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Review article

Persistent air leak - review

Kenneth K. Sakata[a,*], Janani S. Reisenauer[a,b], Ryan M. Kern[a], John J. Mullon[a]

[a] Division of Pulmonary and Critical Care Medicine, Mayo Clinic, 200 First Street SW, Rochester, MN 55905, USA
[b] Division of General Thoracic Surgery, Mayo Clinic, 200 First Street SW, Rochester, MN 55905, USA

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ABSTRACT

A persistent air leak (PAL) can be caused by either an alveolar-pleural fistula (APF) or bronchopleural fistula (BPF). Complications from PAL lead to an increase in morbidity and mortality, prolonged hospital stay, and higher resource utilization. Pulmonary physicians and thoracic surgeons are often tasked with the difficult and often times frustrating diagnosis and management of PALs. While most patients will improve with chest tube thoracostomy, many will fail requiring alternative bronchoscopic or surgical strategies. Herein, we review the bronchoscopic and surgical diagnostic and treatment options for PAL as it pertains to the field of interventional pulmonology and thoracic surgery.

1. Introduction

A PAL is defined by an air leak that persists for greater than 5–7 days [1]. It can be caused by either an APF or BPF. Postoperative PALs are the most common, but they may also occur after a spontaneous pneumothorax due to underlying lung disease. An APF is a communication between the alveoli and the pleura, while a BPF is defined as a communication between the bronchus and pleura.

The incidence of a pneumothorax after transbronchial lung biopsies [1] and ultrasound-guided thoracentesis [2] is between 0-6% and 2.7–3.6%, respectively. Only a fraction of these patients go on to require chest tube thoracostomy drainage [2]. While the incidence of a pneumothorax post-procedure has been established, the incidence of PAL as a result of a post-procedure pneumothorax is not known [1].

Complications from either an APF or BPF arise from the contamination and loss of sterility of the pleural space via direct communication with the non-sterile tracheobronchial tree. It also leads to ventilation/perfusion mismatches and the inability to maintain positive end-expiratory pressure during mechanical ventilation. PALs are associated with a higher morbidity and mortality, longer chest tube duration, prolonged hospital stay, and higher resource utilization [3].

The mortality rate associated with BPFs ranges from 16 to 72% [4,5]. The reported incidence is between 1.5 and 28% for a pneumonectomy, while the rates of BPF following lobectomy are as low as 0.5% [4,6–9]. There is a higher incidence reported for right pneumonectomy and right lower lobectomy. BPF is significantly more prevalent in malignant conditions as opposed to benign conditions [10]. Additional risk factors for developing a BPF include receipt of radiation and/or chemotherapy [10].

This review will focus on the bronchoscopic and surgical diagnostic and treatment options for PAL as it pertains to the field of interventional pulmonology and thoracic surgery.

2. Quantification of air leak volume

The traditional three-chamber drainage system can estimate the severity of an air leak based on its breath-to-breath continuity and whether bubbles persist in the absence of applied suction. A number of commercially available drainage systems also include a multi-column graduated air leak chamber to help estimate severity based on the number of columns of bubbling seen.

Cerfolio et al. developed a 4 grade classification system to assess the severity of an air leak postoperatively (Table 1) [11–13]. The most severe type of leak is a continuous (C) air leak which is observed throughout the entire respiratory cycle. This type of leak is rare and generally only seen if the patient is on mechanical ventilation or in the presence of a large BPF. The second largest type of air leak is an inspiratory (I) air leak. This too is uncommon and seen almost exclusively in patients on positive pressure ventilation or those with a large fistula defect. An expiratory (E) air leak is present only during expiration and is commonly seen after thoracic surgery suggesting a parenchymal air leak or an APF. If a leak is present only with forced exhalation or coughing, this is referred to as forced expiration (FE) leak. FE and E air leaks are very common and account for > 98% of air leaks after elective pulmonary surgery [11]. Daily quick and easy bedside assessments and observations of the air leak transitioning from an E to an FE leak may be

* Corresponding author.
E-mail addresses: Sakata.Kenneth@mayo.edu (K.K. Sakata), Reisenauer.Janani@Mayo.edu (J.S. Reisenauer), Kern.Ryan@Mayo.edu (R.M. Kern), Mullon.John@Mayo.edu (J.J. Mullon).

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Abbreviations (in order of appearance)

PAL	persistent air leak
APF	alveolar pleural fistula
BPF	bronchopleural fistula
POD	postoperative day
RCT	randomized controlled trial
EBV	endobronchial valve
IBV	intrabronchial valve
ABP	autologous blood pleurodesis
FDA	Food and Drug Administration
VAST trial	Valves Against Standard Therapy trial
AD	Amplatzer devices
AVP	Amplatzer vascular plugs
VATS	video-assisted thoracoscopic surgery
FP	fistula plug
ETT	endotracheal tube

an indication that the fistula is healing [11].

