Management of Complications After Lung Resection
Prolonged Air Leak and Bronchopleural Fistula

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KEYWORDS

- Bronchopleural fistula • Air leak • Thoracic surgery • Perioperative management

KEY POINTS

- Prolonged air leak or bronchoalveolar fistula is common and can usually be managed with continued pleural drainage until resolution.
- Bronchopleural fistula is rare but is associated with high mortality, often caused by development of concomitant empyema.
- Bronchopleural fistula should be confirmed with bronchoscopy and often can be treated endoscopically, but may require operative stump revision or window thoracostomy.

PROLONGED AIR LEAK
Background

The most common postoperative complication after elective lung resection is an alveolar-pleural fistula, or air leak.[1] An air leak is defined as a communication between the alveoli of the pulmonary parenchyma distal to a segmental bronchus with the pleural space.[2,3] Prolonged air leak (PAL) is defined by the Society of Thoracic Surgeons (STS) General Thoracic Surgery Database (GTSD) as an air leak persisting longer than 5 days postoperatively. The incidence of air leak after lung resection is 25% to 50% on postoperative day 1 and up to 20% on day 2.[4,5] Although most air leaks resolve spontaneously with chest tube drainage, the incidence of PAL after lung cancer resection was 10% over the past decade within the STS GTSD,[6] and 15% to 25% in other reports.[7,8]

PAL negatively affects other perioperative outcomes. Patients with PAL have significantly increased length of stay, leading to increased cost. Among nonpneumonectomy lung resection patients, those with PAL, compared with those without, had a mean length of stay of 7.2 versus 4.8 days (*P*<.001) and a 30% increase in the inpatient costs ($26,070 vs $19,558; *P*<.001).[9] Similar results were shown in a cohort of video-assisted thoracoscopic surgery (VATS) lung cancer resection patients, with mean length of stay nearly twice as long compared with those without a PAL (11.7 vs 6.5 days; *P*<.001).[10] These results are corroborated in the National Emphysema Treatment Trial data (11.8 vs 7.6 days; *P*<.001).[11] Medicare patients with PAL for 7 to 10 days after lung resection and greater than 10 days after lung resection had 30% and 100%, respectively, greater inpatient hospital costs compared with those with PAL less than 7 days (*P*<.001).[12] Postoperative intensive care unit readmission rates may be higher with PAL (9% vs 5%; *P* = .05),[13] likely caused by associated complications such as pneumonia and empyema.[11,14] The incidence of empyema is 10.4% with PAL greater than 7 days, compared with 1% with air leaks less than or equal to

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7 days (P = .01).[15] PAL requires prolonged chest tube drainage, which increases postoperative pain,[1,16] respiratory splinting leading to increased pneumonia risk,[11] venous thromboembolic risk caused by diminished mobility,[16] and necessity for additional procedures such as chemical or mechanical pleurodesis.[17] In addition, the PAL rate was twice as high among readmitted lobectomy patients compared with those who did not require readmission (21.4% vs 10.2%; P<.001).[18] PAL also is associated with increased in-hospital mortality.[13] Patients with an air leak have a 3.4 times greater risk of death than those without (95% confidence interval [CI], 1.9–6.2).[9]

PREOPERATIVE RISK FACTORS
Demographic Factors

Patients undergoing lung resection who develop PAL are often older than those who do not,[19] with many PAL predictive tools using an age cutoff of greater than 65 years.[20] Men are 11% to 39% more likely than women to have a PAL.[6,9]

Clinical Factors

Patients with a lower body mass index are at increased risk of PAL, with cutoff less than or equal to 25 kg/m^2 commonly studied.[6,20] Emphysematous disease processes such as chronic obstructive pulmonary disease dramatically increase the odds of PAL.[9] Resection through emphysematous bullous tissue can make adequate sealing of parenchymal transection lines with staplers more challenging. Decreased forced expiratory volume in 1 second (FEV$_1$) is a strong independent predictor for PAL.[6,11,20,21] Lower diffusion capacity of the lung for carbon monoxide (DLCO) also increases the risk of PAL.[11,20] Several case series of patients with pulmonary disease associated with infectious agents such as tuberculosis and aspergillosis have shown a high risk of PAL.[22–24]

