52 y/o with hx of HTN, severe COPD for single-lung transplantation

52 y/o man with progressively worsening dyspnea on exertion, limitation of daily activity despite supplemental oxygen, and radiographic and spirometric evidence of severe obstructive pulmonary disease was scheduled for single-lung transplantation. History was remarkable for a one pack per day for 30 years smoking history (although none for 10 years) and mild hypertension.

Discussion questions:

What were the expected manifestations of severe obstructive pulmonary disease in this patient, and why was he a transplant candidate?

This patient suffered from increased airway resistance, reduced expiratory flow rates, and high residual lung volumes. When expiratory airway obstruction and lung hyperinflation become so severe that the chest cannot physically expand to accommodate a normal tidal volume, restrictive physiology becomes superimposed on obstructive disease. This condition is usually refractory to medical management and substantially limits daily activity. This patient’s age and lack of other major systemic illness allowed him to be considered a transplant candidate.

Chronic obstructive pulmonary disease (COPD) (often secondary to smoking), emphysema secondary to at-antitrypsin deficiency, and cystic fibrosis are the most common obstructive disorders in adults undergoing lung transplantation. At one time, concerns about mediastinal displacement and profound ventilation/perfusion mismatch secondary to hyperinflation of the remaining native lung prevented surgeons from attempting single-lung transplantation for emphysema. However, clinical experience has demonstrated that many emphysemic patients can be successfully treated by single-lung transplantation. Because of the severe shortage of organs for transplant, single-lung procedures have been advocated as a means to increase the number of recipients. However, increasing experience suggests that bilateral lung transplantation for COPD is associated with improved functional outcomes and perhaps improved long-term survival compared with single-lung transplantation. Nonetheless, although transplantation may improve the quality of life for patients with severe COPD, recent data
question whether either single or bilateral lung transplant has significant survival benefit.


How does a single-lung transplantation differ technically from a double-lung transplantation?

It is extremely important that anesthesiologists be broadly familiar with the surgical methods, because manipulation of the heart and lungs at specific points during the transplantation can produce marked cardiopulmonary disturbances. Ideally, the anesthesiologist will anticipate these changes and adapt the anesthetic management accordingly. Description of the detailed technical aspects of lung transplantation are readily available.

Single-lung transplantation is usually performed in the lateral decubitus position through a thoracotomy incision, often with the upper leg and pelvis angled to allow groin exposure for potential femoral cannulation and CPB. In contrast, bilateral sequential lung transplantation is usually performed with the patient supine through a “clamshell” incision (bilateral anterior thoracotomies with or without transverse sternotomy). For both single-lung and bilateral lung transplantation, intermittent single-lung ventilation is required during dissection of the native lung to be removed and implantation of the graft. Once stable single-lung ventilation is established, dissection of the lung to be transplanted is initiated with isolation of the PA. To assess the cardiopulmonary response to diverting the entire cardiac output through one lung, progressive temporary occlusion of the vessel is first performed manually; if well tolerated, the vessel is then clamped and stapled. After ligation of the PA, the pneumonectomy is completed. Implantation of the graft begins with anastomosis of the airway. In the past, the bronchial anastomosis was wrapped with an omental pedicle, mobilized through a small abdominal incision in an effort to improve blood supply to the airway and promote healing. However, the use of a “telescoping” bronchial anastomosis has now largely obviated the need for omental wrapping. The PA branch is then attached to the graft, followed by anastomosis of a cuff of
the left atrium containing the pulmonary veins. The implanted lung is then partially inflated, the left atrial cuff and pulmonary veins deaired, and circulation to the organ restored. Patients presenting for single-lung transplantation with chronic persistent pulmonary hypertension (PPH) of primary or secondary etiology often exhibit severe functional compromise of the right ventricle. To avoid additional right ventricular stress, many institutions choose to institute partial normothermic CPB during single-lung transplantation for PPH or in patients with severe pulmonary hypertension and right ventricular dysfunction secondary to restrictive or obstructive disease. Cannulation is typically through the femoral artery and the right atrium unless simultaneous correction of an intracardiac defect is planned. In such patients, conventional aortic and single- or double-stage atrial cannulation are performed. Implantation of the lung is otherwise performed in the same manner as described earlier.

