

# Post Orthotopic Cardiac Transplantation

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## Case Scenario

A 3-year-old male, weighing 14 kg, presents for elective tonsillectomy and adenoidectomy. He has a history of hypoplastic left heart syndrome and underwent a Norwood procedure with a Sano modification soon after birth, which was followed by a bidirectional Glenn procedure at 4 months of age. Shortly after his second-stage surgery he required an orthotopic heart transplant due to severe tricuspid valve regurgitation and moderate-to-severe ventricular dysfunction and the inability to wean from milrinone. Today, his mother states that he is very active and growing well. His cardiologist sees him regularly and his last surveillance annual catheterization 1 month ago revealed good hemodynamics and no evidence of rejection.

## Key Objectives

- Understand common causes of heart transplantation in pediatric patients.
- Describe biatrial versus bicaval surgical implantation techniques.
- Understand the physiology of the transplanted heart.
- Describe the perioperative assessment for a heart transplant patient undergoing noncardiac surgery.
- List common immunosuppressant medications, their side effects, and anesthetic considerations.
- Describe the appropriate perioperative management of this patient.

## Pathophysiology

### What are the most common indications for heart transplantation in children?

The most common indications for pediatric heart transplantation are listed in Table 38.1. Approximately 55% of infants <1 year of age listed for heart transplantation have complex congenital heart disease (CHD). In contrast, 44%–54% of older children listed for transplantation have cardiomyopathy,

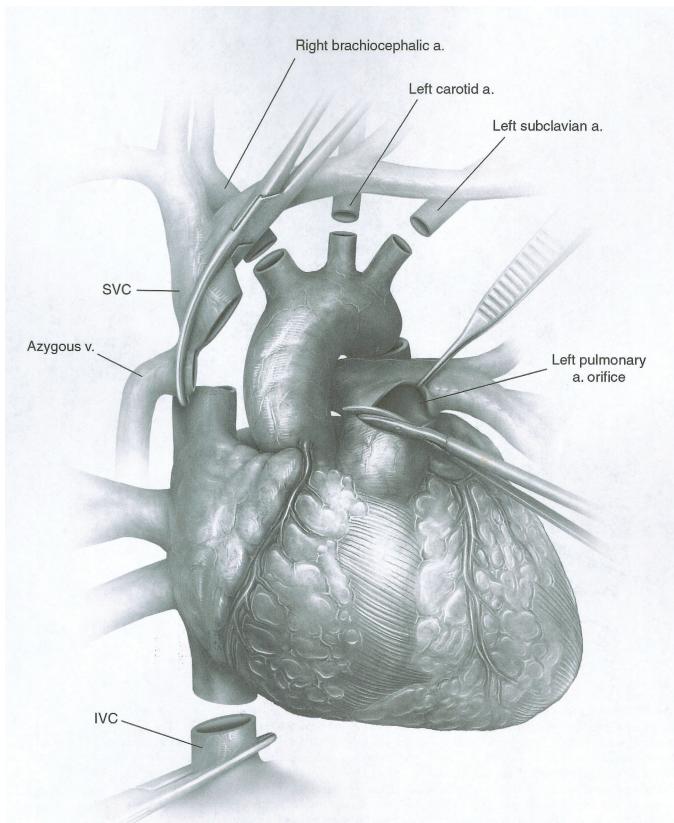
**Table 38.1** Common Indications for Heart Transplantation in Children

<b>Congenital heart disease</b>	Most common: Hypoplastic left heart syndrome, pulmonary atresia with intact ventricular septum and right ventricular dependent coronary circulation, truncus arteriosus, Ebstein's anomaly, unbalanced atrioventricular septal defect
<b>Cardiomyopathy</b>	Dilated cardiomyopathy (idiopathic and familial), idiopathic restrictive cardiomyopathy, and myocarditis
<b>Unresectable cardiac tumors</b>	Sarcoma, lymphoma, fibroma, pheochromocytoma
<b>Chemotherapy-induced myocardial dysfunction</b>	Anthracyclines (doxorubicin, daunorubicin, epirubicin, and idarubicin); trastuzumab (transient cardiomyopathy)

with the percentage of patients transplanted for CHD decreasing steadily with increasing patient age [1].

