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# Bronchopleural Fistula: Causes, Diagnoses and Management

*Güntüç Batıhan and Kenan Can Ceylan*

## Abstract

Bronchopleural fistula (BPF) is a pathological communication between the bronchial tree and pleural space. This clinical condition, which has high mortality and morbidity, is one of the major therapeutic challenges for clinicians even today. BPF may result from a lung neoplasm, necrotizing pneumonia, empyema, blunt and penetrating lung injuries, and a complication of surgical procedures. Lung resection is the most common cause of BPF, and this chapter will focus more on this topic. Frequency ranges from 4.5 to 20% after pneumonectomy and from 0.5 to 1% after lobectomy. Several risk factors have been defined in the development of postoperative BPF; preoperative radiotherapy, pulmonary infection, diabetes, right pneumonectomy, a long bronchial stump, residual cancer at the stump (R1 and R2 resection), and the need for postoperative ventilation (especially with high PEEP). BPFs are divided, based on the time elapsed since surgery, into early or late fistula. This grouping is important in management of patient treatment. In early BPF, surgical treatment is generally the preferred treatment modality, whereas in late BPF, conservative approach is preferred. The management of BPF is still one of the most complex challenges encountered by the thoracic surgeons; so prevention is the best way to manage postoperative BPF.

**Keywords:** bronchopleural fistula, complication, lung resection, empyema

## 1. Introduction

Bronchopleural fistula (BPF) has been defined as a direct communication between the bronchus and pleural cavity. Some authors have grouped BPFs as central and peripheral according to their locations [1]. While a central BPF defines connection between pleura and tracheobronchial tree, a peripheral BPF defines connection between the pleura and airway distal to segmental bronchi or lung parenchyma. In literature, the term of “alveolopleural fistula” is also used to describe peripheral BPFs.

Nonsurgical conditions like trauma, chronic necrotizing pneumonia, empyema, radiotherapy, bulla, or cyst rupture can cause BPF, but the most common cause is lung resection. Frequency ranges from 4.5 to 20% after pneumonectomy and from 0.5 to 1% after lobectomy. BPF-related mortality ranges from 18 to 71% in the literature [2–4]. Because of high morbidity and mortality rates, it is important to define risk factors and apply preventative methods especially in groups of risky patients.

Many authors have divided postoperative BPFs into two groups according to time of onset. There is no consensus about these definitions in the literature, but generally, early BPF was defined as fistula occurring within 30 days after the initial

operation. Late BPF was defined as fistulas occurring after more than 30 days. It is established that early BPFs are most commonly associated with a failure in surgical technique and mostly, it can be repaired with reoperation [1, 3, 5].

Late BPFs are typically secondary to patient-related factors and almost always coexist with empyema, and it usually required complex, long-term, and exhausting treatment process for both the patient and the surgeon.

## **2. Risk factors**

BPF is most commonly encountered after lung resections; therefore, establishing risk factors is important to prevent patients from this highly mortal complication.

Numerous risk factors have been associated with BPF development in the literature [3–6]. We divided these risk factors into three groups: patient-related factors, surgeon-related factors, and anatomic factors.

Age (>60), gender (male), neoadjuvant radiation therapy, diabetes mellitus, malnutrition, smoking, chronic steroid/immunosuppressive usage, and need for postoperative mechanic ventilation can be classified as a patient-related risk factor. Induction chemotherapy has been cited as a risk factor for postpneumonectomy BPF but there is not any increased risk for bronchoplastic procedures.

A large number of studies have reported an increased risk for BPF due to postoperative mechanical ventilation usage after pneumonectomy. Therefore, to prevent bronchial stump from barotrauma extubation must be achieved at the earliest time after surgery.

A low forced expiratory volume in 1 second and low carbon monoxide diffusing capacity were also defined as risk factors for postoperative BPF occurrence.

