CT of Complications in Pediatric Lung Transplantation

L. Santiago Medina, MD
Marilyn J. Siegel, MD

The authors review the computed tomographic (CT) findings following single and double lung transplantation in children to show the spectrum of complications. The most common parenchymal complications following transplantation include acute rejection; chronic rejection or bronchiolitis obliterans; bacterial, viral, and fungal infections; and lymphoproliferative disorders. In acute and chronic rejection, CT shows ground-glass attenuation and interlobar septal thickening. The same CT findings are seen in bacterial and viral infections, with occasional pulmonary abscess seen in the former. Fungal infections are characterized by cavitary lesions, air-space disease, and mediastinal adenopathy on CT scans. In lymphoproliferative disorders, CT demonstrates pulmonary nodules or soft-tissue masses. The most frequent posttransplantation airway complications include stenosis, stent migration, and dehiscence. Dehiscence, which usually results from ischemia at the anastomosis site, is evident on CT scans as a disrupted airway and extraluminal air collections. CT is particularly important in the evaluation of airway complications because the CT results can significantly affect patient management. In parenchymal disease, CT often cannot aid in establishing a specific diagnosis, but it can be used to determine a site for biopsy, document extent of disease, and follow up results of treatment.

INTRODUCTION

Lung transplantation was first successfully performed in 1983 (1). It is currently performed in patients with irreversible and disabling end-stage pulmonary diseases, especially in those with a life expectancy of less than 18 months (2). The most common indications for lung transplantation in children are cystic fibrosis, Eisenmenger complex, pulmonary fibrosis, and bronchopulmonary dysplasia. Bilateral lung transplantation with bilateral bronchial anastomoses is done in patients with cystic fibrosis (3) and in very young children. Single lung replacement is usually performed in children with pulmonary hypertension or pulmonary fibrosis (4–7). Single lung transplantation is contraindicated in cases of cystic fibrosis because of the potential for the native lung to infect the transplanted lung.

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1 From the Mallinckrodt Institute of Radiology, Washington University School of Medicine, 510 S Kingshighway Blvd, St Louis, MO 63110. Recipient of a Cum Laude award for a scientific exhibit at the 1993 RSNA scientific assembly. Received February 22, 1994; revision requested April 26 and received June 24; accepted June 29. Address reprint requests to M.J.S.

2 Current address: Department of Radiology, Children’s Hospital, Boston, Mass.

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Preoperative evaluation of patients who are candidates for lung transplantation includes pulmonary function tests and chest imaging (5). In patients undergoing single lung transplantation, differential lung function is important information in the selection of which lung to replace. Computed tomography (CT) is performed preoperatively in the intended recipient to detect potential anatomic contraindications to transplantation. Extensive pleural calcification and pleural scarring or adhesions are potential contraindications because they make implantation of the donor lung technically difficult. Through imaging, anthropometric measurements of the lungs can be made for closer donor-recipient matching (8).

One-year survival rates after lung transplantation have been reported to be as high as 80%, with survival rates at 2 and 3 years approaching 60%–70% (7,9). In children, as in adults, the major complications of transplantation are rejection, infection, immunosuppression-induced lymphoproliferative disease, and anastomotic failure. Radiologic evaluation, such as with CT, plays an important role in the postoperative management of transplant recipients for the identification of these complications.

In this article, we review our experience with 25 children who underwent CT following lung transplantation. The most common parenchymal and airway complications of lung transplantation are discussed and illustrated with their appearances on CT scans. In addition, the surgical technique for lung transplantation is reviewed.

**SURGICAL TECHNIQUE**

Unilateral lung transplantation in children is done through a thoracotomy with an end-to-end anastomosis performed between the native and
donor pulmonary arteries (4, 5). The venous anastomosis is done by suturing the donor’s left atrial cuff, which contains the pulmonary veins, to the recipient’s left atrium. An end-to-end or telescoping anastomosis between the donor and recipient main stem bronchi is performed (10).

Sequential bilateral lung transplantation is done through a transverse sternotomy (3, 5). The arterial, venous, and airway anastomoses are similar to those described for unilateral lung transplantation.

Omental wrapping was not performed routinely in our population to avoid the additional morbidity of abdominal surgery. However, pericardial wrapping was done around the airway anastomosis to improve healing.

- **POSTOPERATIVE PARENCHYMAL COMPLICATIONS**

The major parenchymal complications are rejection and infection, with lymphoproliferative disorder occurring less often. Early experience suggests that the imaging findings in these complications are similar in children and adults.