### What are the two most common surgical implantation techniques for orthotopic heart transplants?

Transplantation is usually performed using either a biatrial or bicaval technique. (See Figures 38.1–38.3.) In the early days of orthotopic heart transplantation, the biatrial technique was more commonly used. This technique involved excision of the posterior portion of donor left and right atrium, from the inferior vena cava (IVC) to the right atrial appendage, with the intent of preserving the sinoatrial node. The resultant figure-of-eight orientation of both atria, however, actually interfered with atrial contraction and electrical conduction, leading to acute atrial enlargement and atrioventricular (AV) valve regurgitation. Thus, in the late 1980s, the bicaval technique became popular because it preserved the integrity of donor atria by separating the anastomosis of the pulmonary vein confluence from the caval anastomosis. A meta-analysis reported the bicaval technique's superiority in regard to decreased right



**Figure 38.1** Once the heart and lung perfusion is complete, the donor cardiectomy is completed next. From Camp P. C. Heart transplantation: donor operation for heart and lung transplantation. *Oper Tech Thorac Cardiovasc Surg* 2010; **15**: 125–37. With permission.

atrial pressure, perioperative mortality, tricuspid regurgitation, and higher likelihood of sinus rhythm. However, in smaller recipients, the bicaval technique has a higher risk of both superior vena cava (SVC) and IVC stenosis. The biatrial implantation is the preferred technique in cases of caval size mismatch, reoperation, or complex anatomy [2, 3].

#### Clinical Pearl

*The bicaval technique preserves the integrity of donor atria by separating the anastomosis of the pulmonary vein confluence from the caval anastomosis. However, in smaller recipients, the bicaval technique has a higher risk of both SVC and IVC stenosis. The biatrial implantation is the preferred technique in cases of caval size mismatch, reoperation, or complex anatomy.*

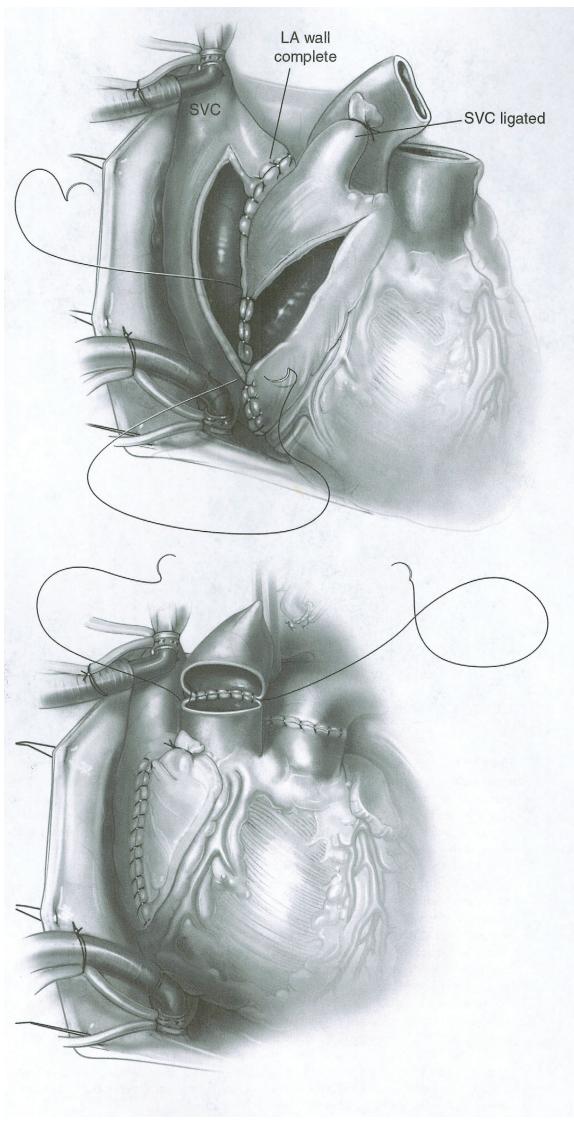
## What is the life expectancy for a heart transplant recipient?

