Bronchopleural fistula and the role of contemporary imaging

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One of the most morbid postoperative complications after a lobectomy or a pneumonectomy is a bronchopleural fistula (BPF). The diagnosis and identification of BPF may be challenging, often requiring repeat imaging and invasive tests, including bronchoscopy, thoracoscopic exploration, or even open exploration. The purpose of this article is to review the types and presentations of BPF and to describe the role of noninvasive imaging for diagnosis and surgical treatment planning. We focused on multidetector computed tomography and advanced postprocessing applications such as multiplanar reconstructions, virtual bronchoscopy, and volume rendering images, including minimum-intensity and maximum-intensity projections. Both multidetector computed tomography and nuclear scintigraphy are reliable noninvasive imaging modalities that can be used expeditiously in an outpatient setting and may prove to be a more cost-effective strategy to identify the fistula as well as conduct postoperative surveillance. These modalities can be used for accurate and efficient testing for earlier diagnosis and treatment planning, thereby significantly improving patient outcome. Additional advanced postprocessing techniques using already acquired imaging data can provide complementary information that is both visually accessible and anatomically meaningful for the surgeon. Better understanding of the potential uses and benefits of these techniques will eventually improve the diagnostic accuracy, optimize preoperative planning, and facilitate follow-up for patients with BPF with improved patient outcomes. (J Thorac Cardiovasc Surg 2014;148:341-7)

A number of pulmonary complications can occur after any lung resection, including pneumonia, abscess, empyema, and a prolonged air leak. Bronchopleural fistula (BPF) remains 1 of the most serious life-threatening complications but is fortunately rare.[1,2] Identifying a BPF is often challenging, sometimes requiring multiple bronchoscopies, because conventional imaging techniques and the initial bronchoscopy can fail to detect a small BPF. Multidetector computed tomography (MDCT) offers significant promise as a reliable noninvasive modality that can be performed expeditiously for accurate identification of a BPF, treatment planning, and post-treatment surveillance. In addition, the application of advanced postprocessing techniques could be a useful adjunct for the surgeon. Other radiologic investigations such as nuclear scintigraphy could also play a role in fistula identification, particularly in suspected cases in which the fistula is below the resolution of MDCT or is very small. In the present report, we reviewed the types of BPF and their clinical presentation and described the role of multimodality imaging for the diagnosis and treatment planning for patients with BPF, with specific emphasis on MDCT and advanced postprocessing applications. This information is critical for the thoracic surgeon, because BPF remains one of the most life-threatening complications of pulmonary resection. However, limited data are available on the role of modern radiologic imaging in the diagnosis and management of BPF.

DEFINITION, CLASSIFICATION, AND ETIOLOGIES

BPF has been defined as a direct communication between the bronchus and pleural space. A central BPF represents a fistulous connection between pleura and trachea or segmental bronchi and can arise after total or partial lung resection or lung transplantation or because of traumatic disruption of the tracheobronchial (TB) tree. A peripheral BPF represents a fistulous connection between the pleura and airway distal to segmental bronchi or lung parenchyma and can occur after necrotizing pneumonia, empyema, radiotherapy, bulla or cyst rupture, or thoracic interventional procedures. Infectious and rheumatologic conditions such as tuberculosis, aspergillosis, granulomatosis with polyangiitis (previously known as Wegener's granulomatosis), and pulmonary sarcoidosis can also result in BPF.

Depending on the published series, the incidence of BPF has ranged from 2% to 20% after pneumonectomy and 0.5% to 3% after lobectomy. Both have been associated with high morbidity and mortality.[2-5] Dehiscence of the bronchial stump in the setting of anatomic resection remains the most common cause of BPF. The risk factors for the development of BPF include the extent of lung resection, residual or recurrent cancer at the bronchial stump, preoperative radiotherapy, concurrent infection (especially fungal), prolonged postoperative ventilator support, adult respiratory distress syndrome, chronic obstructive pulmonary disease, poor nutrition, hypoalbuminemia, steroids, and diabetes.[6-8] In addition to patient-related factors, several technical factors have been implicated in the development of a BPF. For instance, right pneumonectomy is 4 to 5 times more likely to

