Anesthesia and the Sick Heart

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Capitol Anesthesiology Association
Dell Children’s Medical Center
Talk Overview

- The “safety” of anesthesia
- Preoperative evaluation and risk stratification
- Induction of anesthesia: how to safely put a sick heart to sleep
- Putting it all together
Anesthesia-Related Cardiac Arrest

Table 1 Summary table of studies of anesthesia-related cardiac arrest:

<table>
<thead>
<tr>
<th>Author</th>
<th>Country</th>
<th>Year</th>
<th>Definition of anesthesia-related arrest</th>
<th>Age (years)</th>
<th>Cardiac arrests/10,000 anesthetics</th>
<th>Mortality/10,000 anesthetics</th>
<th>Common etiologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beecher</td>
<td>US</td>
<td>1984</td>
<td>Directly responsible/important contributor</td>
<td>&lt;11</td>
<td>14</td>
<td></td>
<td>Anoxia aspiration</td>
</tr>
<tr>
<td>Rachow</td>
<td>US</td>
<td>1981</td>
<td>Same as Beecher</td>
<td>All</td>
<td>3.7</td>
<td></td>
<td>Anesthetic overdose</td>
</tr>
<tr>
<td>Keenan</td>
<td>US</td>
<td>1985</td>
<td>Due solely</td>
<td>&lt;12</td>
<td>4.7</td>
<td>1.5</td>
<td>Failure to ventilate</td>
</tr>
<tr>
<td>Olsson</td>
<td>Sweden</td>
<td>1988</td>
<td>Cannot be excluded as cause</td>
<td>1-2</td>
<td>1.4</td>
<td></td>
<td>Halothane overdose</td>
</tr>
<tr>
<td>Tinti</td>
<td>France</td>
<td>1988</td>
<td>Totally or partially</td>
<td>1-14</td>
<td>4.6</td>
<td>2.3 (all ages)</td>
<td>Hypoventilation</td>
</tr>
<tr>
<td>Cohen</td>
<td>Canada</td>
<td>1990</td>
<td>Not defined</td>
<td>&lt;1 month</td>
<td>28</td>
<td>0.3</td>
<td>Airway obstruction</td>
</tr>
<tr>
<td>Murray</td>
<td>US</td>
<td>2000</td>
<td>Contributed in any way</td>
<td>0-18</td>
<td>1.4</td>
<td>0.36</td>
<td>Laryngo-spasm</td>
</tr>
<tr>
<td>Braz</td>
<td>Brazil</td>
<td>2006</td>
<td>Totally or partially</td>
<td>&lt;1 month</td>
<td>12</td>
<td>0.21</td>
<td>Unable to intubate</td>
</tr>
<tr>
<td>Flick</td>
<td>US</td>
<td>2007</td>
<td>Attributed</td>
<td>0-18</td>
<td>0.65</td>
<td></td>
<td>Failure to intubate</td>
</tr>
</tbody>
</table>

How Safe is Pediatric Anesthesia?

- Incidence of cardiac arrest: **1.4-4.6:10,000** (3-6X higher in children <1 year old, increased risk for ASA physical status > III)

- Overall incidence of anesthesia-related death **1:10,000-1:40,000**

Odegard KC et al. The Frequency of Anesthesia-Related Cardiac Arrests in Patients with Congenital Heart Disease Undergoing Cardiac Surgery. *Anesthesia & Analgesia* 2007; 105: 335-343.
American Society of Anesthesiologists
Physical Status

ASA physical status

1. Normal healthy patient
2. Mild systemic disease
3. Severe systemic disease
4. Severe systemic disease that is constant threat to life
5. Moribund - not expected to survive the operation
6. Brain dead for organ donation
ASA Status and Complications

Table 2: Relation between American Society of Anesthesiologists (ASA) physical status and the rate of complication

<table>
<thead>
<tr>
<th>ASA physical status</th>
<th>Rate of serious complications per 10,000 anesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>34</td>
</tr>
<tr>
<td>3</td>
<td>116</td>
</tr>
<tr>
<td>4-5</td>
<td>154</td>
</tr>
</tbody>
</table>

*P < 0.001

Children with cardiomyopathy: complications after noncardiac procedures with general anesthesia

ALAINA K. KIPPS MD*, CHANDRA RAMAMOORTHY MB†, DAVID N. ROSENTHAL MD† AND GLYN D. WILLIAMS MB†

*Pediatric Cardiology, Children's Hospital Boston, Boston, MA, †Department of Anesthesia, Stanford University School of Medicine, Stanford, CA, and ‡Department of Pediatrics, Division of Cardiology, Stanford CA, USA

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Pediatric Anesthesia

Cardiac arrest upon induction of anesthesia in children with cardiomyopathy: an analysis of incidence and risk factors