- **Acute Lung Rejection**

Acute rejection is an early complication and most often occurs in the first 3 weeks after transplantation (2, 11-15). Histopathologically, it is characterized by both perivascular mononuclear infiltrates and a lymphocytic bronchiolitis or bronchitis (16).

The diagnosis usually can be made clinically on the basis of fever, decreased pulmonary oxygenation, and a rapid response to intravenous administration of high doses of corticosteroids (2, 14). However, transbronchial biopsy is commonly performed to confirm the diagnosis. CT may be used to identify the site of maximal disease for biopsy. CT most often shows areas of ground-glass attenuation and interlobular septal thickening (17, 18) (Fig 1). Less frequent findings include small nodules less than 1 mm in diameter, decreased vascularity, and air-space disease.

- **Chronic Lung Rejection**

Chronic lung rejection is defined as pathologically proved bronchiolitis obliterans, chronic vascular rejection, or both and is seen in 10%-54% of transplantations, usually manifesting 3 months after the surgery (2, 19). It is a major cause of late postoperative morbidity and mortality. Patients present with cough and worsening dyspnea (2). The small airways are predominantly involved, although the disease can progress to compromise larger airways.

The CT findings of chronic lung rejection are similar to those of acute rejection and include areas of ground-glass attenuation and interlobular septal thickening, which occur in 67% and 33% of cases, respectively (18). In addition, addition, bronchial dilatation (Fig 2) and decreased vascularity have been reported (18-22).
Figure 4. Bacterial abscess. CT scan of the superior mediastinum shows a soft-tissue mass (M) in the anterior mediastinum extending into the right paratracheal area (arrow), representing an abscess. Cultures of the specimens obtained at CT-guided aspiration biopsy were positive for Klebsiella organisms. Note the bilateral pleural effusions.

- **Infection**

  **Bacterial Infection.**—The immunosuppression required in lung transplantation patients results in an increased risk of developing bacterial pneumonia especially within the first 8 weeks after transplantation. Gram-negative Enterobacter and Pseudomonas species are the most common bacterial pathogens, although Staphylococcus aureus and Haemophilus pneurnoniae are also frequently encountered (23–26).

  Frequent CT findings are areas of ground-glass attenuation (86% of cases), nodules (57%) (Fig 3), and interlobular septal thickening (57%) (18). Rare findings are pulmonary or mediastinal abscess (Fig 4).

  **Viral Infection.**—Cytomegalovirus pneumonitis is the most common viral infection in transplant recipients, followed in frequency by herpes simplex and Epstein-Barr virus infections, with the manifestation occurring between the 1st and 6th months after transplantation (25,26). Clinical findings include fever, cough, and hypoxemia (2,26).
On CT scans, the most frequent findings are areas of ground-glass attenuation and interlobular septal thickening (18) (Fig 5). Diagnosis is made by means of cultures and histopathologic studies. In cytomegalovirus pneumonitis, cytomegalovirus inclusion bodies are identified within pneumocytes.

**Fungal Infection.**—Fungal infections may occur within the first few postoperative weeks or as late as several years after transplantation (2, 26). *Candida albicans* and *Aspergillus* organisms are the most common causes of fungal infection in lung transplant recipients (26). Invasive aspergillosis of the upper airways has a propensity to disseminate if not treated early.

CT reveals cavitary lesions, air-space disease, and mediastinal adenopathy (Fig 6). Diagnosis is made by means of cultures or histopathologic studies with the use of Gomori methenamine silver stain.

**Figure 5.** Cytomegalovirus pneumonitis. CT scan of a patient obtained 1 month after bilateral lung transplantation reveals ground-glass attenuation (arrow) and septal thickening (arrowheads).

**Figure 6.** Fungal infection. (a) CT scan demonstrates a cavitary lesion in the periphery of the left lung parenchyma and a loculated left pleural effusion. (b) CT scan obtained at a higher level in the same patient demonstrates nonspecific enlargement of multiple superior mediastinal nodes and bilateral effusions. Cultures were positive for *Aspergillus* organisms. *c* = left common carotid artery, *i* = innominate artery, *l* = left brachiocephalic vein, *r* = right brachiocephalic vein, *s* = left subclavian artery.
Figure 7. Lymphoproliferative disorder. (a) CT scan obtained with a lung window reveals a pulmonary nodule in the right lung base. (b) CT scan obtained caudad to (a) and with a mediastinal window shows another soft-tissue mass (arrow) in the left lower lobe.

