Prevalence and Risk Factors for Upper Airway Obstruction after Pediatric Cardiac Surgery

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

Study design A retrospective chart review was performed on 213 patients younger 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 as postextubation stridor with at least one of the following: receiving more than 2 corticosteroid doses, receiving helium-oxygen therapy, or reintubation. 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, greater vasoactive medication requirements, and longer postoperative durations of endotracheal intubation. They also were more difficult to calm while on mechanical ventilation, as indicated by greater infusion doses of narcotics and greater likelihood to receive dexmedetomidine or vecuronium. On multivariable analysis, adjunctive use of dexmedetomedine or vecuronium (OR 3.4, 95% CI 1.4-8) remained independently associated with upper-airway obstruction.

Conclusion Extrathoracic upper-airway obstruction is relatively common after pediatric cardiac surgery, especially in children who are difficult to calm during endotracheal intubation. Postoperative upper-airway obstruction could be an important outcome measure in future studies of sedation practices in this patient population. *(J Pediatr 2015;166:332-7)*.

The outcomes of patients requiring pediatric cardiac surgery have improved steadily during 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 also has 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 a wide-ranging prevalence of upper-airway obstruction in the noncardiac pediatric intensive care unit (ICU) population from 5% to 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 postextubation 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 at which 2 pediatric cardiovascular surgeons perform approximately 300-350 operations per year on patients with congenital

BSA	Body surface area
ICU	Intensive care unit
VIS	Vasoactive-inotropic score

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heart lesions in all of the complexity levels. The cardiac surgical patients recover in our 26-bed pediatric ICU, where a multidisciplinary team provides care led by cardiovascular surgeons and pediatric intensive care physicians. We reviewed all patients younger than 18 years of age recovering from pediatric cardiothoracic surgery that arrived to our ICU at our institution endotracheally intubated on mechanical ventilation between January 1, 2012, and December 31, 2012. Patients with tracheostomy tubes in place before cardiac surgery, patients who underwent cardiac surgery and were admitted to the ICU before January 1, 2012, but underwent their first extubation attempt from mechanical ventilation after this date, and patients who died without any extubation attempt were excluded. For patients who required multiple procedures during the calendar year, only hospital admission after the first procedure was reviewed. We reviewed 213 unique patients who met inclusion criteria, representing a wide variety of congenital heart defects (**Table I**). Of these patients, 54 (25%) were neonates at the time of surgery (<30 days old).

All children undergoing cardiac surgery on cardiopulmonary bypass received 1 dose of intravenous methylprednisolone 30 mg/kg before the initiation of cardiopulmonary bypass. All patients were admitted to the ICU after cardiac surgery with endotracheal intubation 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 μg/kg/hour via continuous infusion. In patients with considerable hemodynamic instability, intravenous fentanyl 1 μg/kg/dose intermittently or 1-2 μg/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 μg/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 3 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 cm H_2O, positive end-expiratory pressure ≤5 cm H_2O, and fraction of inspired oxygen concentration ≤0.4. The decision as to whether or not to provide periextubation 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 periextubation corticosteroids, intravenous dexamethasone 0.5 mg/kg was administered every 6 hours, and the number of doses received before 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.

Table I. 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	7
	Repair of right ventricular outflow tract obstruction	6
	Single ventricle – hybrid procedure	6
	Tricuspid valvuloplasty	6
	Mitral valve replacement	5
	Repair of double chamber right ventricle	4
	Bidirectional cavopulmonary anastomosis	4
	Tetralogy of Fallot – nontransannular patch	3
	Other	9
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

Preoperative data collected included age, sex, 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 (BSA), 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