There is an indirect correlation between age at transplant and survival. Those who receive a heart at 1 year of age or earlier have an average life expectancy of 22.3 years. Those

transplanted at age 1–5 years, 6–10 years, and >11 years can expect to have an average life expectancy of 18.4, 14.4, and 13.1 years post-transplant, respectively. The indication for heart transplantation also impacts mortality. Patients with CHD experience higher mortality than patients with cardiomyopathies (79% survival vs. 88% at 5 years). By 10 years post-transplant, both groups have similar long-term mortalities. Single-ventricle patients have a 53% 10-year survival. The need for extracorporeal membrane oxygenation (ECMO), end-organ damage prior to transplant (need for dialysis or mechanical ventilation), recipient's body mass index, ischemic time, and transplant center volume/experience all influence 1-year mortality rates [4, 5].

## What are the causes of death after a cardiac transplant?

Graft failure, rejection, infection, and coronary allograft vasculopathy (CAV) are all major causes of death within the first 5 years post-transplant. Graft failure is the most common cause of death following transplantation. Coronary allograft vasculopathy becomes more common after 3 years, with an incidence of 10% per year post-transplant [6].



**Figure 38.2** Orthotopic heart transplantation: atrial anastomosis technique. From John R. and Liao K. Orthotopic heart transplantation. *Oper Tech Thorac Cardiovasc Surg* 2010; **15**: 138–46. With permission.

## What are the most common complications following heart transplantation?

Rejection is most common in the first year post-transplant. Older donor age, older recipient age, lack of induction therapy, retransplantation, and repeated cellular rejection are all risk factors for new-onset rejection. Endomyocardial biopsy remains the gold standard for diagnosing acute or chronic rejection. Coronary allograft vasculopathy is the leading cause of mortality after 3 years post-transplant. Once CAV is angiographically present, short-term mortality

risk is high. Classic signs and symptoms of pediatric heart failure will be evident, with tachypnea, tachycardia, diaphoresis, dyspnea on exertion, lack of appropriate growth, and grunting being the most common. In the setting of CAV, ejection fraction  $<45\%$ , right atrial pressure  $>12$  mm Hg, and/or pulmonary capillary wedge pressure  $>15$  mm Hg are all risk factors for graft failure. Due to the diffuse nature of CAV, coronary interventions are rarely effective, and retransplantation is usually the only viable option [6, 7].

### Clinical Pearl

*Coronary allograft vasculopathy is the leading cause of mortality after 3 years post-transplant. Once CAV is angiographically present, short-term mortality risk is high. Classic signs and symptoms of pediatric heart failure will be evident, with tachypnea, tachycardia, diaphoresis, dyspnea on exertion, lack of appropriate growth, and grunting being the most common.*

## What iatrogenic transplant complications should be considered prior to any elective surgery?

If the patient required ECMO support prior to transplantation, this can create future issues if central access is required. Neck and groin vessels are commonly thrombosed or have been sacrificed for ECMO cannulation. The need for multiple indwelling catheters during the perioperative transplant period can also complicate future catheterizations. In addition, some patients are colonized with drug-resistant organisms from their indwelling catheters; in this event communication between the proceduralist and infectious disease specialist (especially if the transplanted heart has valvular issues) is warranted [6].

## Is it important to distinguish between an ABO-compatible and an ABO-incompatible heart transplant patient?

Over the past two decades, pediatric ABO-incompatible (ABO<sup>i</sup>) heart transplantation has become more common in an effort to broaden organ availability and overcome the restriction placed by the need for ABO compatibility. The majority of ABO<sup>i</sup> recipients are children  $<2$  years of age who have not yet developed or have low levels of ABO isoagglutinin; they have low levels of anti-A and anti-B titers. The ABO structures continue to be expressed in the heart graft years after the transplant. Thus, following the transplant, select ABO<sup>i</sup> recipients could encounter ABO isoagglutinins directed toward their donor blood

structures on the transplanted heart. As a consequence, transfusing blood products containing donor-directed ABO isoantibodies could be risky for inciting future organ rejection [8]. Table 38.2 outlines suggested transfusion guidelines for ABOi recipients.

