Lesion and Surgery	*N*
Level 1	Repair of atrial septal defect	9
Complexity Basic Score 1.5-5.9	Repair of partial atrioventricular septal defect	3
N=17 (8.0%)	Other	5
Level 2	Repair of Ventricular septal defect	23
Complexity Basic Score 6.0-7.9	Pulmonary artery-plasty	14
N=104 (48.8%**)**	Systemic-to-pulmonary shunt	9
	Aortic arch reconstruction	8
	Repair of subvalvar aortic stenosis	8
	Repair of right ventricular outflow tract obstruction	7
	Single ventricle – Hybrid procedure	6
	Tricuspid valvuloplasty	6
	Mitral valve replacement	6
	Repair of double chamber right ventricle	5
	Bidirectional cavopulmonary anastomosis	4
	Tetralogy of Fallot – non-transannular patch	4
	Other	10
Level 3	Repair of complete atrioventricular septal defect	11
Complexity Basic Score 8.0-9.9	Tetralogy of Fallot - transannular patch	9
N=62 (29.1%)	Fontan Completion	9
	Mitral valvuloplasty / replacement	6
	Repair of total anomalous pulmonary venous return	6
	Revision of right ventricle-pulmonary artery conduit	6
	Complex aortic arch repair	8
	Other	7
Level 4	D-transposition of great vessels - arterial switch	9
Complexity Basic Score 10-15	Singe ventricle – Norwood procedure	6
N=30 (14.1%)	Repair of ventricular septal defect/aortic coarctation	4
	Repair of truncus arteriosus	2
	Other	9

Table 2. Comparison of Patients With and Without Upper Airway Obstruction

Variable	UAO (*N* = 35)	No UAO (*N* = 178)	*P*-value
Age (months)	5 (0.7-14)	7.25 (1-55)	0.11
Female	16 (46%)	83 (46%)	0.92
Weight (kg)	5.6 (3.7-9.4)	6.5 (3.9-18)	0.07
Body surface area (m^2)	0.31 (0.22-0.43)	0.35 (0.23-0.73)	0.09
Weight Z-Score	−1.4 (−2.5,−0.3)	−1 (−2.1,+0.2)	0.09
Genetic syndrome	11 (31%)	31 (17%)	0.06
Basic Aristotle Score	9 (6.3-10)	7.5 (6-8)	0.006
Preoperative mechanical ventilation	1 (2.9%)	5 (2.8%)	0.66
Intraoperative intubation attempts	1 (1-1)	1 (1-1)	0.94
Cardiopulmonary bypass (minutes)	132 (70-201)	115 (64-172)	0.37
Aortic cross-clamp (minutes)	70 (15-114)	55 (21-97)	0.51
Deep hypothermic circulatory arrest	12 (34%)	37 (21%)	0.08
Max PEEP (cm H_2O)	5 (4-7)	5 (4-6)	0.38
Max PIP (cm H_2O)	24 (21-27)	24 (20-26)	0.64
Inhaled nitric oxide use	9 (26%)	27 (15%)	0.13
48-hour VIS	6 (0-10)	0 (0-7.5)	0.010
Duration of ventilation (hours)	42 (20-95)	23 (9-48)	0.012
Narcotic infusion use	24 (69%)	76 (43%)	0.005
Maximum narcotic rate (mcg/kg/hour) [a]	20 (0-30)	0 (0-20)	0.022
Dexmedetomidine infusion use	20 (57%)	46 (26%)	< 0.001
Maximum dexmedetomidine (mcg/kg/hour)	0.4 (0-0.6)	0 (0-0.2)	<0.001
Midazolam infusion use	5 (14%)	15 (8%)	0.28
Maximum midazolam (mg/kg/hour)	0 (0-0)	0 (0-0)	0.26
Vecuronium use	16 (45%)	26 (15%)	< 0.001
Cumulative vecuronium dose (mg/kg)	0 (0-1.5)	0 (0-0)	< 0.001

Continuous variables represented as median (intraquartile range), categorical data represented as absolute counts (%); *UAO*: upper airway obstruction; *PEEP*: positive end-expiratory pressure; *PIP*: peak inspiratory pressure; *VIS*: vasoactive inotrope score; Statistical significance *P* <0.05

[a] Morphine equivalents; for patients receiving fentanyl (N=17), fentanyl infusion rate was multiplied by 80

Table 3. Multivariable Logistic Regression Model for Upper Airway Obstruction

Factors	Odds Ratio	95% CI's	P-value
Weight	0.89	0.78-1.02	0.10
Genetic Abnormalities	1.46	0.60-3.60	0.41
Basic Aristotle Score	1.12	0.93-1.35	0.23
Endotracheal tube size / BSA	0.89	0.73-1.08	0.26
48-hour VIS	0.99	0.92-1.06	0.79
Duration of Mechanical Ventilation	1.002	0.997-1.007	0.46
Need for Dexmedetomidine or Vecuronium	3.38	1.43-7.96	0.005

VIS: vasoactive inotrope score; *BSA:* body surface area

Figure Legends

Figure 1. The number of patients who received greater than two doses of postoperative corticosteroids, helium oxygen therapy, or re-intubation to treat post-extubation extrathoracic upper airway obstruction. Fourteen patients (40%) with upper airway obstruction ultimately failed extubation and required re-intubation.