Pediatric Cardiomyopathy: Understanding the Pathophysiology and Anesthetic Implications

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Disclosure

I have no financial relationships with industry to disclose.
Learning Objectives

• Review the classification of cardiomyopathy (CM)

• Discuss pathophysiology of CM subtypes

• Review perioperative clinical management

• Review anesthetic management of CM in children
Cardiomyopathy

• Disease of the myocardium

• Associated with cardiac dysfunction

• Classified by dominant phenotype patterns

Williams GD and Hammer GB. Curr Opin Anesthesiol 2011; 24:289-300
Epidemiology

• Pediatric Cardiomyopathy Registry (USA)

  – Primary pediatric CM incidence 1.13 cases per 100,000 children (≤ 18 y.o.)

  – Much higher incidence in infants < 1 y.o. at 8.34 cases per 100,000

# Epidemiology

## Diagnosis of Heart Transplant Recipients

<table>
<thead>
<tr>
<th>Etiology</th>
<th>Age &lt; 1 year (%)</th>
<th>Age 1-10 years (%)</th>
<th>Age 11-17 years (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiomyopathy</td>
<td>31</td>
<td>55</td>
<td>24</td>
</tr>
<tr>
<td>Congenital Heart Dz</td>
<td>63</td>
<td>36</td>
<td>64</td>
</tr>
<tr>
<td>Re-transplantation</td>
<td>1</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Other</td>
<td>5</td>
<td>3</td>
<td>4</td>
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</tbody>
</table>

WHO Cardiomyopathy Classification

- Cardiomyopathy
  - Dilated CM
  - Arrhythmogenic Right Ventricle CM
  - Hypertrophic CM
  - Restrictive CM
  - Unclassified
    - Inflammatory
    - Infectious
    - Idiopathic

WHO Cardiomyopathy Classification

Cardiomyopathy

- Dilated CM
- Arrhythmogenic Right Ventricle CM
- Hypertrophic CM
- Restrictive CM
- LVNC CM
- Inflammatory
- Infectious
- Idiopathic
Subtypes of Pediatric Cardiomyopathy

- Dilated CM: 60%
- Hypertrophic CM: 25%
- Ventricular Non-Compaction: 9%
- Restrictive CM: 4%
- Arrhythmogenic RV dysplasia/unknown: 2%

# Pediatric Cardiomyopathies

<table>
<thead>
<tr>
<th>Primary CM</th>
<th>Acquired CM</th>
<th>Multisystem disease with CM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypertrophic CM</td>
<td>Acute myocarditis (DCM)</td>
<td>Becker muscular dystrophy (DCM)</td>
</tr>
<tr>
<td>Dilated CM</td>
<td>Tachycardia-induced (DCM)</td>
<td>Duchenne muscular dystrophy (DCM)</td>
</tr>
<tr>
<td>Restrictive CM</td>
<td>Pacing-induced (DCM)</td>
<td>Barth syndrome (DCM)</td>
</tr>
<tr>
<td>Left ventricular noncompaction CM</td>
<td>Antineoplastic drugs (DCM)</td>
<td>Emery Dreifuss muscular dystrophy (DCM)</td>
</tr>
<tr>
<td>Arrhythmogenic right ventricular CM</td>
<td>Nutritional CM (DCM)</td>
<td>Limb girdle muscular dystrophy (DCM)</td>
</tr>
<tr>
<td></td>
<td>Takosubo CM</td>
<td>Myotonic dystrophy (types 1, 2, 3) (DCM)</td>
</tr>
<tr>
<td></td>
<td>Infant of diabetic mother (HCM)</td>
<td>Fascioscapulohumeral muscular dystrophy (DCM)</td>
</tr>
<tr>
<td></td>
<td>Prenatal and postnatal</td>
<td>Mitochondrial and respiratory chain disorders (DCM, HCM)</td>
</tr>
<tr>
<td></td>
<td>corticosteroid therapy (HCM)</td>
<td>Fatty acid oxidation disorders</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Very-long chain acyl-CoA dehydrogenase (DCM)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Carnitine deficiency (HCM, DCM)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Glycogen storage disorders</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Type IIA (Pompe disease) (HCM)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Type IIB (Danon disease) (HCM)</td>
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<tr>
<td></td>
<td></td>
<td>Mucopolysaccharidosis types 1, 2, 5 (HCM)</td>
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<tr>
<td></td>
<td></td>
<td>Glycolipid lipidosis (Fabry disease) (HCM)</td>
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<tr>
<td></td>
<td></td>
<td>Hereditary hemochromatosis (DCM)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Carvajal syndrome (DCM)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Noonan’s syndrome (HCM)</td>
</tr>
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<td></td>
<td></td>
<td>Beckwith–Wiedemann syndrome (HCM)</td>
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<tr>
<td></td>
<td></td>
<td>Cardio-facial-cutaneous syndrome (HCM)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Costello syndrome (HCM)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lentiginosis (LEOPARD syndrome) (HCM)</td>
</tr>
</tbody>
</table>