## How does the physiology of the transplanted heart compare to that of a normal heart?

Due to the interruption of the cardiac plexus and the inability for conduction to cross suture lines, the efferent limbs of the autonomic nervous system are compromised. As a result, the normal response to baroreceptor activation is altered. Response to baroreceptor activation is dependent on the generation of circulating endogenous catecholamines for chronotropic and inotropic effect. The resting heart rate of a transplanted patient is generally higher compared to the normally innervated heart but maintains similar minimum and maximum rates. The normal response to exercise and stress occurs at a delay, compared to the innervated heart, as it follows the gradual increase in serum catecholamines, which takes several minutes to generate [9]. Cardiac output is primarily reliant on preload; therefore, adequate hydration is paramount in maintaining adequate end-organ perfusion. In addition, systemic response to atrial

and ventricular filling is also impaired; therefore, hypovolemia will not cause the normal reflex compensatory tachycardia and is poorly tolerated. Due to the absence of sensory efferent pathways, chest pain is also an unreliable symptom of ischemia [5, 10].

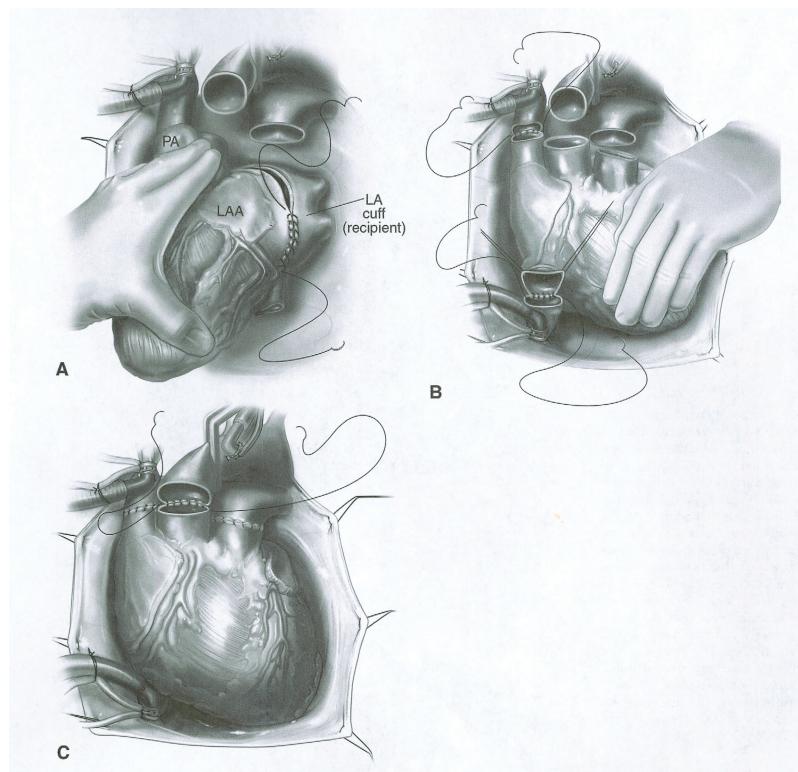
### Clinical Pearl

*Due to interruption of the cardiac plexus the efferent limbs of the autonomic nervous system are compromised, removing sympathetic and parasympathetic innervation to the transplanted heart. Inotropic and chronotropic responses are therefore dependent on endogenous circulating catecholamines. Hypovolemia does not result in the normal compensatory tachycardia.*

**Table 38.2** Transfusion Guidelines for ABO-Incompatible Heart Transplant Patients Receiving Transfusion

Recipient	RBC	FFP, Platelets or Cryoprecipitate
Group O (donor A, B, AB)	O	AB or donor type
Group A (donor B, AB)	A or O	AB
Group B (donor A, AB)	B or O	AB

**Figure 38.3** Orthotopic heart transplantation: bicaval anastomosis technique. From John R. and Liao K. Orthotopic heart transplantation. *Oper Tech Thorac Cardiovasc Surg* 2010; **15**: 138–46. With permission.



