Cardiopulmonary transplantation

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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

Abstract

Heart and lung transplantation rates continue to rise with median survival rates of 11 and 7.4 years, respectively, with transplantation becoming the definitive therapy for end-stage disease of each system. Indications for lung transplantation are categorized as suppurative, obstructive, restrictive and pulmonary vascular. Surgical options include single lung, bilateral sequential single lung and heart–lung transplantation. Each has 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 function 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. Ventricular assist devices and inotropic infusions are often used as a bridge to transplantation. Communication between donor and recipient teams is critical. Reversal of anticoagulation and alteration 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 leading cause of early mortality.

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

Royal College of Anaesthetists CPD Matrix: 3G00

Introduction

Cardiopulmonary transplantation is an effective and evolving treatment for advanced cardiac, pulmonary and pulmonary vascular diseases. The number of paediatric and adult heart and lung transplants has continued to rise over the past decade with 5074 heart, 4218 lung and 46 heart–lung transplants reported in the most recent data to the International Society for Heart–Lung Transplantation (ISHLT) in 2015. The complexity of cases is increasing with advancing recipient age, broadening of suitability criteria, growing use of combined organ transplants, and changes in interim supports and post-transplant care. Advanced preoperative illness and a dynamic intraoperative period with a spectrum of potential perioperative events presents significant management challenges to the anaesthetist.[1]

Lung transplantation

Lung transplantation was first performed in 1963 but it was not associated with reliable outcomes for 20 years. 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 (e.g. 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 with significantly improved survival.[4] Bilateral sequential single lung transplant evolved after experience with double lung transplantation demonstrated high incidence of ischaemia in the tracheal anastomosis as the bronchial arteries are not anastomosed. Now, BSSLTx is the most common technique for all indications. Heart–lung transplant has decreased in frequency over the past 25 years. It is now reserved for patients with complex congenital disease and certain cases where the recovery of the right ventricle (RV) after exposure to persistent pulmonary hypertension is felt to be unlikely. There were only 38 adult and 8 paediatric HLTxs reported in 2015. Heart–lung transplant recipients have a high early mortality, with a median survival of 3.3 years. However, this improves in those who survive the first year to median survival of 10.3 years.[2] 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.[4,5]

Today, lung transplantation is regarded as the definitive therapy for end-stage lung disease and is considered when transplantation is likely to provide an improved quality of life

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and mortality benefit. Public education has increased organ donation awareness; however, the number of patients awaiting transplant still exceeds the number of suitable lung donors. Several strategies have evolved to increase the donation pool. Tailored lung donor management protocols have been shown to enhance organ utilization — from 25% to greater than 65% at some institutions.[4] Lung protective ventilation strategies in potential donors has expanded both donor eligibility and survival in transplant recipients. Donation after circulatory death (DCD) has further expanded the donor pool and now makes up as much as 30% of donor organs in some hospitals, and is associated with lower rates of primary graft dysfunction than after brain dead donation.[4] The partial liberalization of donor recruitment, referred to as extended criteria or marginal donors, includes donors who are older, have a history of smoking, a lower PaO_2/FiO_2 ratio or with mild pulmonary infiltrates on chest X-ray.[5] The use of marginal donors is still an area of increasing experience, but does not seem to negatively influence overall survival.[3] Ex-vivo lung perfusion (EVLP), where donor lungs are connected to a purpose-built perfusion circuit either immediately after donation or delayed until arrival at the recipient hospital, is another strategy to preserve and optimize donor lungs. It allows reconditioning and evaluation of injured lungs and reduces the effects of cold ischaemia. While the clinical role of this is yet to be defined, it is now available in some centres and is hoped to expand the utilization rate of organs offered for donation.[3,4]

Clinical trajectory, functional status and quality of life must be considered in both suitability for transplant listing and resource allocation.[3] There has been a steady increase in recipient age, comorbid disease burden and complexity.[5] In addition to appropriate size and ABO compatibility, lung allocation takes into account clinical urgency and time on the waiting list. There has been an expansion in recent years in combined thoracic and abdominal organ transplants, for example kidneys and liver.[1,2] Despite sicker and older patients presenting for transplantation, survival post transplantation continues to improve, although there is little high quality evidence to guide resource allocation by greatest long term survival benefit.[3]

Indications for lung transplant can be categorized broadly into suppurative, obstructive, restrictive and pulmonary vascular (see Box 1). Chronic obstructive pulmonary disease remains the most common indication but is now closely followed by interstitial lung disease. International disease specific listing criteria were updated by the ISHLT in 2015.[10] Contraindications to lung transplant include recent malignancy, untreatable advanced dysfunction of another major organ (unless proposed as combined organ transplantation), 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.

Assessment of the patient for lung transplantation requires a multidisciplinary approach. There has been a trend towards centres performing high numbers of transplants (>30/year) demonstrating improved outcomes in comparison with lower volume centres (see Figure 1).[2] 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 the intraoperative strategies to support RV function and treat pulmonary hypertension. Additionally it will assist in determining the need for intraoperative extracorporeal haemodynamic support; either cardiopulmonary bypass (CPB) or extracorporeal membrane oxygenation (ECMO). Although these are used routinely at some centres[6] our practice has been to employ such support only in selected cases [10−15%], as CPB support is associated with prolonged postoperative mechanical ventilation and pulmonary oedema and has been linked to primary graft dysfunction.

There is some retrospective evidence for the use of ECMO both as a bridge to transplantation and intraoperatively in lieu of CPB. Preoperatively it may be used as a bridge to transplant; however, complications are common and there is a dramatic decline in survival if bridging therapy lasts longer than 14 days. Even once transplanted, bridged patients have higher rates of primary graft dysfunction and lower survival rates.[3,4]

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 medications are continued, especially bronchodilators, antibiotics and pulmonary vasodilators. Immunosuppressive and antibiotic medications are started preoperatively. Invasive haemodynamic monitors, including arterial line, central venous and pulmonary artery

Indications for lung transplantation[4]

- 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

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