Figure 8. Bronchial stenosis. (a) CT scan of a patient with a left lung transplant reveals long-segment stenosis of the left main stem bronchus at the anastomosis (arrow). Pleural thickening and infiltrate in the right lung due to pulmonary fibrosis are also noted. (b) Follow-up thin-section CT scan obtained after placement of a metallic stent shows improvement of the stenosis (arrow) with increased caliber of the bronchus. (c) Coronal two-dimensional image reconstructed from spiral CT data shows optimal positioning of the stent (arrows) in a patent bronchus.
- **Lymphoproliferative Disorder**
  Posttransplantation lymphoproliferative disorder occurs as a consequence of chronic immunosuppression, and, in the majority of cases, it seems to be induced by the Epstein-Barr virus (27,28). The disorder typically manifests within the 1st year after transplantation (27). Most cases of lymphoproliferative disorder are reversible with reduction of the immunosuppressants. Late presentation (after 1 year), widespread disease, and lack of response to decreasing the immunosuppressants indicate a poor prognosis (27).
  
  CT usually reveals pulmonary nodules or pulmonary soft-tissue masses (Fig 7) and mediastinal or hilar adenopathy (29). Other findings include air-space consolidation, thymic enlargement, pleural effusions, and pericardial masses (11). Diagnosis is made histopathologically with specific immunohistochemical stains.

- **AIRWAY COMPLICATIONS**
  Bronchial stenosis and stent migration are the most common airway complications in children with transplanted lungs (30). Dehiscence is relatively infrequent in children; in contrast, in adults dehiscence is the most frequent airway complication (31).

- **Bronchial Stenosis**
  Bronchial stenosis is a complication of anastomotic healing or dehiscence (32). The caliber and length of the stenosis are important in planning treatment. Long-segment or severe stenoses with more than 50% narrowing of the airway are likely to be treated with stents to maintain airway caliber. Focal, mild to moderate strictures can be treated with laser resection or dilation (33).
  
  Diagnosis is usually made by means of bronchoscopy. However, CT is a noninvasive alternative that is capable of depicting airway stenosis. Conventional CT and thin-section high-resolution CT are comparable in the detection of airway stenosis; however, the latter technique adds conspicuity. CT with two- or three-dimensional reconstruction is used to assess stenosis length and patency of the airway before and after stent placement (Fig 8). CT findings include focal or diffuse narrowing of the airway, usually at the site of the anastomosis.

- **Stent Migration**
  Either plastic or metallic stents can be used to treat airway stenosis. The location of the stent should be assessed on follow-up chest radiographs, because the stent can become displaced or migrate, especially with coughing. Shortness of breath is a clinical feature of stent migration.
  
  CT allows exact localization of the migrated stent before and after repositioning. Pseudodehiscence can be seen due to air between the thin plastic stent and the bronchial wall (Fig 9). This should not be confused with true dehiscence, which is characterized by extraluminal air extending from the airway lumen.
Figure 10. Bronchial dehiscence. (a) Chest CT scan obtained 3 weeks after transplantation shows a large air collection (arrow) communicating with the right main stem bronchus. (b) CT scan obtained at a more caudal level shows inferior extension of the collection into the mediastinum (arrow). Diffuse ground-glass attenuation and alveolar infiltrates were shown to represent nonspecific histopathologic findings after multiple biopsies. (c) Three-dimensional reconstructed CT image reveals dehiscence and extraluminal air (arrowheads).

- **Dehiscence**
  Bronchial anastomotic dehiscence usually occurs early after transplantation and is the result of ischemia at the anastomosis site (32); rarely, it is due to infection. Dehiscence has been thought to be a complication of the immunosuppressants given to control rejection, which subsequently impair anastomotic healing.

  The diagnosis is usually made bronchoscopically. Plain chest radiographs usually are nondiagnostic, although rarely an extraluminal air collection can be seen around the anastomotic site. CT is more sensitive than plain radiography for identifying dehiscence. CT findings of dehiscence are disruption of the airway, with extraluminal air collections (30,31) (Fig 10).

- **CONCLUSIONS**
  CT plays a role in the detection of parenchymal complications in children who have received lung transplants by allowing early detection, improved characterization, and more accurate assessment of the extent of disease. Imaging cannot provide a specific diagnosis in patients with parenchymal disease, pulmonary nodules, or adenopathy, but it can be used to determine a site for biopsy. On the other hand, CT is an excellent, noninvasive examination for assessing airway complications.

- **REFERENCES**