Besides these patient-related risk factors, several anatomic disadvantages were defined for right-sided pneumonectomy:

- i. According to cadaveric studies, presence of two left-sided and one right-sided bronchial artery supply is the most common configuration.
- ii. While the left main bronchus is protected under the aortic arch and surrounded by mediastinal tissue, the right bronchial stump has no such coverage.
- iii. The right main bronchus is wider, and more vertical than the left main bronchus. This condition facilitates secretion retention on the right main bronchial stump.

Early BPFs are usually related with technical failure during surgery. The most common causes of this condition are poorly secured knots, stapler misfiring, and high anastomotic tension. Other surgeon-related risk factors are extensive mediastinal lymphadenectomy and peribronchial dissection, long bronchial stump and not coverage the bronchial stump with viable tissue.

## **3. Clinical presentations and diagnosis**

The size and the time of occurrence of the BPF are major determinants of the clinical presentation but, patients often have infection-related symptoms like: fever, cough with serosanguinous or purulent sputum, night sweats, and chills.

Expectoration and respiratory symptoms typically worsen with the patient lying on the side opposite to the one involving the fistula. Flooding of the infected contents of the pleural space to the contralateral lung can lead to severe pneumonia or respiratory distress syndrome.

If the patient has a chest tube massive and prolonged air leakage would be an important clinical clue for BPF.

White blood cell count and systemic inflammation markers are often elevated.

Chest radiogram often revealed a decrease in the fluid level and enlargement in the ipsilateral pleural cavity. Due to the contamination of the contralateral lung by the infected content of the pleural cavity, parenchymal infiltration can be seen.

Computed tomography of the chest can depict mediastinal emphysema, parenchymal infiltration, and enlargement of the pleural cavity, but its success at demonstrating the presence of the BPF is controversial. By the imaging of the continuation of a bronchus or the lung parenchyma to the pleural space, definitive diagnosis of the fistula can be made (**Figures 1 and 2**). Westcott et al. reported sensitivity of the chest CT as 50% at demonstrating the presence of the peripheral BPFs. Seo et al. reported that chest CT succeed to demonstrate direct or indirect signs of BPF 86% of the patients with central, and 100% of the patients with peripheral BPFs [7, 8].

In the presence of clinical or radiological suspicion of BPF, bronchoscopy must be applied to examine the bronchial stump. Presence of pleural fluid leakage or/and air bubbling in the bronchial stump is pathognomonic (**Figures 3 and 4**).

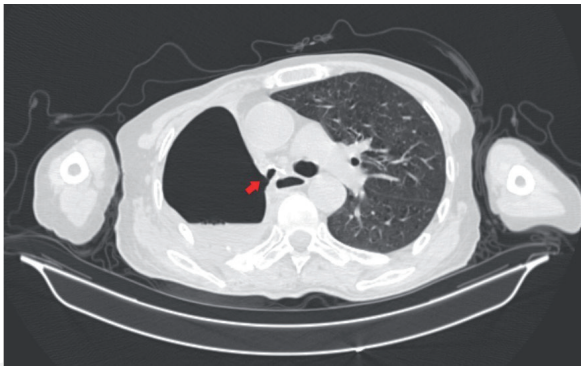
Reconstruction of 2-dimensional, helical CT images provides noninvasive intraluminal evaluation of the bronchus named as “virtual bronchoscopy” [9]. This technique can provide additional benefits, especially, planning endobronchial instrumentation, but it is not an essential diagnostic method of fistula.

Less frequently  $^{133}\text{xenon}$  or  $^{99}\text{technetium}$  ventilation scintigraphy can be used to identify BPF by visualization of the radioactive isotopes in the empty pleural cavity. Mark et al. used  $^{99}\text{technetium}$  ventilation scintigraphy in 28 postpneumectomy patients for the detection of BPF and reported sensitivity of 78% and a specificity of 100% [10, 11]. Although, this is a noninvasive diagnostic procedure, it is not practical and easy-to-use, and has no additional benefit to the detection of underlying lung disease.

