Chapter

32

Dilated Cardiomyopathy

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Case Scenario

A 2-year-old male, weighing 12 kg, and without significant past medical history, presented to the emergency room with fussiness, decreased appetite, and vomiting. He had a 3-day history of a cough and runny nose, followed by fever. In the emergency room he is observed to be pale, sweaty, tachycardic, and tachypneic. Physical examination also reveals bilateral coarse crackles on lung auscultation, cool extremities, delayed capillary refill, and hepatomegaly. The electrocardiogram was significant for low-voltage R waves. A chest radiograph demonstrated cardiomegaly and pulmonary congestion. Laboratory tests revealed hyponatremia and lactic and respiratory acidosis, with elevated troponin and brain natriuretic peptide levels. Viral titers to rule out viral myocarditis were sent. The patient was admitted to the cardiac intensive care unit for close monitoring and treatment of congestive heart failure. He was placed on diuretics, an angiotensin-converting enzyme inhibitor, and an intravenous milrinone infusion. As his clinical status did not significantly improve over the next 48 hours, he was scheduled to undergo placement of a peripherally inserted central catheter for ongoing medical therapy.

An echocardiogram was performed, demonstrating the following:

- *Biventricular dilatation*
- *Severe mitral valve regurgitation*
- *Severely decreased left ventricular function (ejection fraction 25%)*
- *Systolic and diastolic dysfunction*
- *Normal coronary artery anatomy and flow*

Key Objectives

- Describe the pathophysiology and presentation of dilated cardiomyopathy.
- Specify how it differs from other forms of cardiomyopathy.
- Identify preprocedural assessment for patients with dilated cardiomyopathy.
- Discuss anesthetic options and risks for the patient in this scenario.

Pathophysiology

How is dilated cardiomyopathy defined?

Cardiomyopathy is a disease of the myocardium associated with cardiac dysfunction that cannot be explained by abnormal loading conditions or congenital heart disease. Dilated cardiomyopathy (DCM) is a phenotypic class of cardiomyopathy that is defined by ventricular chamber dilation with dysfunction that is secondary to ineffective systolic shortening. One or both ventricles can be affected. It is frequently associated with increased myocardial mass but decreased wall thickness.

What causes DCM?

In children without known structural heart abnormalities DCM is the most common cause of congestive heart failure (CHF), with the highest incidence noted in infancy. While two-thirds of cases are idiopathic, it is imperative to search for underlying causes, especially in infants who are more likely to have metabolic disease that can be treatable. Identifiable causes of DCM include myocarditis, neuromuscular disorders, familial and metabolic disorders, and toxin exposure. Viral infections are the most common cause of myocarditis. Anthracycline exposure is a risk factor for the development of cardiomyopathy in patients who have been treated with this chemotherapeutic agent for neoplastic disease.

How do other forms of cardiomyopathy differ from DCM?

Other cardiomyopathy phenotypes include the following:

- ***Hypertrophic cardiomyopathy*** is characterized by abnormal left and/or right ventricular hypertrophy that occurs in the absence of an obvious stimulus. Ventricular volumes are normal or diminished.

https://doi.org/10.1017/9781108657341.033 Published online by Cambridge University Press

Hypertrophy is usually asymmetrical, with the interventricular septal wall being thicker than the free wall. Obstructions to left or right ventricular outflow tracts are common because of septal hypertrophy. Systolic ventricular function is normal, or even hyperdynamic, until later in the disease process. Familial predisposition and idiopathic origins are most prevalent. It is a leading cause of sudden death in young people.

- ***Restrictive cardiomyopathy*** is primarily idiopathic in nature and characterized by diastolic dysfunction with normal or reduced ventricular volume and normal ventricular wall thickness. Systolic function is normal in the early phases of the disease and progressively worsens. Atrial enlargement may be present along with elevated atrial and ventricular end-diastolic pressures.
- ***Left ventricular noncompaction cardiomyopathy*** is caused by the abnormal development of deep myocardial trabeculations, predominantly in the apex of the left ventricle (LV), but right ventricular (RV) involvement can also occur. It is frequently associated with a neuromuscular disorder.
- ***Arrhythmogenic RV dysplasia*** is characterized by fatty and fibrous infiltration of the myocardium that creates loci for spontaneous arrhythmia development. There is typically regional hypokinesis on echocardiogram. The RV free wall is most often involved, but recent evidence suggests the LV wall can also be affected.

How does DCM present clinically?