The usual clinical phenotypes are indicated in parentheses for cardiomyopathies that are acquired or associated with multisystem disease. CM, cardiomyopathy; D, dilated; H, hypertrophied.
Anesthesia for Patients with CM

• Diagnostic procedures
  – CT, MRI, cardiac catheterization

• Therapeutic procedures
  – Placement of CVP, gastrostomy tube
  – Pacemaker, ICD
  – Cardiac transplantation
Dilated Cardiomyopathy
Dilated Cardiomyopathy

- Complex remodeling of ventricles
- Enlargement of all chambers
- Ventricles more dilated than atria
- Left ventricle more spherical
- Raised wall stress
Pathophysiology of Dilated CM

- Biventricular dilation
- Systolic and diastolic myocardial function
- Ejection fraction (EF)
- Cardiac output
- LVEDP
- Atrial filling pressure

Dilated Cardiomyopathy

- Mitral regurgitation
- Tricuspid regurgitation
- Ventricular arrhythmias
- Congestive heart failure
Etiology of Dilated CM

- Idiopathic: 66%
- Myocarditis: 16%
- Familial: 9%
- Neuromuscular disorders: 5%
- Inborn errors of metabolism: 4%
- Malformation syndrome: 1%

Legend:
- Blue: Idiopathic
- Red: Myocarditis
- Green: Familial
- Purple: Neuromuscular disorders
- Cyan: Inborn errors of metabolism
- Orange: Malformation syndrome
Myocarditis and Dilated CM

- Viral infection most common cause

![Diagram](A) Acute Inflammation → (B) Immune Response → (C) Myocyte Injury → Fibrosis

Myocarditis and Dilated CM

• Clinical presentation
  – Mild clinical malaise and flu-like symptoms
  – Decompensated CHF
  – Arrhythmias
  – Cardiac arrest

• Diagnosis
  – Endomyocardial biopsy
  – Cardiac MRI

Preoperative Assessment of Dilated CM

- Detailed history

- Echocardiogram is mandatory!

- Review medications
  - ACE-inhibitors for afterload reduction
  - B blockers
  - Diuretics
  - Digoxin

- Laboratory assessment
Preoperative Assessment of Dilated CM

• Often have low blood pressure at baseline
  – Heart failure
  – Multiple medications
  – Intravascular hypovolemia
  – Exacerbated by perioperative fasting

• Even with normal vital signs and exam, can have acute deterioration with anesthesia

Preoperative Assessment of Dilated CM

• Poorly contracting LV will not maintain cardiac output in presence of high SVR

• May require low-dose inotropy prior to anesthetic induction
  – Milrinone
  – Dobutamine
  – Low dose epinephrine

Anesthetic Goals for Dilated CM

- Normal diastolic arterial pressure to optimize coronary perfusion

- Maintain preload

- Avoid
  - Tachycardia
  - Decreased myocardial contractility
  - Increased SVR
Anesthetic Management for Dilated CM

• High-dose opioid anesthetic not always practical

• Many anesthetics are myocardial depressants
  – Propofol
    • Decreases preload (dilates venous capacitance vessels)
    • Decreases afterload (SVR)
    • Decreased myocardial contractility
  – Ketamine
    • Sympathomimetic
    • Decreased cardiac output and hypotension

Anesthetic Management for Dilated CM

• Etomidate
  – Less myocardial depression than other agents
  – No decrease in myocardial contractility
  – Adrenal suppression?

Children with cardiomyopathy: complications after noncardiac procedures with general anesthesia

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Table 5
Periprocedural complications

<table>
<thead>
<tr>
<th>Systemic ventricle dysfunction</th>
<th>Mild (4) moderate (9)</th>
<th>Severe (21)</th>
<th>Total all patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypotension^a</td>
<td>3</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>Arrhythmia^b</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Pneumonia^c</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Respiratory arrest^d</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Neurologic deficit^e</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PRBC transfusion^f</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Wound infection^g</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>ECMO^h</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Death^i</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Any complication</td>
<td>3</td>
<td>15^j</td>
<td>18</td>
</tr>
</tbody>
</table>
Anesthetic Management for Dilated CM

• Complications greatest in longer procedures
  – Will require inotropic support
  – Invasive monitoring (arterial line)
  – Postoperative ICU monitoring

Hypertrophic Cardiomyopathy
Hypertrophic CM (HOCM)

- Leading cause of sudden death in children
- More common in adults
- In children, most common in males and infants < 1 y.o.

- Idiopathic and familial cause 75% of cases
  - Inborn errors of metabolism
  - Neuromuscular disorders

Hypertrophic Cardiomyopathy

- Increased regional or global wall thickness
- Can have focal hypertrophy around coronary artery
Hypertrophic Cardiomyopathy

Figure 2: Cardiovascular MRIs depicting the hypertrophic cardiomyopathy phenotype.