Johanne Lynch¹, Carolyne Pehora², Helen Holtby²,³,⁴,⁵, Steven M. Schwarz³,⁴,⁵ & Katherine Taylor²,³,⁵
Retrospective chart review

129 patients with cardiomyopathy undergoing 236 anesthetics

4 cardiac arrests (in 2 patients)
Take-Home Points

- Fractional shortening \( \leq 16\% \) in both patients
- Many different combinations of induction drugs with no ideal choice
- All successfully resuscitated
26 patients undergoing 34 general anesthetics

- Non-cardiac surgical

- 18 complications in 12 patients (38% complication rate for 34 anesthetics)

- Stratified into 3 groups based on preoperative shortening fraction
Echocardiographic Function

Dilated Cardiomyopathy

<table>
<thead>
<tr>
<th>Function</th>
<th>Shortening Fraction</th>
<th>Ejection Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>&gt; 28%</td>
<td>&gt;55-63%</td>
</tr>
<tr>
<td>Mild</td>
<td>23-28%</td>
<td>&gt;45%</td>
</tr>
<tr>
<td>Moderate</td>
<td>16-22%</td>
<td>20-45%</td>
</tr>
<tr>
<td>Severe</td>
<td>&lt;16%</td>
<td>&lt;20%</td>
</tr>
</tbody>
</table>
### Periprocedural Complications

<table>
<thead>
<tr>
<th></th>
<th>Mild (4)</th>
<th>Moderate (9)</th>
<th>Severe (21)</th>
<th>Total all patients</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Systemic ventricle dysfunction</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypotension</td>
<td>3</td>
<td>8</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Arrhythmia</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Pneumonia</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Respiratory arrest</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Neurologic deficit</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>PRBC transfusion</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Wound infection</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>ECMO</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Death</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>Any complication</strong></td>
<td>3</td>
<td>15</td>
<td>18</td>
<td></td>
</tr>
</tbody>
</table>
Take-Home Points

n 15 (83%) occurred in patients with severe ventricular dysfunction

n Patients with shortening fraction < 16% are at the highest risk for perioperative morbidity and mortality

n 14 of 21 patients (67%) with severe ventricular dysfunction observed in ICU postoperatively

n Importance of a multispecialty team approach to caring for these patients
Incidence of cardiac arrest after induction: 170:10,000 (40-120 times more likely than with healthy patients)

Patients with severe ventricular dysfunction at the highest risk


Types of Cardiomyopathies

- Dilated (60%)  
- Hypertrophic (30%)  
- Restrictive (3%)  
- Left Ventricular Noncompaction (rare)
Anesthetic Goals for Hypertrophic Cardiomyopathy

- Dynamic left ventricular outflow tract obstruction
- Maintain or increase afterload
- Ensure adequate volume loading
- Decrease heart rate
- Decrease contractility
Plan of Attack

- Beta blockade perioperatively often
- Establish good venous access
- Preinduction fluid bolus (10ml/kg)
- Avoid decreases in afterload: Etomidate or Ketamine

Anesthetic Goals for Dilated Cardiomyopathy

- Avoid increases in SVR
- Maintain or augment contractility
- Appropriate volume load
- Plan for invasive monitors
- For most severe cases, consider ECMO backup
Plan of Attack

- Continuation of preoperative inotropes
- Adequate premedication to facilitate placement of good intravenous access +/- arterial monitoring
- Gentle induction
- Ensure adequate anesthesia depth prior to laryngoscopy to avoid sudden increases in SVR
Preinduction Questions?

- Does the child have intravenous access or can it easily be obtained?
- Does the patient need preoperative anxiolysis?
- Intravenous or mask induction?
Premedication =

- Mode of delivery: intravenous, oral, nasal, intramuscular
- Most commonly: midazolam 0.5-1 mg/kg po or 0.05-0.1 mg/kg iv
- Relieves anxiety and provides amnesia
The Art of Induction

- The ideal induction agent
  - Preserve hemodynamic stability
  - Minimal depression of contractility
  - Maintain relationship between pulmonary and systemic vascular resistances

# Anesthesia Induction Drugs

<table>
<thead>
<tr>
<th></th>
<th>HR</th>
<th>CO</th>
<th>Contractility</th>
<th>SVR</th>
<th>PVR/SVR</th>
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<tbody>
<tr>
<td>Sevoflurane</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>↓</td>
<td>—</td>
</tr>
<tr>
<td>Propofol</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Ketamine</td>
<td>—</td>
<td>↑</td>
<td>↑</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Etomidate</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Fentanyl-Midazolam</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>↑</td>
<td>—</td>
</tr>
</tbody>
</table>
Sevoflurane

- Sweet smelling anesthetic gas
- Predominant hemodynamic effect is decrease in SVR, leading to decreased arterial pressure
- PVR:SVR maintained
- Single ventricle with \textit{stable ventricular function} no decrease in myocardial performance index