Children with DCM most often present with signs and symptoms of CHF, which can be variable and nonspecific. Therefore, diagnosis requires a high index of clinical suspicion. Presenting symptoms also vary with age of the patient. Infants commonly present with feeding intolerance and failure to thrive. Respiratory complaints include tachypnea, shortness of breath, and increased work of breathing. For older children, a low cardiac output state can manifest as poor exercise capacity and gastrointestinal complaints of abdominal pain, nausea, and/or vomiting. Additionally, patients with DCM caused by viral myocarditis may also present with a classic prodrome of fever and myalgias in addition to respiratory and gastrointestinal symptoms.

Clinical Pearl

Dilated cardiomyopathy often presents with signs of CHF, such as failure to thrive, gastrointestinal distress, diminished exercise tolerance, or pulmonary edema. Manifestations may differ depending on the age at presentation.

What does a focused physical exam reveal?

Patients with nonfulminant heart failure can actually present with normal findings on physical examination. Further confounding the matter, examination findings can overlap with other conditions such as gastroenteritis, asthma, or pneumonia. Common physical examination findings are listed in Table 32.1. Hypotension is generally a late and ominous finding, as it implies that the body's compensatory mechanisms have been exhausted. Weak peripheral pulses and cool distal extremities with poor capillary refill are also suggestive of decompensated heart failure.

Clinical Pearl

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What is the prognosis of DCM in children?

The outcome of patients presenting with DCM is variable, with some children presenting with fulminant heart failure requiring mechanical circulatory support and transplantation while others recover normal function. Transplant-free survival rates for 5 years post-diagnosis range from 60% to 75% [1]. Factors associated with worse outcomes include older age at diagnosis (>6 years of age), lower shortening fraction, greater LV dilation, and elevated LV end-diastolic pressure (>20–25 mm Hg) [2]. Congestive heart failure at the time of presentation is associated with a higher risk of death or transplantation only in infants <1 year of age. Transplant waitlist mortality is 11%, except in patients who are mechanically ventilated or on mechanical circulatory support [3]. In patients in whom DCM represents part of a multisystem process the underlying disease can also impact patient outcome. Sudden death in children with DCM is quite uncommon.

Table 32.1 Dilated Cardiomyopathy Physical Exam Findings by System

Respiratory	Gastrointestinal	Cardiac
Tachypnea	Hepatomegaly	Tachycardia
Hypoxia	Poor weight gain	Hypotension
Crackles/rales/ wheezing		Murmur/gallop
Retractions		Cool extremities
Increased work of breathing		Delayed capillary refill
		Jugular venous distention

https://doi.org/10.1017/9781108657341.033 Published online by Cambridge University Press

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What are the hemodynamic features of DCM?

The primary pathophysiologic features of DCM are ventricular dilation with systolic and diastolic dysfunction, decreased ejection fraction, and decreased cardiac output (CO). The diastolic dysfunction affects both active relaxation and passive compliance, thereby reducing ventricular filling and elevating end-diastolic pressures. Atrial and LV filling pressures are usually elevated. Associated mitral valve regurgitation, tricuspid valve regurgitation, or both often exist. The dilated heart chambers also have the potential to be arrhythmogenic.

What diagnostic modalities are generally utilized?

An echocardiogram is typically diagnostic and essential to quantify systolic and diastolic function, LV end-diastolic dimension, and LV volume. Patients typically have global systolic hypokinesis but may have segmental wall motion abnormalities as well. Atrioventricular valve regurgitation from annular dilation and additional anatomic abnormalities (i.e., outflow obstruction, coarctation, coronary anomalies) can also be identified. In patients with a low cardiac ejection fraction, intracardiac thrombi may be detected.

Electrocardiogram findings are usually nonspecific. A chest radiograph typically demonstrates cardiomegaly and there may be evidence of pulmonary edema. A cardiac magnetic resonance imaging study may show myocardial fibrosis and inflammation in addition to the assessment of myocardial volumes, contractile function, and wall thickness. While brain natriuretic peptide levels are routinely measured in adults for risk stratification of patients in acute decompensated heart failure, their utility in the pediatric population remains unclear. There is some evidence that levels greater than 300 pg/mL are associated with worse outcomes, including death, hospitalization for heart failure, and transplantation [4].

When treating new-onset heart failure in children, it is also important to simultaneously look for underlying metabolic, congenital, or acquired causes. Thus, in this patient, viral titers were sent to rule out myocarditis, and the echocardiogram was also reviewed for structural anomalies such as abnormal coronary artery anatomy.

Clinical Pearl

By helping quantify systolic and diastolic function, ventricular dimensions, and valvular competency, an echocardiogram is essential for planning anesthetic management and pharmacologic choices.

What pharmacologic therapies are used in DCM patients?

