Cardiopulmonary transplantation: anaesthetic implications

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Abstract

Heart and lung transplantation rates continue to rise with median survival rates of 11 and 7 years, respectively. Lung transplantation is definitive therapy for end-stage lung disease with indications categorized as suppurative, obstructive, restrictive and pulmonary vascular. Surgical options include single lung, bilateral sequential single lung, and heart lung transplantation. All have their own intraoperative challenges, especially at induction, commencement of positive pressure ventilation, one lung ventilation, pulmonary artery clamping and lung reperfusion. A double lumen tube and a period of one lung ventilation is generally required for cases performed without cardiopulmonary bypass. Strategies to reduce pulmonary pressures and support right ventricular dysfunction are important. Perioperative fluids are minimized and lung protective strategies implemented to optimize lung function. Thoracic epidural anaesthesia is commonly used for postoperative pain management. The most common indication for heart transplantation is non-ischaemic cardiomyopathy (55%). Left ventricular assist devices are often used as a bridge to transplantation. Communication between donor and recipient teams is critical. Reversal of anticoagulation and alteration of settings of implanted medical devices may be necessary. Anaesthetic management requires invasive monitoring, optimization of ventricular function and preparation for coagulopathy. Right ventricular dysfunction is the cause of early mortality in 20% of recipients.

Keywords Heart transplantation; lung transplantation; pulmonary hypertension; trans-oesophageal echocardiography

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Introduction

Cardiopulmonary transplantation is an effective and evolving treatment for advanced cardiac, pulmonary and pulmonary vascular diseases. The number of heart and lung transplants has continued to rise over the past decade with 4196 heart and 3719 lung transplants reported to the International Society for Heart-Lung Transplantation (ISHLT) in 2012.[1] Advanced preoperative illness and a dynamic intraoperative period with a spectrum of potential perioperative events presents significant management challenges to the anaesthetist.

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Learning objectives

After reading this article, you should be able to:

- list the common indications for heart and lung transplantation
- describe the basic pathophysiology before and after transplantation
- explain the anaesthetic considerations for heart and lung transplantation

Lung transplantation

Lung transplantation was first performed in 1963 but it was not associated with reliable outcomes for 20 years.[2] Today it is regarded as the definitive therapy for end-stage lung disease. Indications can be categorized broadly into suppurative, obstructive, restrictive and pulmonary vascular (Box 1).[3] Chronic obstructive pulmonary disease remains the most common indication but is now closely followed by interstitial lung disease.[1] Consideration for lung transplantation occurs when there is end-stage disease and transplantation is likely to provide an improved quality of life with mortality benefit. Clinical trajectory, functional status and quality of life must be considered in this process. International disease specific listing criteria were updated by the ISHLT in 2015.[4] Contraindications to lung transplant include recent malignancy, untreatable advanced dysfunction of another major organ, BMI >35 kg/m^2, significant chest wall/spinal deformity, non-compliance with medical therapy, absence of social support, substance addiction and psychiatric conditions with an inability to comply with medical therapy. With increased experience in lung transplantation there has been a gradual broadening of suitability criteria. In addition to appropriate size and ABO compatibility between donor and recipient, lung allocation takes into account clinical urgency and time on the waiting list.

Indications for lung transplantation

- Obstructive
  - Chronic obstructive pulmonary disease (smoking related)
  - Alpha- 1 antitrypsin disease
  - Bronchiectasis
  - Re-transplant: bronchiolitis obliterans
- Restrictive
  - Idiopathic pulmonary fibrosis
  - Pulmonary fibrosis, other
  - Sarcoidosis
  - Connective tissue disease
- Suppurative
  - Cystic fibrosis
- Pulmonary vascular
  - Idiopathic pulmonary arterial hypertension
  - Congenital heart disease

Box 1

Four types of lung transplantation are practised: single lung (SLTx), bilateral sequential single lung (BSSLTx), heart lung (HLTx) and living related lobar transplantation. Initially SLTx was the preferred technique as it is technically simpler and allows a greater number of recipients from a limited donor pool. It is avoided in recipients with suppurative disease (cystic fibrosis) due to potential contamination of the transplanted lung. In pulmonary vascular disease (pulmonary artery hypertension), SLTx would direct the majority of the cardiac output (CO) through the low-resistance transplanted lung, potentially inducing injury. Additionally, SLTx results in lungs with different compliance, complicating intraoperative and postoperative ventilation strategies. More recently there has been a trend towards BSSLTx for all indications. This eases ventilation management as well as improves the more significant outcome mortality.[5] BSSLTx evolved after experience with double lung transplantation demonstrated a high incidence of ischaemia in the tracheal anastomosis. Now, BSSLTx is the most common technique for all indications.[1] HLTx is reserved for patients with complex congenital heart disease and certain cases of pulmonary artery hypertension where recovery of the right ventricle (RV) is felt to be unlikely. There were only 75 adult HLTx reported in 2012.[1] Living related lobar transplantation, introduced in the 1990s, is rarely performed due to concerns about donor complications and lack of survival advantage in recipients, as compared to conventional techniques.[2]