## What are common symptoms of heart failure in children and can they occur after heart transplantation?

Depending on the age of the child, heart failure symptoms can include failure to thrive, feeding dysfunction, lack of appropriate weight gain, nausea and vomiting, chest pain, abdominal pain, palpitations, increased daytime sleepiness, reduced exercise tolerance, and problems sleeping while supine [5]. Symptoms of ongoing rejection mimic those of heart failure prior to transplantation. The ability of transplant patients to experience chest pain is dependent on sympathetic afferent reinnervation and is not a reliable symptom. An abnormally high heart rate (tachycardia) may be present and representative of ongoing rejection, thereby warranting further evaluation.

## Anesthetic Implications

### What findings on physical examination warrant additional workup prior to an elective anesthetic?

Carefully worded, open-ended questions are necessary to elucidate accurate information regarding activity level, rest requirements after activity, and increased daytime sleepiness. Any significant change in physical activity level is worrisome and should be investigated further. The integrity of pacemakers and/or defibrillators should be queried, including last interrogation date and any patient-triggered discharges. Signs and symptoms of heart failure specific to children should be noted, including feeding dysfunction, early satiety, poor weight gain, nausea/vomiting, and dyspnea. Dependent edema, hepatomegaly, and jugular venous distension may be present as well. Unexplained tachycardia in the preoperative setting may be the only sign of subclinical rejection and warrants consultation with the transplant cardiologist.

#### Clinical Pearl

*Unexplained tachycardia may be a sign of subclinical rejection and should be investigated.*

### What imaging is important to order and/or review prior to an anesthetic?

A chest radiograph may show evidence of cardiomegaly, increased pulmonary vascular markings due to left heart failure, and fluid overload, all of which are highly suggestive of ongoing rejection. Reviewing computed tomography scans

and/or cardiac magnetic resonance imaging can be helpful in evaluating the patency of systemic veins and arteries. Of note, if the patient previously required ECMO prior to transplantation, neck and/or groin vessels may have been sacrificed and would therefore be inaccessible for future cannulation. Previous cardiac catheterization data, including filling pressures and vascular resistance calculations are important to note, with special attention paid to any trends. An electrocardiogram (ECG) may reveal arrhythmias and should be obtained prior to an anesthetic. Additionally, after induction of anesthesia it is important to be vigilant for any ST segment and/or rhythm changes. The most important imaging modality to review is the patient's most recent echocardiogram. An echocardiogram within the last 6–12 months is acceptable, unless new onset or worsening symptoms of heart failure are present, in which case a more recent study is warranted. Contractility, valvular function, and patency of anastomosed structures should be assessed.

### What preoperative labs should be ordered prior to this patient's anesthetic?

In addition to a thorough physical exam, basic preoperative labs should be obtained to evaluate for anemia, thrombocytopenia, and pre-tonsillectomy, any possible coagulopathies due to either medications or impaired liver synthetic function. Additionally, labs reflecting end-organ function such as blood urea nitrogen/creatinine, liver function tests, and brain natriuretic peptide or B-type natriuretic peptide are also important. Looking for trends in a patient's laboratory results can aid in differentiating between a stable or an acutely or chronically decompensating patient. B-type natriuretic peptide levels have a high sensitivity for evaluation of acute rejection in pediatric heart transplant patients. Some institutions will also order immunosuppressive drug levels to assess patient medication compliance, as rejection will increase morbidity and mortality.