INTRAOPERATIVE RISK FACTORS

Larger parenchymal resections tend to increase the risk of PAL. Fissure dissection during lobectomy and bilobectomy, particularly in the setting of an incomplete fissure, can cause parenchymal tears leading to air leaks.[1,25] Using a fissureless dissection technique significantly reduces the risk of PAL (odds ratio [OR], 0.32; 95% CI, 0.22–0.51).[25] In addition, longer staple lines required for lobectomies rather than sublobar resections increase the length over which a staple line air leak can potentially occur. As such, lobectomy has been shown to have 1.5 to 2.0 times increased odds of PAL compared with segmentectomy or wedge resection.[9,13] When comparing types of lobar resections, resection of upper lobes regardless of laterality has been shown to increase the odds of PAL.[13] Concordantly, review of the Cleveland Clinic experience in lobectomies found that resection of the left lower lobe was an independent predictor for protection against PAL.[26]

Presence of pleural adhesions, which can be highly vascular and require extensive adhesiolysis, is a substantial risk factor for PAL.[11] Pleural adhesions were the only independent risk factor for PAL in a recent cohort of 1051 lung cancer resection patients (OR, 2.38; 95% CI, 1.43–3.95)[10] and are an important intraoperative risk factor in several PAL prediction scores.[20,27,28]

POSTOPERATIVE RISK FACTORS

Postoperative mechanical ventilation is the only postoperative risk factor identified for development of PAL,[29] with up to a 19% incidence of air leak in pneumonectomy patients requiring postoperative ventilation.[30]

PROLONGED AIR LEAK PREDICTIVE SCORES

Numerous investigators have proposed scoring systems to predict the risk of PAL.[6,20,27,28,31–36] Brunelli and colleagues[32] proposed a PAL risk score in 2004 including FEV$_1$, pleural adhesions, and upper lobe resections.[20] Their group revised and validated their score in 2010, based on 4 factors: age greater than 65 years (1 point), pleural adhesions (1 point), FEV$_1$ less than 80% (1.5 points), and body mass index (BMI) less than 25.5 kg/m^2 (2 points) (Table 1). PAL risk increased stepwise with each class: class A (0 points), 1.4%; class B (1 point), 5.0%; class C (1.5–3 points), 12.5%; class D (>3 points), 29.0%. Lee and colleagues[27] devised a PAL prediction tool based on the Canadian experience that similarly included pleural adhesions, FEV$_1$, and DLCO, and a more complex index of PAL model was produced by French investigators including male sex, BMI, dyspnea score, pleural

Table 1 Aggregate prolonged air leak risk score derived by Brunelli and colleagues[32]	
	Points
Age >65 y	1
Presence of pleural adhesions	1
Forced expiratory volume in 1 s <80%	1.5
BMI<25.5 kg/m^2	2

From Brunelli A, Varela G, Refai M, et al. A scoring system to predict the risk of prolonged air leak after lobectomy. Ann Thorac Surg. 2010;90(1):206; with permission.

adhesions, lobectomy or segmentectomy, bilobectomy, bullae resection, pulmonary volume reduction, and upper lobe resection.[28,34] Brunelli and colleagues[33] have updated their own European Society of Thoracic Surgeons risk score, finding that male gender, FEV_1 less than 80%, and BMI less than or equal to 18.5 kg/m^2 better predict PAL in VATS patients.

An STS GTSD study of 52,198 patients formulated a PAL score dichotomizing patients as either high or low risk. The score includes all variables easily determined preoperatively: BMI less than or equal to 25 kg/m^2 (7 points), lobectomy or bilobectomy (6 points), FEV_1 less than or equal to 70% (5 points), male sex (4 points), and right upper lobe (3 points) (Table 2). A score greater than 17 points predicted a high PAL risk compared with less than or equal to 17 points as a low PAL risk (19.6 vs 9% incidence, respectively), with a sensitivity of 30%, specificity of 85%, negative predictive value of 91%, and positive predictive value of 19%.

