Children with heart disease: Risk stratification for non-cardiac surgery☆,☆☆

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Abstract

Study objective: Children with congenital or acquired heart disease have an increased risk of anesthesia-related morbidity and mortality. The child’s anesthetic risk is related to the severity of their underlying cardiac disease, associated comorbidities, and surgical procedure. The goal of this project was to determine the ease of use of a preoperative risk stratification tool for assigning pediatric cardiac staff and to determine the relative frequency that children with low, moderate, and high risk cardiac disease present for non-cardiac surgery at a tertiary pediatric hospital.

Design: A risk-stratification tool was prospectively applied to children with congenital heart disease who presented for non-cardiac surgery.

Setting: Perioperative.

Patients: We identified a subset of 100 children with congenital heart disease out of 2200 children who required general anesthesia for surgical or radiological procedures over a 6 week period.

Interventions: A risk stratification tool was utilized to place the patient into low, moderate, or high risk categories to help predict anticipated anesthetic risk. Each grouping specified assignment of staff caring for the patient, clarified preoperative expectations for cardiac assessment, and determined if patient care could be performed at our freestanding ambulatory surgical center.

Measurements: Electronic perioperative records were reviewed to obtain demographic information, the underlying heart disease, prior cardiac surgery, associated conditions, anesthetic management, complications, and provider type.

Main results: Approximately 4.5% of children presented with cardiac disease over a 6 week period. In 100 consecutive children with cardiac disease, 23 of the children were classified as low risk, 66 patients were classified as moderate risk, and 11 of the patients were classified as high risk. Pediatric cardiac anesthesiologists provided care to all high risk patients. There were no serious adverse events.

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1. Introduction

Pediatric patients with congenital or acquired heart disease are at increased risk of anesthesia related cardiac arrest and death when having non-cardiac surgery [1,2]. The underlying cardiac lesion can vary from a repaired septal defect to those which cause complex alterations in normal anatomy and physiology such as a single ventricle. An understanding of the underlying lesion is the primary determinant in anesthetic planning and risk assessment for a majority of children, but a patient’s medical comorbidities and type of surgery can contribute to additional risks as well.

The complexity of managing these patients has led many centers to assign or request pediatric anesthesiologists with additional experience managing children with cardiac disease for patients who present for non-cardiac surgery. The increasing number of children who present with a history of cardiac disease and the limited number of pediatric cardiac anesthesiologists often makes scheduling procedures more difficult to accomplish. A risk stratification system that would categorize children with heart disease into different groups based on their anticipated anesthetic risk would allow a more efficient method to determine the need for additional resources and when a pediatric or pediatric cardiac anesthesiologist should manage their anesthetic care. Additional expectations of the preoperative assessment can also be defined based on anticipated risk including preoperative needs such as cardiology consultation or diagnostic testing, determining anesthetizing location, and postoperative discharge for each level of anticipated risk.

The purpose of this project was to describe a risk stratification method that was used to assign anesthetic care of high risk children to pediatric anesthesia faculty who provide pediatric cardiac anesthesia. A second goal of the study was to determine how often children with cardiac disease present at a tertiary care center and to determine the frequency that risk categories were observed. We also describe the anesthetic outcome of children who are assigned to these risk categories.

2. Methods

Two years prior to the study, a classification system was implemented to stratify children with congenital or acquired heart disease into low, moderate, and high risk categories based on their anticipated perioperative risk for cardiac complications. These risk classifications evolved from cardiac conditions described as leading to increased morbidity and mortality [1-8] as well as opinions gathered among pediatric cardiac anesthesiologists practicing at our hospital. Each individual’s classification occurred after a visit to our outpatient Pediatric Center for Preoperative Assessment and Planning. During this visit, a full anesthetic assessment was completed with questions asked to all pediatric patients such as anesthetic history and recent respiratory infections as well as questions specific to the patient’s cardiac history including growth, baseline oxygen saturations, and functional status.

The initial step in risk assessment is to define the underlying cardiac disease. Simple lesions would fall into the lowest risk category whereas children with more complex lesions, residual defects, or unrepaired lesions are in a higher risk group (Table 1).