#### Clinical Pearl

*Basic preoperative workup for elective nonthoracic or abdominal surgery should include:*

- Noting changes in activity level or medication compliance
- Chest radiograph (day of surgery, if recent changes noted in clinical status)
- Echocardiogram (within 6 months) unless worsening symptoms present
- Cardiology/transplant clinic visit (within 6 months)
- Basic labs (coagulation panel, hemoglobin/hematocrit, platelet count, electrolytes, BUN/creatinine, and liver enzymes)

## Which commonly utilized anesthetic medications are effective and ineffective in a transplanted heart?

Due to a lack of parasympathetic innervation, anticholinergic therapies are ineffective and treatment for symptomatic bradycardia should rely on drugs with direct  $\beta$ -stimulation (isoproterenol) or electrical pacing. Cardiac medications with direct effect on  $\beta$ -receptors (agonist or antagonist) and calcium channel blockers will elicit their appropriate response. Another important consideration is the bradycardic effect of acetylcholinesterase inhibitors; advanced heart block has been reported in some transplant recipients with administration of anticholinesterase inhibitors.

### Clinical Pearl

*Due to a lack of parasympathetic innervation, anticholinergic therapies are ineffective and the best treatment for symptomatic bradycardia should rely on drugs with direct  $\beta$ -stimulation (isoproterenol) or electrical pacing.*

## What cardiac dysrhythmias are common in the transplanted heart?

There is a propensity to develop heart block after transplant because of an increased refractory period at the sinus node. Any implanted pacemaker should be interrogated before and after any operation (asynchronous mode should be programmed during the operation). Ectopic beats are more common than atrial or ventricular arrhythmias. The presence of ventricular dysrhythmias should be concerning for acute rejection due to CAV. Carotid massage and Valsalva maneuvers have no effect on heart rate in transplant patients due to vagal denervation [7].

## What ECG findings would be considered normal?

The ECG may show two separate P-waves due to recipient and donor atrial focus. Pacing spikes, if present, should be consistent with the programming of the pacemaker and/or implantable cardioverter-defibrillator.

## What should parents be told about anesthetic risk for elective surgery following heart transplantation?

Local, regional, or general anesthesia can be safely administered to pediatric heart transplant recipients. Little data

are available with regard to morbidity and mortality of surgical procedures after pediatric heart transplantation. However, data from adult heart transplant patients suggest a 15% rate of surgical complications, the most common categories being major bleeding (26%), impaired wound healing (22%), and local infections (22%) [11].

## What fasting considerations exist?

The American Society of Anesthesiologists (ASA) fasting guidelines of 8 hours for solids, 6 hours for formula, 4 hours for breast milk, and 2 hours for clear liquids should be followed. No special considerations are necessary for heart transplant patients undergoing elective noncardiac surgery.

## Is bacterial endocarditis prophylaxis indicated?

According to the American Heart Association subacute bacterial endocarditis prophylaxis guidelines [12], a cardiac transplant patient *with valvulopathy* is considered high risk for adverse outcome from endocarditis and should receive antibiotics, even if the specific operation does not require their use.

### Clinical Pearl

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## What anesthetic considerations exist with commonly utilized immunosuppressant medications in heart transplant patients?

Commonly utilized immunosuppressive agents include cyclosporine, azathioprine, antilymphocyte globulin, monoclonal antibodies, and corticosteroids.

Immunosuppressive agents may be divided into six groups according to their mechanism of action:

- **Broad-spectrum immunosuppressants:** corticosteroids
- **Calcineurin inhibitors:** cyclosporine and tacrolimus
- **Antiproliferative agents:** mycophenolate (MMF) and azathioprine
- **Antibodies against interleukin-2:** basiliximab and daclizumab
- **Mammalian target of rapamycin protein (mTOR) inhibitors:** sirolimus and everolimus
- **Mono- and polyclonal T-cell antibodies:** OKT3, antithymocyte globulin (ATG), antilymphocyte globulin

Patients may be treated with a combination of any of these agents in the perioperative period. The specific combination is largely dictated by institutional experience, new or recent episode of rejections, other comorbid conditions, and time since transplantation [13].