AIR LEAK EVALUATION

An air leak is identified by observing air bubbling into the water seal chamber of the pleural drainage canister. Such a finding warns that removal of a chest tube is likely to result in continued parenchymal air leak with subsequent pneumothorax development. Recently, digital drainage systems have been developed to better objectively evaluate air leaks.[37] Such drainage systems can provide real-time monitoring of continuous air flow and pleural pressure as well as accurate drainage volume measurements.[38] A recent Japanese study found that persistent air flow greater than or equal to 20 mL/min at 36 hours postoperatively was highly predictive of PAL, with sensitivity and specificity of 91% and 73%, respectively, and receiver operating characteristic c-statistic of 0.88 (95% CI, 0.80–0.96).[39] A Canadian group used modeling of

Table 2
Prolonged air leak score derived by Seder and colleagues[6]

	Points
BMI $\leq$ 25 kg/m^2	7
Lobectomy or bilobectomy	6
Forced expiratory volume in 1 s $\leq$70%	5
Male sex	4
Right upper lobe procedure	3

From Seder CW, Basu S, Ramsay T, et al. A prolonged air leak score for lung cancer resection: an analysis of the STS GTSD. Ann Thorac Surg. 2019;108(5):1480; with permission.

digital drainage system data to accurately predict air leak recurrence after chest tube removal with sensitivity of 80% and specificity of 88%.[40] Other studies have found no difference in chest tube duration or length of stay with the use of digital drainage systems.[5] Although widespread implementation of digital pleural drainage systems to improve chest tube removal decision making has been slow to gain traction, this may change in the future as health systems attempt to identify ways to reduce prolonged lengths of stay.

PRINCIPLES OF MANAGEMENT

Most uncomplicated alveolar-pleural fistulae resolve with chest tube drainage and expectant management.[41] Although chest tube management strategies vary, many surgeons advocate keeping chest tubes on −20 cm of water suction until the morning of postoperative day 1, at which time tubes are transitioned to water seal.[4,42,43] A small air leak at this time may be best managed on water seal, but a new or enlarging pneumothorax or development of subcutaneous emphysema should prompt return to suction.[44] A meta-analysis of 7 randomized trials found no differences in the incidence of PAL, chest tube duration, or hospital stay when comparing initial postoperative chest tube management on suction versus water seal.[45]

With the advent of portable pleural drainage systems, outpatient management of PAL is feasible and common, given that most resolve with adequate visceral and parietal pleural apposition.[46] Thus, patients can be safely discharged with chest tube in place for outpatient leak testing and removal.[47,48] Such strategies may in part contribute to increasing postoperative day 1 discharges after anatomic lung resections, without increased risk of mortality or readmission.[49–51] Four percent of STS GTSD contributing centers discharge more than 20% of anatomic lung resection patients on postoperative day 1.[50] However, this must be balanced with recent data indicating a 25% readmission rate and nearly 17% incidence of empyema in patients discharged with a chest tube after pulmonary resection, with more than 12% requiring decortication.[52]

More aggressive management strategies have been explored for PAL, such as chemical pleurodesis (with tetracycline, talc, iodine, or silver nitrate),[17,53] blood patch administration,[54] and endobronchial 1-way valve placement,[55–58] which have shown some efficacy. None of these techniques have been compared in a randomized fashion, but case series have shown PAL resolution rates of greater than 95% with chemical pleurodesis, greater than 92% with autologous blood

patches, and greater than 93% with endobronchial valve (EBV) placement.[17]

BRONCHOPLEURAL FISTULA
Background

In contrast with alveolar-pleural fistulae, a bronchopleural fistula (BPF) is defined as a communication between a main stem, lobar, or sublobar bronchus with the pleural space.[59] The incidence of BPF is less than or equal to 1% for lobectomy and sublobar resections and 4% to 20% after pneumonectomy.[60–62]

Historically, the mortality associated with BPF ranged from 20% to 50%.[60,63–67] Modern series show a mortality of 11% to 18% for early BPF (within 30 days of surgery)[62,68,69] and 0% to 7% for late BPF (beyond 30 days of surgery).[68–70] BPF mortality risk is particularly high after pneumonectomy because there is often concomitant empyema caused by failure to control the bronchial stump leak, resulting in pneumonia of the remaining contralateral lung. Empyema after lobectomy likely occurs as a combination of PAL, percutaneous drain as a potential infectious nidus, and persistent pleural space.[71] In contrast, more than 75% of postpneumonectomy empyemas occur in the setting of a bronchial stump BPF.[62,72,73] The cause of BPF-induced empyema is direct pleural space contamination by mucocutaneous, respiratory, or digestive tract microbes. BPF-associated empyema carries a significant risk of cardiopulmonary complications, in excess of 61.5% versus 11.4% in patients without BPF ($P<.001$), and a mortality risk of 30.8% versus 3.9% in patients without BPF ($P<.001$).[29] BPF in conjunction with postpneumonectomy empyema has repeatedly been shown to be an independent predictor of mortality,[67,74] especially early in the postoperative course when mortality ranges from 11.6% to 18% compared with late BPF from 0% to 7.1%.[68,69] More recent data from France reported early (within 2 weeks of surgery) BPF-associated empyema mortalities of 19% compared with 5% when empyema occurs later (after postoperative day 14).[63] Survival differences become even more pronounced over time, with 1-year survival of 80% versus 47% for late versus early postpneumonectomy empyema ($P = .01$).[63] As such, this complication, which is primarily seen in pneumonectomy patients, must be recognized and addressed early to prevent significant morbidity and mortality.