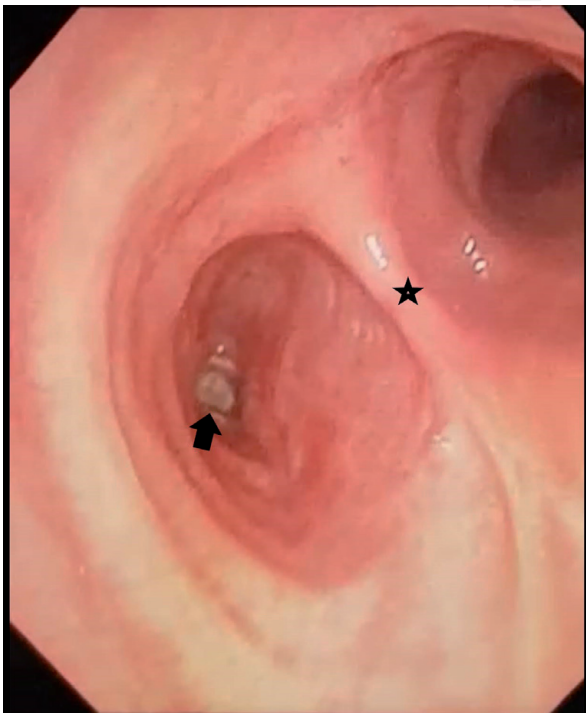


**Figure 1.**  
*Left sided BPF is seen in the Chest CT. BPF may not always be as clear as this CT image.*

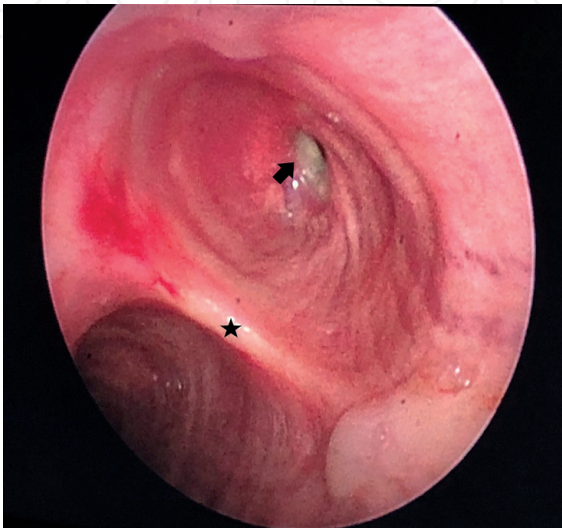




**Figure 2.**  
*Another chest CT image shows right sided BPF. Chest CT also allows the examination of the remaining lung for possible pneumonic infiltrations and metastases.*



**Figure 3.**  
*Bronchoscope view of the left-sided BPF (arrow) (Asterix shows the main carina). In bronchoscopy, the fistula patency may not always be clearly seen. Air bubbles originating from the stump of the bronchus may be the only sign of the BPF.*



**Figure 4.**  
*Bronchoscope view of the right-sided BPF (arrow) (Asterix shows the main carina).*

## 4. Management

The management of the BPF needs prolonged hospitalization, complex surgical procedures, and close follow-up, but first step in the treatment is management of the life-threatening conditions like sepsis, tension pneumothorax, and respiratory failure. Protection of the contralateral lung from aspiration of the pleural fluid is important to reduce the risk of pneumonia and respiratory failure. Therefore, chest tube must be applied to ensure the drainage of the pleural cavity. Broad spectrum antibiotic therapy against Gram-Positive, Gram-Negative, and anaerobic microorganisms must be initiated, and it should be tailored based on the results of culture-antibiograms.

Early BPFs are mostly associated with failure in the surgical technique. Repairment of the bronchial stump with re-operation is the best treatment modality in these patients.

Patients with late BPF mostly have poor medical condition and major surgical approaches cannot be applied. Conservative treatment modalities like drainage and reduction of the pleural space, pleural irrigation, antibiotics, and nutritional supplementation. Boudaya et al. reported their experience with conservative management of postresectional BPF in 17 patients and BPF is successfully closed in 16 patients [12].