This initial placement can then be changed to a higher risk category based on comorbidities, surgical procedure, or age. If any of these additional considerations are present, the patient’s risk would increase to the next higher category. A low risk patient would become moderate risk. A moderate risk patient would become high risk (Fig. 1).

Infants less than one year of age are considered at increased risk and their risk class increases. Medical comorbidities that would classify the patient as American Society of Anesthesiologists physical status (ASA PS) 3 or higher would increase the patient’s risk as well. Specified disease processes include children with acute or chronic renal disease, insulin dependent diabetes, and developmental delay to less than half age appropriate normal. We define high risk surgeries as those that can cause hemodynamic instability, large fluid shifts, or high anticipated blood loss. This would include vascular, open abdominal, thoracic, intraparenchymal neurosurgery, or spinal fusion [1,2,9].

2.1. Low risk cardiac patients

This category of patients comprises those deemed to be at low to no increased risk for perioperative cardiac complications such as a repaired atrial or ventricular septal defect. These patients have often been discharged from cardiology care or are expected to have infrequent follow-up visits. Children in this category were considered appropriate for our pediatric outpatient ambulatory surgical center and any pediatric anesthesiologist in our group is expected to be able to provide care for non-cardiac surgery.

2.2. Moderate risk cardiac patients

The moderate risk category was children who did not belong to the low risk category and did not meet the criteria described below to be considered in a high risk cardiac group. Many of these children are maintained on cardiac medications or had repairs of cyanotic or complex congenital heart disease.

Conclusions: We found this risk stratification method an effective method to differentiate children into low, moderate, and high risk categories for anesthesia planning and management.

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These children were expected to have had a cardiology evaluation within the last 12 month period to determine whether any additional testing to evaluate the cardiac disease would be required prior to their non-cardiac surgery. Children with pulmonary hypertension were categorized into the moderate or high risk category. The severity of pulmonary hypertension, course and progression of the disease, pulmonary vascular reactivity, comorbid conditions, and the type of anesthetic and surgery being planned all combine to predict the anesthetic risk of the individual patient. Due to the large variability in the diagnosis of pulmonary hypertension, additional criteria were created to help categorize the patient into either the moderate or high risk group. High risk predictors include New York Heart Association/World Health Organization functional class III or IV, severely elevated pulmonary arterial pressures (equal or suprasystemic), cardiac index $<2.2$ L/min per square meter, intraventricular septal diastolic flattening, severe right atrial enlargement and pressure $>12$ mmHg, or brain natriuretic peptide (BNP) $>330$ pg/mL [7].

As expected the majority of children fit into the moderate risk group while only a small proportion are deemed as high risk.

### 2.3. High risk cardiac patients

This category includes children with unrepaired complex cardiac anomalies, children with Williams syndrome, high risk pulmonary hypertension, valvular heart disease with significant valvular gradients, hypertrophic obstructive cardiomyopathy, congestive heart failure, or ventricular assist devices.

An elevated level of perioperative planning occurs with these patients. Preoperative optimization is discussed including the need for hydration or initiation of inotropes as well as optimal timing of elective procedures. Postoperative disposition is decided which may include arranging for a bed in the intensive care unit. These considerations and arrangements are communicated with the patient’s cardiologist and surgeon to solidify the perioperative plan.

This risk stratification system was implemented at our hospital. After approval was obtained through Washington University’s institutional review board, we identified 100 sequential patients with cardiac disease who required a general anesthetic for non-cardiac surgery or procedure through our electronic anesthesia database. Each patient chart was reviewed to verify presence of heart disease, correct risk stratification placement, and type of provider caring for patient. Complications were obtained by searching both the anesthetic record and our quality improvement database. Specific complications queried included provider documented cardiovascular complications (arrhythmias, unresponsive desaturation), airway complications (laryngospasm, reintubation), and postoperative complications (emergence delirium, severe nausea and vomiting).