Therapeutic guidelines have largely been extrapolated from adult data as high-quality pediatric studies are lacking. Commonly used chronic heart failure medications used in symptomatic pediatric patients with ventricular dysfunction include angiotensin-converting enzyme inhibitors (ACEi), angiotensin receptor antagonists, and ß-blockers. Diuretics are used therapeutically for treatment of both acute and chronic volume overload and are a mainstay therapy for acute decompensated heart failure. Digoxin has also been used to treat myocardial dysfunction and volume overload in children.

Inotropic support is reserved for low CO states or ongoing hypotension. Milrinone (an inodilator), dobutamine, or low-dose epinephrine may be titrated to effect. However, it is important to keep in mind that a patient with end-stage cardiomyopathy may not show significant improvement with inotropic therapy.

What other treatment options exist?

Children with end-stage heart failure unresponsive to inotropic support may require mechanical circulatory support, either with extracorporeal membrane oxygenation (ECMO) or with a ventricular assist device (VAD). This support may be utilized as a bridge to either recovery (in cases of myocarditis) or heart transplantation. Survival at 10 years post transplantation is 72% [3].

Anesthetic Implications

What are the preoperative considerations?

A thorough history and physical exam along with a review of current medications aids in establishing the patient's current functional baseline. A review of the most recent echocardiogram, chest radiograph, and other available imaging facilitates preanesthetic risk assessment. The patient's cardiologist is also an excellent source of information regarding the patient's clinical status.

https://doi.org/10.1017/9781108657341.033 Published online by Cambridge University Press

Patients on diuretic therapy should have their potassium level checked and normalized if necessary. Most anesthesia providers advocate withholding ACEi on the morning of the procedure to avoid intraoperative hypotension. Patients with an implantable device for biventricular pacing as part of their medical therapy should have their device interrogated to ensure functionality.

What should the parents be told about anesthetic risk?

The anesthetic management of patients with severe cardiomyopathies is associated with high morbidity and mortality. Patients with DCM may suffer from significant cardiopulmonary instability secondary to administration of anesthetic agents, intubation and mechanical ventilation, and noxious stimulation. Life-threatening ventricular arrhythmias may also occur during the perioperative period. For these reasons, parents must have a thorough understanding of the patient's high-risk condition when consent is obtained. Discussions of rescue strategies including mechanical circulatory support should take place prior to the procedure.

What are the intraoperative hemodynamic considerations?

The intraoperative hemodynamic goal for DCM patients is simply to maintain cardiac output while minimizing any increases in oxygen consumption.

This can be achieved by the following:

- Maintain preload.
- Avoid increases in heart rate above baseline (excessive tachycardia).
- Avoid elevations in systemic vascular resistance (SVR).
- Preserve myocardial contractility.
- Optimize coronary perfusion.

A significantly dysfunctional ventricle will not be able to maintain CO in the face of increased SVR, so inotropic support may be needed to optimize contractility.

How might the anesthetic be conducted for this child? How should the airway be managed?

There is no single best approach for induction or maintenance of anesthesia in this patient population. It is advisable to establish reliable intravenous (IV) access prior to induction. Although this patient currently has vascular access, as he is receiving milrinone, it is always advisable to have separate, dedicated IV access for administration of anesthetic and sedative medications. It is important to keep the hemodynamic goals in mind and to titrate anesthetic agents accordingly. Circulation time can be substantially slowed given the low CO state in many of these patients, so sufficient time should be given for divided doses of medications to take effect. If the patient is receiving IV inotropic and/or vasodilator therapy, these should be continued, and care should be taken to neither interrupt nor inadvertently bolus these medications.

In a child presenting without IV access, oral premedication may be helpful to attenuate anxiety and facilitate separation from the parents. Premedication can also facilitate securing IV access in the operating room or procedure room prior to induction. Oral midazolam 0.25–0.5 mg/kg and, if needed, oral ketamine 4–6 mg/kg is usually adequate. Patients with existing IV access can be premedicated with IV midazolam in titrated doses (0.03–0.05 mg/kg) or IV ketamine in doses of 0.5–1.0 mg/kg if necessary for severe anxiety. Decisions regarding premedication in patients with severe ventricular dysfunction should be made on an individualized basis, and medications should be carefully titrated while the patient is being monitored.

For placement of a peripherally inserted central catheter (PICC), infiltration of the insertion site with local anesthesia can blunt hemodynamic responses to noxious stimulation without causing undue myocardial depression, vasodilation, or hypotension. For this particular case, carefully titrated doses of ketamine 0.5–1.0 mg/kg in combination with titrated doses of dexmedetomidine 0.5–1.0 mcg/kg are often sufficient and can be used for both induction and maintenance. With this technique, spontaneous ventilation can be maintained without necessitating the use of an invasive airway. Supplemental oxygen via nasal cannula is often required to maintain appropriate levels of oxygenation; it is also useful for monitoring of end-tidal CO_2.