Various endoscopic techniques for the control of small BPFs have been reported, especially in patients with poor condition. Sealants, fibrin glue, coils, and endo-bronchial silicon or metal stents have been used to treat small BPFs (ranging from 0.8 to 1.0 mm). Dutau et al. used self-expanding metal stents in seven patients with large fistulas (>6 mm) and reported improvement in patients' respiratory parameters in early postoperative period [13].

### 4.1 Surgical interventions for infection control

Besides conservative treatments, several surgical procedures to treat BPFs have been defined in the literature. Main objectives in these surgical interventions are debridement of the pleural space, minimizing the residual pleural cavity, closure of the fistula, and reinforcement of the bronchial stump with autologous tissue.

There are several factors in choosing the appropriate surgical method:

1. Medical condition of the patient
2. Time of onset of the fistula
3. Size and localization of the fistula
4. State of the pleural cavity

#### 4.1.1 Video-assisted thoracoscopic surgery (VATS)

In the presence of pleural infection together with the fistula, tube-thoracostomy must be applied in all cases. Pleural irrigation with antibiotic and povidone-iodine solutions is suggested in sterilization of the infected postpneumonectomy pleural cavity but this treatment modality alone cannot provide sufficient debridement, especially in patients with late fistulas and cause prolong hospitalization.

VATS is a useful method to obtain drainage and debridement of the infected pleural cavity. Single port is usually sufficient in most cases; material and debris can be safely removed with surgical instruments and in the presence of small BPFs (<3 mm) fibrine glue can be applied. Hollaus et al. applied videothoracoscopic

debridement in nine patients and defined it as an efficient method to treat post-pneumonectomy empyema [14]. Gossot et al. reported series of 11 patients with postpneumonectomy empyema. These 11 patients underwent videothoracoscopic debridement and 8 of 11 patients discharged without need of additional surgical procedures [15]. These similar studies have shown that VATS is a feasible option for treatment in select patients with PPE and small BPF.

#### *4.1.2 Open window thoracostomy*

In the presence of empyema drainage of the pleural cavity is essential to control the septic status of the patient. Different kinds of drainage techniques were defined in the literature. Open-window thoracostomy was first described by Robinson in 1916 in patients with nontuberculous empyema and Eloesser has revised this procedure for patients with tuberculous empyema [16, 17]. This procedure contains:

1. Segmental resection of 2–3 ribs
2. Creation of a skin flap (Muscle should be preserved if possible)
3. Marsupialization of the cavity

With this procedure, epithelialized thoracostomy window is obtained and effective drainage is ensured.

After this operation, the wound is packed at least daily with gauze moistened with normal saline. Granulation tissue in the wound begins to form over time and when the pleural space is clean closure of the window can be considered.

It is very important to have a good cooperation with patient and relatives for this treatment modality and they should be informed that this treatment procedure may require several weeks.

#### *4.1.3 Clagett procedure*

Clagett and Geraci described a two-step treatment technique for the management of postpneumonectomy empyema in 1963 [18]. Step 1 contains the open window thoracostomy to drain the septic cavity. Step 2 contains obliteration of the pleural cavity with antibiotic solution. Pairolero and Arnold has modified this procedure and described transposition of a well-vascularized extrathoracic muscle as an intermediate step [19]. With this modification, further reinforcement of the bronchial stump was ensured.

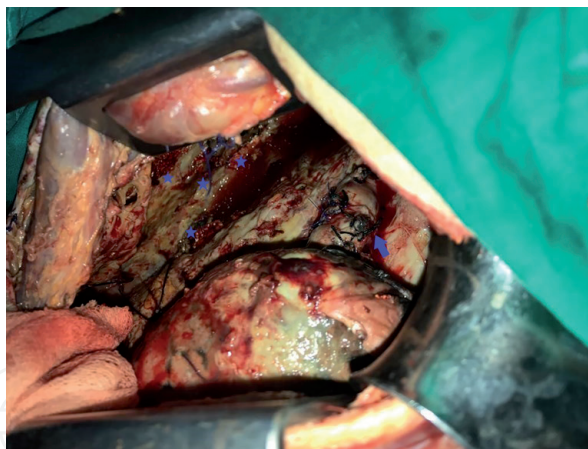
Clagett procedure shows a success rate (OWT closed without PPE recurrence) of 61–89% with a mortality rate between 0 and 24% in the literature.