### 3. Results

When we applied our classification system to 100 consecutive children who had a history of cardiac disease based on their preoperative anesthesia assessment, we found that the anesthetics were completed in a timeframe of approximately 6 weeks at our medical center. During that same time period, a total of approximately 2200 children had anesthesia for non-cardiac procedures. This equates to approximately 4.5% of children in this cohort having a history of cardiac disease.

| Table 1 | Examples of specific cardiac lesions with associated risk |
| --- | --- | --- |
| **Low risk** | **Moderate risk** | **High risk** |
| Conduction Abnormalities | Wolff Parkinson White | Unrepaired complex cardiac lesions |
| Structural lesions | Simple unrepaird lesions such as ventricular or atrial septal defect | Systemic arterial to pulmonary arterial shunts |
| | Complex cardiac defects with full repair | -Severe valvular disease |
| | Single ventricle with Glenn or Fontan palliation | Pulmonary arterial pressures equal or higher than systemic pressures |
| Pulmonary hypertension | New York Heart Association functional class I | -Decreased cardiac index |
| | Normal cardiac index | -Severe heart failure |
| Miscellaneous | Heart or lung transplant | -Ventricular assist devices |
| | | -Williams syndrome |
| | | -Hypertrophic obstructive cardiomyopathy |
Twenty three of the children were classified as low risk, 66 patients were classified as moderate risk, and 11 of the patients were classified as high risk. Of the 26 pediatric anesthesiologists in our practice, 9 anesthesiologists care for children in our cardiac catheterization suites and cardiothoracic operating rooms. All eleven children that were identified as high risk were cared for by one of these 9 individuals (Table 2). Since these individuals also work in the general operating rooms, several of the low and medium risk patients were cared for by a pediatric cardiac anesthesiologist (Fig. 2).

In the low and moderate risk cohort, anesthetic complications were noted for seven of the 89 (8%) children. These included postoperative stridor (n = 1), severe postoperative nausea and vomiting (n = 1), emergence delirium (n = 2), laryngospasm (n = 1), and intraoperative reintubation due to endotracheal tube mucus plugging (n = 1). One child had a brief period of ST wave changes that resolved without treatment. The anesthetics were performed by pediatric anesthesiologists in 4 of these cases including the case of laryngospasm, both emergence deliriums, and reintubation. Pediatric cardiac anesthesiologists had been assigned to the other 3 cases including the one with ST wave changes, stridor, and postoperative nausea and vomiting. One child in the high risk group developed (9%) mucous plugging of the endotracheal tube requiring suctioning.

4. Discussion

We found that by using our guidelines, we were able to readily classify 100 consecutive children with a history of cardiac disease into different risk stratification groupings. Prior
studies describe certain characteristics and surgical procedures such as children under age 3 (especially infants), ASA PS of 3 or greater, and emergency surgery as associated with increased major and minor complications in all children [1,9-11]. Pediatric patients with both congenital and acquired heart disease are often included in this highest risk tier and may require additional consideration of the pathophysiology of their underlying cardiovascular disease.

With ever increasing subspecialization, the question of who best to care for a specific patient is frequently asked. In pediatric anesthesia, further training and subspecialization in certain clinical areas such as pediatric cardiac as well as pediatric pain and regional is increasingly common. This differentiation between training levels has been solidified with the creation of board certification in pediatric anesthesiology. In many pediatric anesthesia practices, only a subset of faculty rather than all provide care in the cardiothoracic operating rooms and cardiac catheterization suites. White et al has previously described an approach for when a pediatric patient with cardiac disease could be managed at a local hospital or when their care should be transferred to tertiary center [8]. Once at the tertiary center, there are currently no guidelines to determine when anesthesiologists with additional training in pediatric cardiac anesthesia should be selected to provide care to the pediatric patient with congenital heart disease presenting for non-cardiac surgery.

We found this stratification system was a useful and practical method to prospectively assign anesthesia care for non-cardiac surgery.

We used a multi-disciplinary approach to determine the anesthetic risk assessment by involving our surgical and cardiology colleagues, but we applied these criteria based on our division’s assignment scheduling methodology. Developing a system to facilitate this decision making allows these decisions to be made internally and not just in response to external requests or demands. The prospective method to differentiate the risk and match to anesthesiologists with specialized cardiac training was useful to assign these children with increased anesthesia risk.