PREOPERATIVE RISK FACTORS
Demographic Factors

Similar to alveolar-pleura fistulae, advanced age increases the risk of BPF. Age cutoffs of greater than 60 years and greater than 70 years have been shown to dramatically increase the risk of BPF development, with ORs of 1.18 (95% CI, 1.12–1.62) to 2.14 (95% CI, 1.14–3.93), respectively.[68,69] A recent French BPF prediction model found that men had a 2.63 times greater odds of postpneumonectomy BPF than women ($P<.001$).[75]

Clinical Factors

Diabetic microangiopathy causes small vessel ischemia throughout the end organs of the body, and the bronchial stump circulation is particularly prone to poor wound healing secondary to ischemia.[71,76] A recent meta-analysis found that diabetic patients undergoing pulmonary resection had pooled increased odds of BPF of 1.97 (95% CI, 1.39–2.80) compared with nondiabetic patients,[77] which is corroborated in other BPF risk models.[68] Preoperative albumin level less than 3.5 g/dL is an independent predictor of BPF after pneumonectomy ($P = .02$), suggesting that poor wound healing of the bronchial stump leads to BPF development.[78] In addition, low BMI has been shown to increase BPF risk, with each additional 1-kg/m^2 decrease in BMI increasing the odds of BPF by 1.7 times ($P<.001$).[75]

Benign Lung Disease

In general, the risk of BPF after pneumonectomy is higher for benign pulmonary disease, primarily infectious, rather than for cancer resections. Most case series analyzing BPF describe patients undergoing completion pneumonectomy (during which the risk of operative complications is invariably higher), because primary pneumonectomy for benign disease is rare.[79–84] Analysis of the STS GTSD pneumonectomy experience shows 2.8 times greater odds of major complication, including empyema and BPF, for patients with benign disease versus lung cancer (95% CI, 1.35–5.82).[85] The French experience found that, of 5975 pneumonectomies over a decade, only 3.4% and 2.0% underwent pneumonectomy and completion pneumonectomy, respectively, for benign conditions.[86] However, these patients had a significantly higher complication rate (53% vs 39%) and in-hospital mortality (22% vs 5%) compared with those undergoing pneumonectomy for malignancy ($P<.001$). Other factors contribute to this increased risk of BPF and mortality in pneumonectomy patients with benign pathology. Thirty-seven percent of the pneumonectomies for benign disease were done in a nonelective fashion (compared with only 1.6% for malignant disease), which is a known risk factor for operative complications. In addition, pulmonary decortications and resections for

infectious disease are fraught with complication risk caused by dense adhesions and an infected operative field.[71,87] Highly vascularized adhesions can cause significant bleeding and also increase the risk of bronchial ischemia intraoperatively. In addition, the proinflammatory state of acute infections such as pneumonia has been shown to increase the risk of BPF.[69,88]

Neoadjuvant Therapy

For patients with malignancy, there are mixed results on the risk of BPF associated with induction chemotherapy. One purported effect is the risk of poor wound healing associated with chemotherapy.[80] One study from MD Anderson reported zero incidence of BPF or empyema in lobectomy and pneumonectomy patients who received neoadjuvant chemotherapy.[89] This finding was corroborated by more recent data from Pittsburgh, where investigators found similar BPF and empyema rates between patients receiving neoadjuvant chemotherapy versus upfront pneumonectomy (8.8% vs 7.3%; P = .61). Analysis by Hu and colleagues[68] of 684 patients undergoing pneumonectomy found neoadjuvant therapy to be an independent predictor of BPF (hazard ratio, 2.48; 95% CI, 0.05–0.28).