### **4.2 Surgically closure of a bronchopleural fistula**

Large BPF can cause loss in the tidal volume, aspiration of infected pleural fluid, and respiratory distress. Therefore, bronchial defect must be controlled, especially in patients with large fistulas, for this purpose, two major approaches were defined in the literature.

#### *4.2.1 Transpleural approach*

Transpleural approach is the most common method to closure of the BPF (**Figure 5**). First, BPF must be identified. By careful dissection, bronchus must be mobilized as close to the carina as possible to provide adequate length. Aggressive



**Figure 5.**  
*Image of the left thoracic cavity of the patient with BPF and empyema. Pleural debris and plaques covering the chest wall are seen (Asterix). Infected vascular stumps also are seen (arrow).*

dissection and devascularization of the proximal bronchus should be avoided because of the risk of failure of the repair and recurrence of BPF. Stapler devices can be used if there is a sufficient length in the bronchial stump. Manual suturation also can be applied above the BPF. After repairment, bronchial stump must be buttressed with well-vascularized tissue such as extrathoracic muscle, omentum, or diaphragm flap.

#### *4.2.2 Transsternal transpericardial approach*

In some cases, surgical management of BPF may be challenging through a lateral transpleural approach. Presence of short bronchial stumps, left-sided BPF, necrotic bronchial stumps and/or history of prior BPF closures via thoracotomy are the main reasons that make transpleural approach difficult. In these cases, transsternal transpericardial approach would be a good alternative to transpleural approach [20, 21]. This approach provides work in healthy, inflammation-free planes. Therefore, in this technique, isolation of the airway is easier and safer than others. Biggest benefit of this technique is that it provides the opportunity to work in a healthy plane. Retraction of the superior vena cava and aorta laterally provide sufficient exposure to make a successful repairment. It is also possible to achieve transpericardial approach by anterior thoracic incision with division of multiple costal cartilages which was described by Padhi and Lynn [22]. This approach was found to be a difficult and complicated compared to transsternal approach. Therefore, transsternal transpericardial approach has become more widely used among surgeons in the repairment of BPF.

#### *4.2.3 Thoracoplasty*

One of the major concerns in the treatment of the BPF is obliteration of the persistent space after control of pleural infection. Thoracoplasty is originally considered as a treatment for active tuberculosis but this procedure is also functional for obliterate pleural space with the viable tissue of the chest wall in the cases of BPF. This is achieved by resection of multiple ribs. Traditional thoracoplasty requires removal of the first 11 ribs periosteum, and intercostal muscles with associated neurovascular bundles. After removal of these structures, skin and thoracic muscles fill the pleural cavity. As can be expected, this procedure has high mortality and morbidity rates and is now abandoned. Removing fewer than five ribs named as “tailored” thoracoplasty is still in use especially in the treatment of chronic BPFs [23, 24].

It would be rational to use these treatment modalities in combination to deal with space problem. Tailored thoracoplasty, muscle transposition, omentoplasty,