For more invasive cases or if endotracheal intubation and mechanical ventilation are necessary, induction of anesthesia with etomidate (0.3 mg/kg) can avert hemodynamic instability. Ketamine (2–4 mg/kg) avoids hypotension, *except for patients with end-stage heart failure*, in whom it can lead to myocardial depression. In general, the anesthetic induction phase must be monitored carefully as patients can swiftly deteriorate due to anesthetic-induced vasodilation. The initiation of low-dose inotropic therapy may be warranted in fragile patients prior to anesthetic induction.

The use of inhaled agents for maintenance of anesthesia should be managed judiciously to avoid hemodynamic instability in light of failing cardiac function. Alternately, a combination of propofol and ketamine infusions can also be used. Caution must also be exercised when opioids are used in conjunction with benzodiazepines, as these medications act synergistically in producing side effects of increased venous capacitance and decreased SVR.

https://doi.org/10.1017/9781108657341.033 Published online by Cambridge University Press

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A PICC placement can often be accomplished while maintaining spontaneous respiration with a natural airway. If endotracheal intubation is required, inhaled anesthetics should be administered judiciously due to their direct myocardial depressant and vasodilatory properties. Even ketamine can lead to hypotension due to direct myocardial depression in children with end-stage heart failure.

What are the specific risks for a child with DCM undergoing anesthesia?

Generally speaking, children are not as cooperative as adults and therefore require moderate-to-deep sedation or general anesthesia, even for diagnostic procedures. A deeper level of anesthesia inherently exposes the patient to a greater myocardial depressant effect, which is generally not well tolerated in a patient with severe ventricular dysfunction. Children with cardiomyopathy undergoing noncardiac surgery have a high complication rate, with hypotension requiring inotropic therapy occurring in 61% of patients [5]. The Pediatric Perioperative Cardiac Arrest (POCA) registry reports a mortality rate of 50% in children with cardiomyopathy who sustain a perioperative cardiac arrest [6]. Therefore, it is recommended that hemodynamic support, invasive monitoring, and postoperative cardiac intensive care monitoring should be available for patients with severe DCM undergoing anesthetic procedures. In some cases, intraoperative echocardiography may be helpful in determining real-time function and volume status. The availability of ECMO and the patient's suitability for ECMO or mechanical circulatory support options should also be discussed with both the family and the surgical team preprocedure.

What are the considerations if hemodynamic instability occurs?

Episodes of hemodynamic compromise must be responded to swiftly in a patient with DCM. During a bradycardic event, atropine should be used cautiously because it may initiate tachycardia which can result in compromised subendocardial perfusion. Ephedrine, a direct and indirect-acting α- and β-agonist dosed at 0.03–0.07 mg/kg, is a reliable agent to increase heart rate without compromising diastolic coronary perfusion. In addition, the augmentation in diastolic blood pressure is beneficial when hypotension accompanies bradycardia.

Excessive tachycardia is detrimental for patients with DCM as it can cause subendocardial ischemia and hemodynamic compromise, but many patients may have tachycardia at baseline due to their heart failure. The cause of the tachycardia must be identified and addressed, and anesthesia depth is increased if indicated. β-blockers should be used very selectively intraoperatively considering the patient's severely depressed systolic function.

If hypotension due to reduced SVR occurs, volume infusion (5–10 mL/kg) to increase preload to preinduction levels or the use of incremental doses of phenylephrine (0.5–1.5 mcg/kg) will usually correct the problem. Phenylephrine reliably increases SVR, but caution must be exercised in DCM patients with severe systolic dysfunction since excessive use of phenylephrine will increase afterload and reduce stroke volume. If the patient fails to respond with a prompt increase in systemic blood pressure, an inotropic agent should be started to avoid a downward spiral of acute heart failure manifested by ventricular dilatation, increased wall stress, reduced stroke volume, and worsening hypotension. Dopamine 3–5 mcg/kg/minute or epinephrine 0.03–0.05 mcg/kg/minute would be reasonable choices in this situation.

Clinical Pearl

Tachycardia is detrimental for patients with DCM and should be treated to avoid subendocardial ischemia and hemodynamic compromise.

What is the appropriate postoperative disposition for this patient?

This patient should return directly to the intensive care unit on completion of the procedure. For patients with less severe cardiac dysfunction, postoperative disposition should be predicated on their stability during the procedure and any ongoing concerns regarding airway or hemodynamic stability.

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Suggested Reading

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https://doi.org/10.1017/9781108657341.033 Published online by Cambridge University Press