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Abbreviations and Acronyms

2D = 2-dimensional
3D = 3-dimensional
BPF = bronchopleural fistula
CT = computed tomography
MDCT = multidetector computed tomography
TB = tracheobronchial
VB = virtual bronchoscopy

result in a BPF than left pneumonectomy.[9,10] Several hypotheses exist to explain this phenomenon, including less mediastinal coverage of the bronchial stump, lack of a dual blood supply to the right bronchus, and the presence of a cartilaginous ring at the vertical orientation of the right main stem bronchus that allows accumulation of secretions and predisposes the bronchial stump to infection and dehiscence.[11] Additionally, the duration of postoperative ventilator assistance and the length of the stump can affect stump healing and the incidence of dehiscence.[6,7,10] Thus, thoracic surgeons have tended to perform several intraoperative maneuvers designed to decrease the risk of developing a BPF, such as minimizing tension on the bronchial stump, keeping the length of the bronchial stump to <1 cm, preserving or providing a vascular supply to the stump by minimizing airway mobilization, and covering the bronchial closure with intercostal muscle, pericardium, pericardial fat pad, or omentum.[7,11]

CLINICAL PRESENTATION AND MANAGEMENT

Typically, a BPF presents about 1 week to 3 months postoperatively, with the greatest incidence at 8 to 12 days.[2,3] Surgical management of BPF involves limiting airflow through the fistula, closure of the fistula, and drainage of the pleural space, which, by definition, has been contaminated. Protection of the contralateral lung from spillage of pleural fluid through the BPF is also critical in the treatment of these patients. The approach to treatment depends on the location and size of the BPF, the extent of pleural contamination, and the patient's clinical status. Early postoperative BPFs will usually be central in location and primarily result from technical failure. They can be diagnosed immediately postoperatively by bronchoscopy or suggested by a large air leak. The development of a BPF beyond the perioperative period, however, often results from distal parenchymal defects and will usually be a smaller communication that tends to be more difficult to diagnose and manage.[8] Although there are no classic signs or symptoms, patients will often present with low-grade fevers, chills, lethargy, poor appetite, or cough productive of brown-colored, or sometimes salty, sputum. A decreasing air fluid level in the pleural space, a prolonged air leak, and acute respiratory failure due to aspiration pneumonia of the contralateral lung are also suggestive features of a BPF.[12]

One of the first diagnostic studies used by surgeons to identify a BPF was bronchoscopy, which allows the surgeon to examine the apposition of the cartilaginous and membranous walls of the bronchial stump and differentiate among stump dehiscence due to wound infection, necrosis, and tumor recurrence. However, the false-negative rate of bronchoscopy in the diagnosis of BPF has been high,[13] with failure to diagnose and repair the BPF resulting in worsening respiratory status owing to aspiration and sepsis and, thus, delaying the initiation of lifesaving therapy.

If the BPF is associated with a pleural infection, prompt drainage and washout of the hemithorax while protecting the contralateral lung is warranted. The early initiation of broad-spectrum antibiotics and aggressive nutritional supplementation will be key to healing and quick recovery. When possible, early central fistulas should be treated with primary repair by repeat resection and revision of the stump. The bronchus should be reinforced with pleura, pericardium, mediastinal fat, omentum, or a muscle flap. In contrast, peripheral fistulas should be treated according to the underlying disease and the patient's clinical condition, with a focus on maximizing pleural apposition. The treatment options include tube thoracostomy, decortication, pleurodesis, and open drainage.[14] More recently, surgeons have been using a variety of surgical and transbronchial occlusive agents and methods to directly close the central BPF, with intermediate success reported with the use of free or pedicled muscle flaps, fibrin sealants, coils, stents, and 1-way valves.[15-20]

ROLE OF IMAGING IN BPF DIAGNOSIS AND MANAGEMENT

In patients with a suspected BPF, several questions must be answered to appropriately treat the patient. The first step is to identify the size and location of the BPF (central or peripheral) and its relationship to the bronchial tree and adjacent mediastinal structures. Next, the pleural space must be controlled with either closed drainage or decortication. Finally, the underlying cause of BPF should be identified and addressed appropriately, in addition to studying the anatomic relationship of the BPF to the major vessels and mediastinal structures. It is also important to investigate and search for tumor recurrence. The presence of malignancy at the bronchial stump and the location and volume of tumor growth within the thoracic cavity are important to define. If the underlying cause of BPF is infection, it is important to identify the source of infection, such as aspiration pneumonia from reflux or empyema. If a hypertrophied vessel or a pseudoaneurysm is adjacent to the BPF, the need for embolization should be assessed to prevent life-threatening hemorrhage. Several imaging