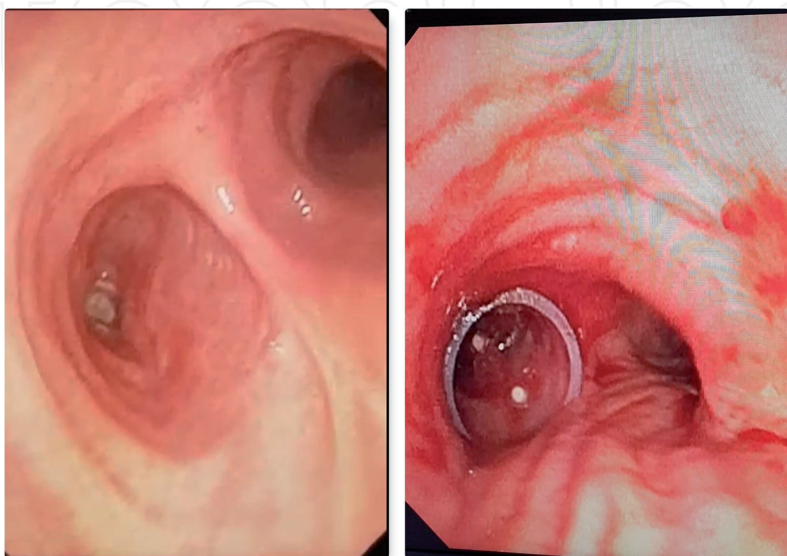
and diaphragm flaps can be used and combined with each other. Clinical condition and performance status of the patient are also important for selection of the best method in the treatment of BPF.

5. Bronchoscopic management of BPF

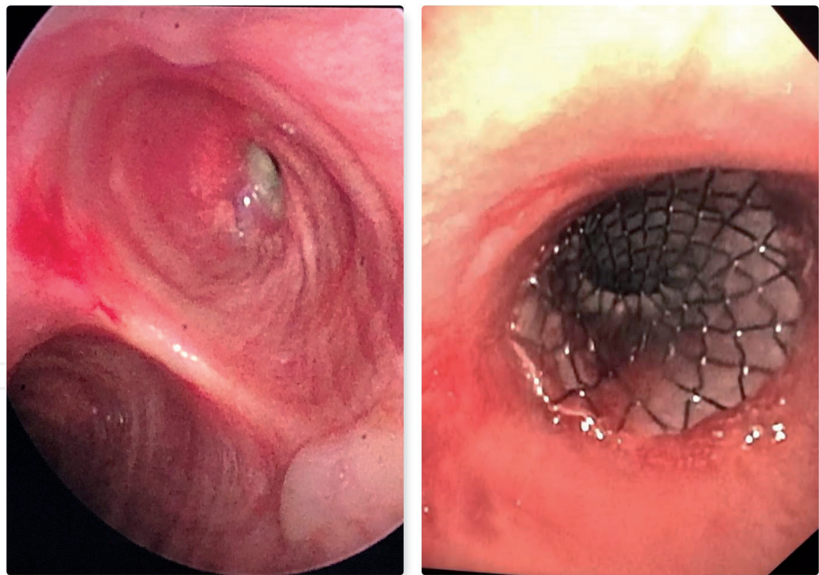
Various endoscopic techniques like bronchoscopic application of sealants, fibrin glue, silver nitrate cautery, coils, and endobronchial stents for the control of small BPFs have been reported [25–29]. There is no consensus on which method is most effective for BPF closure. We use endoscopic techniques only for the patients with poor clinical condition and not for proper major surgical intervention. Proper technique must be selected depending on the length of the bronchial stump, the location, and size of the fistula (**Figures 6 and 7**).



**Figure 6.**  
*Image of the customized (closed in one side with a stapler) silicone stent.*



**Figure 7.**  
*Left-sided BPF was closed with customized silicone stent. After this procedure, air drainage from the chest tube was decreased and respiratory condition of the patient was improved.*