To this end, a recent meta-analysis of 30 studies of 14,912 lung cancer resection patients found that neoadjuvant chemotherapy alone did not increase the risk of BPF (OR, 1.86; 95% CI, 0.88–3.91).[90] Neoadjuvant radiotherapy alone (OR, 3.91; 95% CI, 1.40–10.94) or as combination chemoradiotherapy (OR, 2.53; 95% CI, 1.35–4.74) significantly increased the risk of BPF. Similarly, neoadjuvant radiotherapy was an independent predictor of late (but not early) BPF in the Shanghai experience (OR, 2.83; 95% CI, 3.12–30.96).[68] Radiotherapy induces bronchial mucosa ischemia,[91] but the mucosal blood flow can recover in as little as 8 to 10 days after completion of therapy.[92] Early radiation can cause mucosal edema and inhibit capillary angiogenesis, but late effects can cause fibrotic small vessel disease through radiation vasculopathy.[91] In addition, radiation-induced mucosal ischemia may be exacerbated by the ischemia from bronchial vessel disruption associated with lymphadenectomy during lung cancer resection.[71]

POSTOPERATIVE RISK FACTORS

Immediate or early extubation should be the goal because prolonged positive pressure ventilation is an independent risk factor for early BPF.[29] The incidence of BPF can be as high as 19% in patients requiring mechanical ventilation postoperatively.[30,61]

DIAGNOSIS

The signs and symptoms of BPF after lung resection can be varied and nonspecific, therefore it is important to have a high index of suspicion. Signs of empyema (leukocytosis, fever, pleural fluid on imaging, and purulence fluid on thoracentesis) should raise the concern for an underlying BPF. Continued air leak is common after lung resection, but a large continuous air leak should immediately raise the suspicion for air leaking from a bronchial rather than a parenchymal source. Development of a pneumothorax after chest tube removal could represent a continued parenchymal PAL, but a large pneumothorax days or weeks after resection is highly concerning for a BPF.

The classic radiographic sign of postpneumonectomy BPF is a decreasing air-fluid level over time ($\geq$2 cm), indicating displacement of the postoperative pleural fluid (Fig. 1). During this time, the patient often has a persistent and worsening cough, and is at risk of developing pneumonia in the contralateral lung.[71] All patients suspected of having a BPF should be evaluated with a chest computed tomography scan and flexible bronchoscopy. Saline can be instilled during bronchoscopy to look for bubbling at the staple line. If radiographic and bronchoscopic findings are still equivocal, transthoracic exploration and submersion of the stump under saline for a bubble test under positive pressure ventilation can make the definitive diagnosis.

PRINCIPLES OF MANAGEMENT

If empyema is suspected or confirmed, antibiotics are necessary. Most BPF-associated empyema is monomicrobial, with the most common pathogens being *Staphylococcus* and *Streptococcus* species.[63] Next, adequate drainage should be established by placement of a thoracostomy tube and instillation of fibrinolytics if the empyema is loculated.[78]

In postpneumonectomy BPF, care should be taken to avoid spillage of any empyema into the contralateral lung by keeping the patient upright at least at 45° and decubitus on the operative side down if able.[71] After drainage of the pleural space, bronchoscopy should be used to identify the BPF and to assess the viability and length of the bronchial stump. As discussed earlier, thoracoscopy can be paired with bronchoscopy to identify occult BPFs with a saline leak test under positive pressure.