Double-lung transplantation was first described by the Toronto Lung Transplant Group in the mid-1980s as en bloc implantation of both lungs simultaneously. The procedure is performed through a median sternotomy using hypothermic CPB, cardioplegic cardiac arrest, and single tracheal (or double bronchial) anastomosis of the trachea and main PA. Although the procedure initially produced encouraging results, considerable limitations related to technical complexity, morbidity, mortality, and application to many patients with end-stage lung disease soon became apparent. Not surprisingly, use of this procedure declined sharply and has now been largely replaced by the bilateral sequential implantation technique, which does not uniformly require hypothermic CPB. Introduced in 1990, bilateral sequential (or bilateral single) lung transplantation has become the surgical procedure of choice when replacement of both lungs is necessary. As noted earlier, in contrast to single-lung transplantation, bilateral sequential lung transplantation procedures are performed in the supine position. In general, the procedure can be regarded as having two phases. First, the most severely compromised lung (as determined by preoperative ventilation/perfusion lung scanning) is removed during ventilation of the “good” contralateral lung. Implantation is achieved through a bronchial anastomosis as with a single-lung transplantation. The second lung is then removed and transplanted during ventilation of the new lung alone.
Is preoperative epidural catheter placement advantageous?

Pain control after lung transplantation can be critical in facilitating patient extubation and rehabilitation. Both lumbar and thoracic epidural catheters have been used for postoperative pain management. At many institutions, catheters are placed immediately before the procedure in most patients, despite the rare possibility of anticoagulation and CPB during the transplantation procedure. This practice is supported by data indicating no adverse sequelae to preoperatively placed epidural catheters, including patients who required emergent heparinization and CPB. Obvious exceptions to this approach are patients anticoagulated preoperatively or those in whom CPB is planned. Delaying placement of the epidural catheter until the postoperative period may actually increase the potential risk of complications, because both hemodilution and immunosuppression tend to promote a coagulopathy.


How would you ventilate this patient? What kind of endotracheal tube would you use?

After induction, the trachea is usually intubated with a left endobronchial double-lumen tube (DLT) for both single-lung and bilateral lung transplantation. Use of a single-lumen endotracheal tube with either an external or an internal bronchial blocking catheter has been described but does not appear to be clearly superior to the left endobronchial tube for most procedures. Furthermore, an endobronchial tube allows for differential lung ventilation if required postoperatively. One exception to this approach has been in patients with cystic fibrosis who exhibit thick tenacious secretions that are difficult to suction through the small-lumen suction
catheters necessary for DLTs. In these patients, it is often helpful to first place a large single-lumen tube and perform extensive bronchoscopic-directed bronchial lavage and suctioning before placement of the DLT. The transition from spontaneous to mechanical ventilation invariably produces hemodynamic alterations resulting from acute changes in intrathoracic pressure and chest wall compliance. With obstructive lung disease, mechanical ventilation magnifies airtrapping, leading to "pulmonary tamponade." Varying degrees of this phenomenon should be expected during anesthesia induction. The treatment consists of intermittent apnea with an open ventilator circuit, adjustment of the ventilatory pattern to an I : E ratio of 1 : 5 or less with moderate tidal volumes, and administration of bronchodilating drugs. Prompt restoration of blood pressure usually ensues. If hypotension persists, other causes of circulatory compromise must be excluded including pneumothorax. With restrictive disease, higher inflation pressures and positive end-expiratory pressure (PEEP) are often required. In patients with obstructive and patients with restrictivedisease, optimal balance of ventilation with hemodynamic stability often necessitates tolerating a degree of hypercapnia. In pulmonary hypertensive patients, mechanical ventilation usually produces less cardiovascular disturbance if caution is exercised not to increase pulmonary vascular resistance (e.g., from hypoxia, hypercarbia, or lung hyperinflation.

Because lung recipients have little pulmonary reserve, ventilation with 100% oxygen is commonly used intraoperatively. Although this approach is somewhat controversial, few data suggest acute oxygen toxicity to a transplanted lung. High Pao2 may also directly promote pulmonary vasodilation and therefore be beneficial in reducing right ventricular afterload.


How does single-lung ventilation affect cardiopulmonary function? What are the problems of single-lung ventilation in this patient? How would you treat them?

Isolated ventilation of the dependent lung is often accompanied by a marked acute increase in peak inspiratory pressure and a subsequent gradual progressive rise in PA pressure. Because of the beneficial effect of gravity on redistributing blood away from the nondependent nonventilated lung, single-lung ventilation is often tolerated better from a respiratory standpoint by patients undergoing single-lung transplantation in the lateral position than those undergoing bilateral lung transplantation in the supine position. Close monitoring of right ventricular performance during conversion to single-lung ventilation is extremely important because of the increase in afterload produced by hypoxic vasoconstriction and redistribution of blood flow. Though unusual, if the right ventricle becomes hypokinetic and distended, and if the ejection fraction decreases, ventilation may have to be altered to minimize airway pressure.


How would you deal with problems related to clamping of the PA?