**Figure 8.**  
*Bronchoscope image of the right-sided BPF. It was closed with self-expandable metallic stent.*

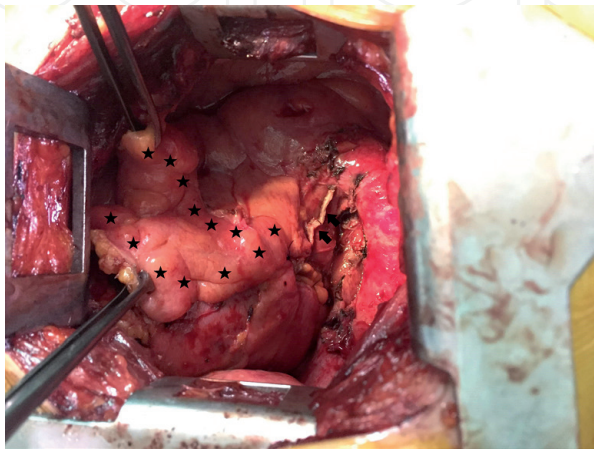
We often prefer metallic J-stents and silicon Y-stents (**Figure 8**). The most seen complication of these stents is migration and occlusion with secretion. Migration and occlusion of the stent can cause severe respiratory distress. Retention of the secretion can also cause contamination of the remaining lung and resulted in severe pneumonia.

Despite these complications, in selected patients, endobronchial stents can reduce air leakage and prevent remaining lung from contamination with pleural fluid.

**6. Prevention of bronchopleural fistula in pulmonary resection-  
bronchial stump coverage**

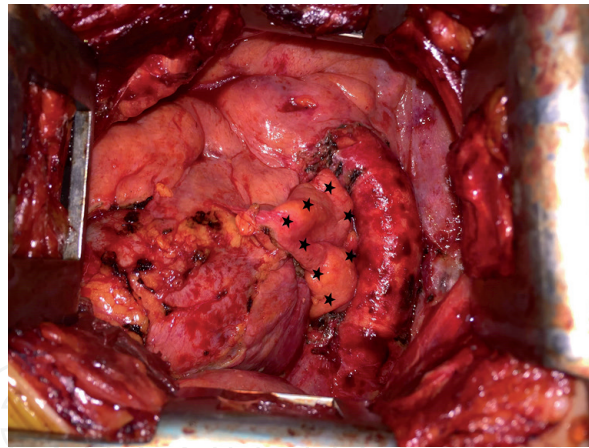
To prevent postpneumonectomy bronchopleural fistula, coverage of the bronchial stump is recommended, especially for patients with high risk of BPF.

Pediced intercostal and extrathoracic muscles, diaphragm, pericardium, pericardial fat pad, and pleura can be used to make a flap to coverage the bronchial stump [30–32]. There is no consensus for best bronchial stump coverage method and related techniques with several complications were defined in the literature.



**Figure 9.**  
*Pericardial fat pad (Asterix) is very useful material to coverage of the bronchial stump. It is dissected from surrounding tissues by preserving the vascular pedicle. Once the fat pad has been mobilized, it is then rotated over the hilum to cover the bronchial staple line (arrows).*





**Figure 10.**  
*The view of the thoracic cavity after coverage of the left main bronchial stump.*

Diaphragm flaps can cause visceral herniation. The pedicled intercostal muscle flap is useful method for coverage of the bronchial stump but developing heterotopic ossification can cause severe problems. Omentum is a great tissue to promote re-vascularization and healing of the bronchial stump but it requires the opening of the abdominal cavity [33]. Pericardial fat pad coverage appears to be safe and feasible when compared with other coverage techniques (**Figures 9 and 10**). It can be applied without risk of additional comorbidity and composes a mechanical barrier between bronchial stump and pleural cavity.

## 7. Conclusion

In modern thoracic surgery, bronchopleural fistula is still associated with significant morbidity and mortality. Treatment techniques have evolved and there are many options to use in patients with BPF, therefore surgeon must evaluate clinical status of the patient, the size, and location of the BPF and the status of the pleural cavity to select the treatment method that will show the most benefit.

It is important to remember that the best treatment is to prevent the disease. Therefore, rigorous surgical technique and bronchial stump coverage are the main steps in the treatment.

## Conflict of interest

The authors declare no conflict of interest.

## Appendices and nomenclature

BPF	bronchopleural fistula
CT	computed tomography
VATS	video-assisted thoracoscopic surgery

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