Individual agents deserve special considerations. The blood level of both cyclosporine and tacrolimus must be kept within a certain level to achieve the desired therapeutic effect. Both of these drugs are metabolized by the cytochrome P450 system of the liver, and therefore many drugs administered perioperatively can affect their plasma levels. In addition, the two mTOR inhibitors used in cardiac transplantation, sirolimus and everolimus, have been associated with impaired wound healing that results in higher rates of wound complications. In transplant patients undergoing elective noncardiac surgery, mTOR inhibitors should generally be stopped at least 1 week prior to surgery, with resumption approximately 10–15 days after surgery once adequate wound healing has been achieved [14]. However, any adjustments to immunosuppression regimens should be discussed with the primary transplant team.

Arterial hypertension is relatively common after transplantation; it is present in 75% of patients in long term follow-up. Early risk factors include the administration of calcineurin inhibitors and corticosteroids, especially when administered in high doses. Renal dysfunction, although uncommon, is also another complication after early initiation of calcineurin inhibitors, especially when drug levels are elevated.

Another important consideration is the interaction of grapefruit juice with the metabolism of specific immunosuppressant medications. Grapefruit juice is an inhibitor of the intestinal cytochrome P450 3A4 system, which is responsible for the first-pass metabolism of many medications. As such, grapefruit has marked effects on blood levels of cyclosporine, 1,4-dihydropyridine calcium antagonists, and some 3-hydroxy-3methylglutaryl coenzyme A reductase inhibitors.

## Is there a need for stress dose steroids?

Corticosteroids were widely used in the pre-cyclosporine era. More recently, steroids have been used during the induction phase of immunosuppression (pulse dose steroids tapered for 7 days in combination with thymoglobulin) or during episodes of acute rejection. Many institutions attempt to minimize the use of corticosteroids due to their extensive list of known side effects. Some studies suggest steroids may be withdrawn soon after transplantation in low-risk patients without circulating anti-HLA antibodies and in those without a history of rejection. However, patients receiving more than

20 mg/kg of prednisone or its equivalent for more than 3 weeks should be considered to have a suppressed hypothalamic-adrenal axis (HAA) and are at risk of adrenal insufficiency with the stress of surgery. The HAA is not suppressed with doses of less than 5 mg/day of prednisone or its equivalent, whereas intermediate doses have equivocal effects on axis suppression [10]. However, even patients taking low or intermediate doses should receive stress dose steroids if unexplained intraoperative hypotension persists despite adequate resuscitation from fasting or blood loss.

### Clinical Pearl

*Perioperative administration of stress dose steroids should be considered for patients receiving steroids as part of their immunosuppression regimen.*

## Are there interactions between immunosuppressants and commonly utilized anesthetic agents?

Immunosuppression represents a unique challenge during the perioperative period of any heart transplant patient undergoing noncardiac surgery. It potentially contributes to an increased risk of infection, delayed wound healing, drug interactions, and more importantly, hemodynamic instability due to adrenal insufficiency. Evidence of major drug interactions between immunosuppressants and anesthetic agents is lacking; however, minor reactions have been reported [5, 9].

### Corticosteroids

- **Prednisone** and **methylprednisolone** are known to decrease the effectiveness of nondepolarizing neuromuscular blockers, prolong muscle weakness, and promote steroid-related myopathy. If succinylcholine is used, expect prolonged neuromuscular blockade.

### Calcineurin Inhibitors

- **Tacrolimus:** Sevoflurane and ondansetron are associated with QT-prolongation. Furosemide and bumetanide may precipitate acute renal failure. Diltiazem, verapamil, and amiodarone may increase the risk of QT-prolongation and increase tacrolimus levels.
- **Cyclosporine:** Midazolam clearance is decreased in the presence of cyclosporine. Cyclosporine is a weak CYP3A4 inhibitor, and thus the potential of increased opioid toxicity exists.

Nonsteroidal antiinflammatory agents are generally contraindicated in heart transplant patients due to the risk of renal failure when combined with some immunosuppression agents.

Chronic immunosuppressive therapy has multiple adverse effects, including diabetes, hyperlipoproteinemia, hypertension, lowered seizure threshold, hyperkalemia, hypomagnesemia, increased risk of wound infections, pancytopenia, and poor wound healing [15].