Assessment of the patient for lung transplantation requires a multidisciplinary approach with input from many specialties. There has been a trend towards centres performing higher numbers of transplants (>30/yr) demonstrating improved outcomes in comparison with lower volume centres.[1] A thorough preoperative workup occurs during assessment and prior to listing. It is important to note that the disease may have progressed by the time surgery occurs. Pulmonary function tests assist with understanding the nature of the lung disease (restrictive/obstructive) and guide intraoperative ventilation. Lung perfusion scans will determine which side will tolerate one lung ventilation (OLV) more efficiently and thus order of transplantation in BSSLTx. Transthoracic echocardiography (± right heart catheterization) evaluates pulmonary pressures and the effect of chronic lung or pulmonary vascular disease on the RV. This allows the anaesthetist to develop induction and intraoperative strategies to support RV function and treat pulmonary hypertension. Additionally it will assist in determining the probability of cardiopulmonary bypass (CPB) being required, although this is used routinely at some centres. Whether CPB alters short- and long-term outcomes remains controversial, but its use may be associated with prolonged postoperative mechanical ventilation and pulmonary oedema.[3]

Important phases during the procedure include induction, commencement of positive pressure ventilation, initiation of OLV, pulmonary artery clamping and lung reperfusion. The approach to induction and maintenance of anaesthesia will depend on the indication for lung transplant as well as the comorbid disease burden. The recipient's normal medication is continued, especially bronchodilators, antibiotics and pulmonary vasodilators. Immunosuppressive and antibiotic medications are started preoperatively. A thoracic epidural is often placed prior to induction. If there is high likelihood of requiring CPB, or a turbulent immediate postoperative course expected this may be deferred to the postoperative period. Invasive haemodynamic monitors, including arterial line, central venous and pulmonary artery catheters (PAC) are routine.

The haemodynamic goals of induction include maintenance of contractility and systemic vascular resistance while avoiding acute increases in pulmonary vascular resistance (PVR). The utility of transoesophageal echocardiography (TOE) is well established to evaluate the right and left heart, determine the aetiology of periods of haemodynamic instability, detect the presence of intracardiac air and assess pulmonary vein flows post-transplant. A double lumen tracheal tube (DLT) is generally used to allow for OLV, with fibreoptic bronchoscopy to confirm position. Selection of a ventilation strategy is critical. Patients with obstructive lung disease will require larger tidal volumes, prolonged expiratory time and a slow respiratory rate to avoid dynamic hyperinflation and potential pneumothoraces. End tidal CO_2 will underestimate $PaCO_2$ given significant alveolar dead space. Suppurative lung disease frequently causes poor gas exchange and may require aggressive pulmonary toilet via a single lumen tube (SLT) prior to DLT placement. Restrictive lung disease necessitates small tidal volumes, short inspiratory times and high airway pressures. Some disease processes such as cystic fibrosis and bronchiolitis obliterans may have components of both restrictive and obstructive lung diseases. Patients with severe pulmonary hypertension may require the initiation of peripheral CPB under local anaesthetic prior to induction.

Perioperative fluids are used judiciously to limit pulmonary oedema in the vulnerable transplanted lung that lacks lymphatic drainage. Vasopressors are employed to limit the effects of peripheral vasodilatation and maintain adequate perfusion pressure. We preferentially use noradrenaline (1–10 mcg/min) as a first line agent. During pneumonectomy, a clamp is placed on the pulmonary artery. This improves oxygenation by limiting ventilation/perfusion mismatch but the acute increase in RV afterload may impair its function. The RV may also fail at induction, during OLV or lung reperfusion. Management of this includes avoiding hypoxemia, hypercapnia, acidosis and hypothermia but pharmacologic therapy is frequently needed. Common agents to support right heart function include noradrenaline (1–10 mcg/min), vasopressin (0.01–0.04 units/kg/h), adrenaline (1–10 mcg/min), milrinone (0.125–0.75 mcg/kg/min) and nitric oxide (20–40 ppm). Despite its attractive properties, nitric oxide has a limited role outside of acute RV failure. Noradrenaline is often an effective choice as it raises perfusion pressure to the RV without increasing oxygen demand. Surgical access on the right frequently results in dysrhythmias and compression of the superior vena cava, while left sided access compresses the left ventricle (LV).

Implantation of the lung requires anastomosis of the main bronchus, pulmonary vein cuff and pulmonary artery. After back bleeding, clamps are released and the lung reperfused. This is a dynamic period with potential for significant haemodynamic instability. Contributors include the washout of ischaemic metabolites, bleeding and embolism of residual air. A protective strategy (4–6 ml/kg, lowest acceptable FiO_2 and titrated PEEP) is used to ventilate the implanted lung. If a BSSLTx is being performed, this process is repeated on the other side. In patients with pre-existing pulmonary hypertension it is usual to expect pulmonary pressures to normalize. At the end of the procedure, the DLT is exchanged for an SLT and the patient transported to