Maron BJ, Maron MS. Lancet 2012
Pathophysiology of HOCM

- LVOT obstruction
- Ventricular cavity
- Normal EF may be recorded despite poor function
- Diastolic myocardial relaxation
- 2D LV mass

Symptoms of HOCM

• Decreased cardiac output

• Pulmonary congestion

• Myocardial ischemia
  – Diastolic lag time with under-filled coronary vessel
  – Tachycardia can result in sudden death
Preoperative Assessment of HOCM

• Echocardiogram
  – Assess 2D LV mass
  – Infants with severe HCM and 2D LV mass index >150 g m\(^{-2}\) (normal 60 g m\(^{-2}\)) predisposed to:
    • Perioperative arrhythmias
    • Myocardial ischemia with tachycardia and low diastolic arterial pressure

Preoperative Assessment of HOCM

• Medications
  – Propranolol
    • Relieves symptoms and may improve exercise capacity
  – Calcium channel blockers
    • Improves diastolic relaxation to improve subendocardial perfusion
    • Decrease dyspnea
    • Increase exercise capacity

• AVOID diuretics and ACE-inhibitors
  – Increase the LVOT gradient
Anesthetic Goals of HOCM

• Minimize increases in LVOTO
  – Maintain normal or slightly increased SVR
  – Prevent hypovolemia
  – Avoid increased myocardial contractility

• Optimize diastolic filling time
  – Heart rate kept at a normal or low rate

• Sinus rhythm
  – Rely on atrial contraction to fill non-compliant ventricle

Anesthetic Management for HOCM

• Volatile agents and Etomidate
  – Well tolerated

• Propofol
  – Decreases preload and SVR by 20%
  – HCM due to inborn errors of metabolism of lipid oxidation can have increased free fatty acids (propofol infusion syndrome)

• Ketamine
  – Preserves spontaneous ventilation and diastolic pressure
  – Associated tachycardia can produce ischemia

Anesthetic Management for HOCM

• Inotropes
  – Can decrease cardiac output due to a decrease in diastolic filling time and worsened LVOT obstruction
  – If hypotension due to low coronary perfusion
    • Low dose phenylephrine and beta-blockers
    • Will control heart rate and reduce systolic cavity obliteration
Left Ventricular Non-Compaction
LV Non-Compaction

• Due to arrest of myocardial maturation during embryogenesis

• Often familial

• Mitochondrial disorders

• Neuromuscular disorders

LV Non-Compaction

• Compacted epicardial layer

• Non-compacted layer
  – Abnormal loose, spongy trabecular outpunching that communicates with the LV cavity

Symptoms of LV Non-Compaction

• Similar to dilated cardiomyopathy but worse outcome

• Heart failure in infancy

• Arrhythmias

• Mural thrombi

• Ventricular dyssynchrony
Treatment of LV Non-Compaction

• Control of symptoms
  – ACE-inhibitors
  – Beta-blockers
  – Diuretics
  – Inotropy with milrinone
Anesthetic Considerations in LVNC

• Screen for neuromuscular diseases that impact anesthesia

• May have muscular weakness

• Improve function with inotropic support

• Ventricular dyssynchrony improves with biventricular pacing

Arrhythmogenic Right Ventricular Cardiomyopathy
Arrhythmogenic Right Ventricular CM

- Genetic disorder of cardiac desmosomes
- Thinned RV infiltrated by fibro-fatty tissue
- Echo shows regional or global RV hypokinesis
Arrhythmogenic Right Ventricular CM

- Presents in adolescence with ventricular arrhythmias
- Palpitations
- Syncope
- Atypical chest pain
- Dyspnea
- Can present as sudden death
Arrhythmogenic Right Ventricular CM

• Four stages of disease
  – Concealed phase
  – Overt arrhythmogenic phase
  – Isolated right heart failure
  – Biventricular failure

• Therapy
  – ICD
  – Radiofrequency catheter ablation

Anesthetic Considerations in ARVC

• Avoid catecholamine-induced arrhythmias
  – Epinephrine for regional anesthesia
  – Pancuronium

• Propofol has been safely used

• Place external cardioversion/defibrillator pads

• Continue anti-arrhythmic medications

Restrictive Cardiomyopathy
Restrictive Cardiomyopathy

• Endomyocardial fibrosis

• Increased stiffness of myocardium

• Impaired ventricular filling

• Gene mutation of cardiac sarcomere

Pathophysiology of Restrictive CM

- Progression of endomyocardial fibrosis
- LVEDP increase
- Decreased stroke volume
- Decreased cardiac output
- Increased pulmonary vascular resistance
Preop Assessment of Restrictive CM

- **Echo**
  - Small ventricles
  - Massively dilated atria

- **Jugular venous pressure elevated**

- **High PVR**
  - Symptomatic exercise intolerance with PVR >10-15 Woods units m$^{-2}$

Anesthesia in Restrictive CM

• Cardiac output is heart rate dependent

• Often have arrhythmias

• Inotropic agents
  – Milrinone
  – Dobutamine

• Avoid increases in PVR
  – High airway pressures, hypercarbia, and hypoxia
Conclusions

• Multiple forms of cardiomyopathy

• Each has unique hemodynamic consequences

• Fragile patients

• Balanced and safe anesthesia necessary

• We will see more of these patients in our practice!
Thank You