Recently developed digital drainage systems are able to further quantify the flow of air (displayed as mL/min) through the device and have the capability to display dynamic real-time pleural pressures. In small randomized controlled trials (RCT) [7,14] and one large international randomized trial [15], the use of these digital devices has been shown to improve patient satisfaction, reduce the duration of an indwelling chest tube, hospital length of stay, and cost when compared to conventional drainage systems.

3. Defect localization

Successful bronchoscopic treatment of BPF is dependent on directly or indirectly visualizing the defect or proving that occlusion of the affected segment decreases or stops the air leak [6].

3.1. Sequential balloon inflation and occlusion

BPFs associated with lung resection can often be directly visualized, while the more distal BPF or APF require the use of balloons to systematically occlude the bronchial segments to locate the airway leading to the fistula (Fig. 1) [6]. There are several commercially available balloon catheters that are compatible with flexible bronchoscopes. It is recommended to initially start with a complete mainstream balloon occlusion of the affected side to assess the integrity of the tubing and drainage system. If the air leak persists, the entire circuit from the exit site of the chest tube to the wall suction requires interrogation. Once the APF or BPF is confirmed and the defect localized to a specific airway, the application of occlusive devices or sealants can be attempted. This process can be tedious, time-consuming, and cannot be performed with accuracy in the absence of bubbling from the box drainage system.

3.2. Methylene blue

Instillation of methylene blue into the pleural drainage catheter can be a quick alternative approach to localize the origin of an air leak. This is performed simultaneously with bronchoscopic visualization of the bronchi. Careful observation of dye entering the tracheobronchial tree from the affected airway establishes the diagnosis (Fig. 2) [16]. A particular advantage of this technique is that it does not require the observation of bubbling in the chest drain box as is required for accurate assessment using the sequential balloon occlusion technique [16].

Methylene blue is commonly distributed in 10 mg/mL vials, and only a single milliliter is typically required. It is then diluted with a desired volume of either normal saline or 5% dextrose in water. A potential pitfall to this approach is that administering methylene blue may not discretely localize a multifocal BPF as the dye will follow the path of least resistance, thus localizing one BPF at a time [16]. Occlusion of the initial affected segment with a balloon followed by repeating this technique may obviate this limitation. Additionally, if the patient requires surgery, the dye characteristics on the organs and tissues in the pleural space may limit the surgeons' ability to easily identify mediastinal and thoracic structures [16].

Table 1
Cerfolio classification of air leaks.

Grade and classification	Maneuver
Grade 1, FE	During any forced exhalation (ie. Cough)
Grade 2, E	Expiratory phase only
Grade 3, I	Inspiratory phase only
Grade 4, C	Continuous bubbling during both inspiration and expiration

4. Treatment

In 2001, the American College of Chest Physicians published guidelines on the management of spontaneous pneumothoraces [17]. For patients with PAL, the panel recommended a 4 day observation period for spontaneous closure of the defect. If the air leak is present beyond 4 days, a surgical evaluation for pleurodesis is recommended. Bronchoscopic treatment options were only recommended in special circumstances in which surgery is contraindicated or patients refuse an operative procedure. A similar recommendation was made in the 2010 British Thoracic Society guidelines stating a surgical opinion should be sought in cases of PAL or failure of the lung to reexpand after 3–5 days [18]. There were no specific recommendations addressing situations where surgery was not an option.

In patients who are non-operable candidates or for those who refuse surgery, there are multiple less invasive approaches to the management of PAL. Since the first reported successful endobronchial management of BPF using tissue glue and a lead shot [19], many reports using different materials have been attempted. These include ethanol [20], silver nitrate [21], polyethylene glycol [22], cyanoacrylate compounds [23–25], coils [26,27], fibrin or tissue glue [28–30], doxycycline [31,32], albumin-glutaraldehyde tissue adhesive [33,34], cellulose [35], balloon catheter occlusion [36], calf bone [6], stents [6], gel foam [37], Watanabe spigots [38], endobronchial valves (EBV) [39–41], vascular devices and plugs [10,42–45], and autologous blood

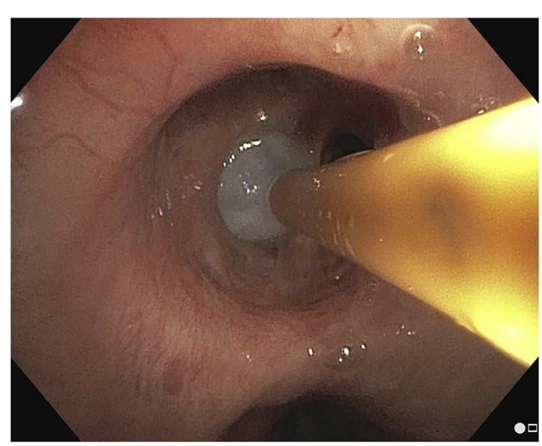

Fig. 1. Sequential balloon occlusion of the bronchi using a Fogarty balloon.