Propofol

- "Milk of amnesia"
- Decreases preload (dilates venous capacitance vessels) and afterload (15% decrease in SVR) leading to hypotension (30% decrease in ABP)
- Dose- and rate-dependent decrease in cardiac index, especially with preexisting cardiac dysfunction
- Decreases Qp:Qs

Williams GD. The Hemodynamic Effects of Propofol in Children with Congenital Heart Disease. Anesthesia & Analgesia 1999;89:1411-1416.
Hemodynamic effects of propofol in 30 children

3 groups: No shunt, L→R and R→L

Decreased Qp:Qs lead to statistically significant arterial desaturation in patients with cyanotic heart disease (Qp:Qs < 1)

In 2 patients oxygen saturations decreased >10%
Avoid Propofol In...

- Situations where decreased afterload is BAD (severe aortic stenosis and hypertrophic cardiomyopathy)

- Cyanotic patients where systemic and pulmonary vascular resistances need to be balanced (HLHS after Norwood or TOF)

- Any significant cardiomyopathy
Ketamine: The Good

- Noncompetitive NMDA receptor antagonist
- "Dissociates" cortex from the limbic system
- "Cocaine-like" effect: Increases circulating NE and reduces neuronal reuptake → maintenance of SVR
- Analgesic, bronchodilator, maintains HR

Ketamine: The Bad

- Increased secretions/salivation, bad dreams, emergence agitation
- Negative inotropic effects in human heart muscle
- Chronic illness, prolonged hyperdynamic state or patients on drugs like dopamine (depletes catecholamine stores) can lead to worsened cardiac performance

Ketamine: The Ugly

Amy Winehouse Overdoses on Ketamine and much more...
Etomidate

- GABA<sub>A</sub> receptor agonist
- Excellent hemodynamic stability, even in the failing heart
- No good studies in children with severe ventricular dysfunction

12 children with SVT or ASD for cardiac catheterization

0.3 mg/kg bolus etomidate

No significant changes in hemodynamics

Further studies needed in children with cardiomyopathies
Etomidate Pros

- Improved myocardial oxygen supply/demand ratio
- Lack of histamine release
- Absence of malignant hyperthermia
- Lack of effect on hepatic and renal function
- Lack of dissociative hallucinogenic side effects

Etomidate Cons

- **Dose-dependent adrenocortical suppression**
- Pain on injection (acidic pH)
- Myoclonus
- Tremors and seizures
- Anaphylactoid reaction
- Possible platelet inhibition

Fentanyl-Midazolam

- Analgesia and amnesia
- Hemodynamically stable
- Decreased HR, despite preserved contractility leads to decreased cardiac index
- Decreased sympathetic tone
- Combination use increases risk of circulatory depression
Eight-year-old boy with dilated cardiomyopathy (DCM), skeletal myopathy and hepatic fibrosis secondary to juvenile polysaccharidosis presents for percutaneous placement of a gastrostomy tube for nutritional support.

What are the risks and how do you proceed?

On children with end-stage cardiomyopathies...

“The only procedure for which they should have an anesthetic is cardiectomy for transplantation.”
Preoperative Evaluation

- Echo: DCM, shortening fraction of 15%
- ECG: SR, First degree AV block, left bundle branch block, lateral ST-T segment abnormalities
- History of ventricular tachycardia
- On 10-day course dobutamine to optimize ventricular function
Facing the Charging Bull
Case Induction

- Dobutamine infusing at 7.5 mcg/kg/min
- Midazolam (0.1 mg/kg), Ketamine (1.5 mg/kg), Vecuronium (0.15 mg/kg) and Fentanyl (5 mcg/kg)
- Hypotension, loss of pulse, CPR with return of perfusion and eventual extubation in PICU later that night
Putting It All Together

- Eight-year-old boy returns to operating room for PEG
- What might have gone wrong last time and what do you do now?
“You said we learn from our mistakes, so I must be learning a lot.”
Learning from our mistakes...

- Primary myocardial depression from ketamine?
- Decreased HR from combination of opioid and vecuronium leading to decreased cardiac output
- Sympatholysis from opioid/benzodiazepine combination leading to decreased LV filling
- Decreased beta receptor density and sensitivity from chronic stimulation (dobutamine infusion)

Take Two

- Dobutamine infusion increased prior to induction
- Etomidate (0.3 mg/kg), midazolam (0.05 mg/kg), rocuronium (0.6 mg/kg)
- No change in blood pressure or heart rate
- Anesthesia maintained with isoflurane 0.25% and fentanyl (total dose 8 mcg/kg)
- Extubated and transferred to PICU in stable condition
Take Home Points

- Adequate preparation and risk stratification can help minimize anesthetic risk and facilitate a smoother perioperative course.

- Taking care of children with cardiomyopathies requires a coordinated approach with multiple pediatric specialists.
Thank you!