In our cohort, the perioperative complications noted were similar between both risk groups and were comprised of complications that can commonly occur in any pediatric patient without being directly attributable to a specific cardiac condition. The low rate of cardiac complications could be due to the overall low incidence of these complications even in those with high risk cardiac disease or it is possible that the small number of cardiac complications seen even in the high risk group is attributable to the anesthetic management individualized to a patient’s cardiac condition tailored by the pediatric cardiac anesthesiologist. The small number of patients makes it impossible though to discern any true conclusions.

### Table 2 Description of high risk cardiac patients

<table>
<thead>
<tr>
<th>Patient</th>
<th>Diagnosis</th>
<th>Comorbidities</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 month old: laryngoscopy/bronchoscopy</td>
<td>Pulmonary hypertension (pulmonary vascular resistance index of 3.9 Woods units x m²)</td>
<td>History of difficult airway, severe obstructive sleep apnea, failure to thrive (6.3 kg), low cardiac index</td>
</tr>
<tr>
<td>8 month old: bilateral meatal tubes, auditory brainstem response, central line placement</td>
<td>Hypoplastic right heart s/p Mee central shunt</td>
<td>Ventilator dependence</td>
</tr>
<tr>
<td>5 month old: echocardiogram</td>
<td>Unrepaired AV canal</td>
<td>Downs syndrome, prematurity, congestive heart failure</td>
</tr>
<tr>
<td>4 month old: cardiac MRI</td>
<td>Double outlet right ventricle s/p Blalock-Taussig shunt</td>
<td>Sepsis, ventilator dependence</td>
</tr>
<tr>
<td>6 month old: central line placement</td>
<td>Hypoplastic left heart with interrupted aortic arch s/p heart transplant</td>
<td>Multiple chromosomal translocations and deletions, multiple limb abnormalities</td>
</tr>
<tr>
<td>2 year old: external fixation of right radius</td>
<td>Hypoplastic right heart with transposition of great vessels s/p bidirectional cavopulmonary anastomosis</td>
<td>Ventilator dependence</td>
</tr>
<tr>
<td>7 month old: brain MRI</td>
<td>Hypoplastic right heart s/p Mee central shunt</td>
<td>Downs syndrome, development delay</td>
</tr>
<tr>
<td>18 year old: cardiac MRI, echocardiogram</td>
<td>Tetralogy of Fallot s/p repair with pulmonary artery stenosis and equal right and left ventricular pressures</td>
<td></td>
</tr>
<tr>
<td>10 year old: cardiac MRI</td>
<td>Hypertrophic cardiomyopathy</td>
<td></td>
</tr>
<tr>
<td>4 day old: central line placement</td>
<td>Unrepaired Tetralogy of Fallot</td>
<td></td>
</tr>
<tr>
<td>14 year old: cardiac MRI</td>
<td>Myocarditis with severe biventricular heart failure</td>
<td>Obstructive sleep apnea</td>
</tr>
</tbody>
</table>

![Fig. 2](image-url) Distribution of patients by provider.
Our approach has limitations. The method used to capture all children with a cardiac history could have missed some children due to a poorly defined medical or cardiac history. The small number of children included in the study combined with the low frequency of major complications in anesthesia does not provide an incidence of morbidity and mortality. We reviewed charts in a retrospective manner to determine whether this methodology was a practical method to use prospectively. Additional studies are required to determine how this approach would be applied in a larger prospective manner.

In summary, as more and more patients with congenital heart disease are surviving, there will be more and more patients presenting to operating rooms and procedural suites in need of general anesthesia. Pediatric anesthesiologists have training and knowledge in all aspects of pediatric anesthesiology including congenital heart disease and its implications. Though pediatric cardiac anesthesiologists have specialized training in this patient population, that additional training is often unnecessary in patients with low to moderate risk of having perioperative cardiac complications. This training does become more appreciated in patients with a high risk of perioperative cardiac complications; not only in preventing cardiac complications but also having the ability to respond to these complications should they occur. Developing a set of guidelines helps to not only appropriately identify and staff high risk patients, but also to prevent the overuse of this resource. This set of guidelines was developed to help guide staffing decisions for patients with acquired or congenital cardiac disease presenting for non-cardiac surgeries and procedures and allows for selective assignment of pediatric cardiac faculty to anesthetics in which there is a high risk of cardiac complications.

References