To assess the cardiopulmonary response to diverting the entire cardiac output through one lung, progressive occlusion of the vessel is first performed manually. Careful assessment of right ventricular function is performed with the TEE looking for evidence of right ventricular distension or hypokinesis. If well tolerated, the vessel is then clamped and stapled. If occlusion is poorly tolerated, the vessel is unclamped and a pulmonary vasodilator such as prostaglandin E1 or NO and/or positive inotropic infusion begun. If severe respiratory or cardiovascular derangement persists after reclamping of the vessel despite pharmacologic intervention, heparin is administered and CPB instituted to avoid profound hypoxia or right ventricular failure. However, for most patients undergoing single-lung transplantation, hypoxemia during single-lung ventilation and after PA clamping is rarely a problem and right ventricular performance can be adequately maintained.

When is CPB necessary for lung transplantation?

CPB may be used electively for patients with severe PA hypertension, in whom double-lumen endobronchial tubes cannot be placed, or when visualization of hilar structures is poor. However, in the absence of intraoperative complications, CPB is not desired because it can increase bleeding and blood product usage. It has also been suggested that CPB may aggravate postoperative lung dysfunction although this has not been evident in cases where lung transplant was performed in conjunction with cardiac surgery. Nonetheless, the use of CPB has been associated with longer duration of mechanical ventilation and hospitalization, although it is difficult to differentiate whether the latter results directly from CPB or is the result of a complicated procedure that resulted in the need for CPB. Indications for CPB include right ventricular dysfunction not responding to medical therapy, early graft dysfunction occurring during implantation of the second lung during bilateral procedure and surgical misadventures. Unplanned CPB is reported to occur in 17% to 41% of lung transplantation procedures, but predicting which patients may require this intervention is extremely difficult. Some report that CPB is more likely to be necessary for restrictive lung diseases than obstructive diseases.

In an attempt to derive the benefits of CPB while reducing complications, some centers advocate the use of heparin-bound ECMO systems. This approach allows for pulmonary support both during and after the procedure with minimal systemic anticoagulation.


What are the major complications after lung transplantation?

Early graft dysfunction, episodes of rejection, infection, and airway complication are the major early complications of lung transplantation. Early graft dysfunction varies in severity from mild shunting and chest radiograph infiltrates to gross pulmonary edema. Management is with fluid restriction, diuretics, PEEP, NO, and ECMO for severe cases.

Immunosuppression is usually initiated before surgery and the induction phase of therapy is continued for 5 to 10 days. The exact regimen varies between institutions but typically includes azathioprine, steroids, cyclosporine, and polyclonal antilymphocyte/antithymocyte globulins or interleukin-2 receptor antagonists. Acute rejection episodes are usually treated with intense steroid therapy and optimization of other immunosuppressant dosages. A challenge arises in differentiating acute rejection from infection as a source of shunting and chest radiograph infiltrates. Transbronchial biopsy is often necessary to make the distinction from histologic specimens. Bacterial pneumonia is the most frequent infection in the first 2 weeks. Though unusual in the first 2 weeks after transplantation, cytomegalovirus is the second most common source of infectious pneumonitis. This virus is treated with ganciclovir. Broad-spectrum antibiotics are given perioperatively, and the regimen is adjusted based on the results of donor and recipient cultures. Antibiotic therapy for patients with cystic fibrosis is challenging, and the drug chosen is dictated by the patient’s cultures and
prior history of the organisms colonizing his or her lungs. Prophylactic acyclovir appears to be effective in reducing infections caused by herpes simplex, and trimethoprim-sulfamethoxazole is given to prevent infections from Pneumocystis carinii.


What special precautions should be taken when a lung transplant recipient requires general anesthesia for subsequent nonpulmonary surgery?

In general, after lung transplantation, the patient can be treated like any other ill immunocompromised patient. Recipients have subsequently undergone various surgical procedures unrelated to their pulmonary disease after lung transplantation and have few anesthetic problems. Not surprisingly, differences in the compliance and expiratory flow rates of a native and transplanted lung after single-lung transplantation for emphysema can result in alterations in intraoperative capnography. This phenomenon has been described as producing a biphasic pattern of carbon dioxide exhalation, with the first peak reflecting exhalation from the transplanted lung and the second peak exhalation from the native lung. In addition, the transplanted lung is denervated so the cough reflex is present only in the proximal native airway and mucociliary function is impaired. In contrast, hypoxic pulmonary vasoconstriction is intact after lung transplantation and central respiratory control is unaffected. However, a blunted response to carbon dioxide may persist for patients with preoperative hypercapnia.

The major factor limiting long-term survival from lung transplantation is bronchiolitis obliterans. This progressive condition characterized by progressive narrowing of small airways must be considered in patients with prior lung transplantation presenting for surgery and anesthesia after the initial recovery phase.