## Is invasive monitoring indicated?

The degree of intraoperative monitoring will depend on the type of surgery as well as the availability of monitoring. In the case of elective major surgery (intrathoracic or abdominal) or emergent surgery, monitoring of invasive arterial blood pressure and central venous pressures may be indicated. Perioperative invasive monitoring requires special attention to aseptic technique to minimize the risk of infection and should be discussed in terms of the risk/benefit ratio. For minor surgery such as a tonsillectomy and adenoidectomy, the use of recommended ASA standard monitoring with 5-lead ECG is acceptable.

## What methods are appropriate for induction of anesthesia?

Either intravenous (IV) or inhalation induction is safe for heart transplant recipients who remain healthy. Age, cognition, weight, comorbidities, and cardiac reserve are factors that should be considered when planning an induction. If concern for rejection exists, a carefully titrated IV induction is safer. Transplanted patients have increased systemic vascular resistance (SVR) and are dependent on venous return for cardiac output. The use of any technique that may suddenly reduce either venous return or SVR necessitates careful monitoring. When considering general endotracheal anesthesia, oral endotracheal intubation is preferred over nasal intubation because of potential infection caused by nasal flora and blood loss from friable nasal mucosa. The use of a laryngeal mask airway is acceptable in appropriate situations.

## What is an appropriate anesthetic maintenance strategy for patients post-transplantation?

The ability of post-transplant patients to tolerate premedication is similar to patients without transplant. The intraoperative anesthetic strategy is dictated by the underlying surgical diagnosis and any other complicating factor that may be present. Following safe and uneventful induction of anesthesia, maintenance of anesthesia can be

provided with a combination of IV and inhaled anesthetics. Most forms of anesthesia and sedation are well tolerated in cardiac transplant patients with stable graft function.

## Are there any special drug or equipment considerations based on the physiology of the transplanted heart?

The occurrence of advanced heart block and cardiac arrest have been reported after the use of either pyridostigmine or neostigmine to reverse neuromuscular blockade. Bradycardia has also been reported after reversal with sugammadex, so it is unclear whether this drug is a safe alternative in this population. Careful attention to intraoperative volume status is warranted to avoid hypotension. Because of the absence of reflex sympathetic tachycardia due to autonomic denervation, heart transplant patients may be very sensitive to the vasodilating properties of anesthetics such as propofol and volatile agents. Additionally, knowledge of the mechanisms of metabolism and excretion for anesthetic drugs is imperative. The presence of chronic kidney disease may diminish the ability to excrete various anesthetics. In the absence of any hepatic or renal insufficiency, there are no strict contraindications to using an IV versus inhaled anesthetic technique.

### Clinical Pearl

*The occurrence of advanced heart block and cardiac arrest have been reported after the use of either pyridostigmine or neostigmine to reverse neuromuscular blockade.*

## Can patients post-heart transplant undergo same-day surgery?

Post-heart transplant patients who have stable graft function, are on stable maintenance immunosuppressive therapy, and have recently undergone evaluation by their transplant cardiologist can be appropriate candidates for same-day surgery for low-risk procedures when minimal concern exists for postoperative pain or limited functional capacity. Nevertheless, planned outpatient procedures (annual catheterization, endoscopy, or magnetic resonance imaging) should still be performed at a hospital with in-house cardiology consultants, heart transplant team, and admission capability should any complication arise. This patient would be suitable to undergo same-day surgery with recovery in the post-anesthesia care unit and discharge home after meeting appropriate discharge criteria. If the patient experienced postoperative nausea and/or

vomiting resulting in limited oral intake, it would be prudent to plan overnight hospital admission.

## Do specific postoperative concerns exist?

Early extubation is desirable to minimize the risk of ventilator-associated pneumonia. Depending on the surgical procedure, the function of other organs (kidney and liver) should be closely monitored by laboratory testing. The kidneys are at risk for acute kidney injury in the presence of large volume loss and hypotension. Also, the ECG should be monitored in the immediate postoperative period for signs of silent ischemia due to high demand states, such as shivering, uncontrolled pain, and fever.

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