In appropriately selected patients, BPF can be treated via endobronchial therapy, avoiding a major reoperation. Small defects (<5 mm) in patients
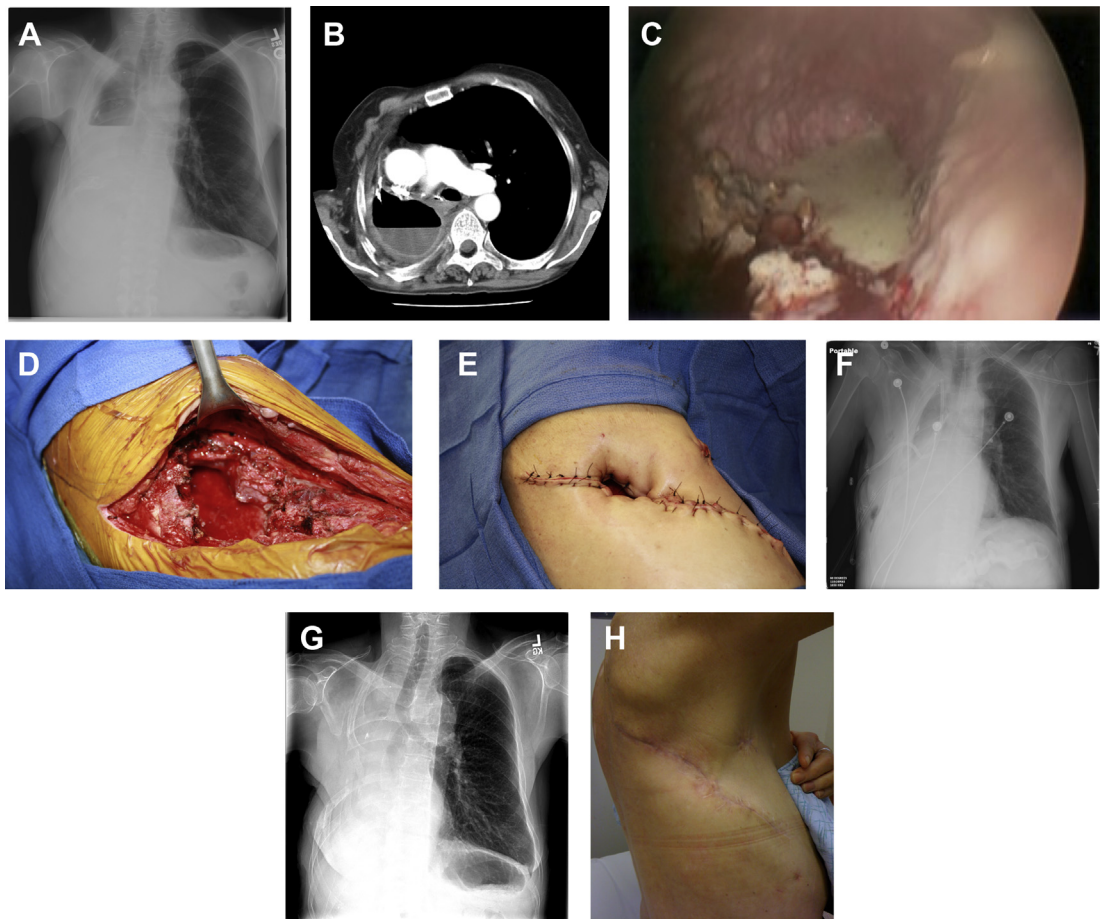
Fig. 1. A 59-year-old woman who underwent right pneumonectomy for adenocarcinoma and 16 years later developed failure to thrive secondary to chronic postpneumonectomy empyema. Chest radiograph at presentation with air-fluid level (*A*). Computed tomography imaging showing BPF and empyema (*B*). Empyema intraoperatively (*C*) during bronchial stump closure with Eloesser thoracostomy window intraoperative dissection (*D*) and creation (*E*). She then underwent omental flap and partial chest wall closure with a pleural drainage system 8 weeks after Eloesser thoracostomy window, as seen on chest radiograph (*F*). She eventually had the drainage system removed with resolution of the BPF and empyema on chest radiograph (*G*), and chest wall wound closure with latissimus dorsi flap coverage 18 weeks after initial Eloesser thoracostomy window creation (*H*).

without sepsis can often be managed with endoscopic fibrin glue[93,94] or silver nitrate.[64,95] Fibrin glue can have high rates of success, up to 100% after 2 to 3 applications.[94] Silver nitrate has been shown to have success rates ranging from 80% to 100%.[64,95] A Japanese case series of 7 patients showed 100% success with bronchoscopic instillation of a polyglycolic acid mesh with fibrin glue over the fistula area.[96] Most recently, airway stenting has shown considerable success, with 97% first-attempt and 100% second-attempt success rates in a series of 148 patients from China.[97]

Nevertheless, the need for operative reexploration is common, with historical case series indicating rates of greater than 90% and reclosure of the bronchial stump in nearly half of those cases.[61] The need for and success of reoperative

interventions depend on many factors, including early versus late presentation, dehiscence size, length of the bronchial stump, quality of the remnant stump tissue, presence of remnant malignancy at the stump site, and extent of contamination of the ipsilateral pleural cavity or infectious involvement of the contralateral lung.[30] In general, early dehiscence tends to be more amenable to immediate repair or stump revision, whereas late dehiscence can be more technically challenging to repair because of diminished tissue quality, development of a matured fistula tract, and significant pleural contamination and scarring.[71] Longer stumps should be trimmed back to healthier tissue leaving a minimum of 3 mm of remnant bronchial stump length,[98] and, if there is insufficient length for a new staple line, then direct suture repair
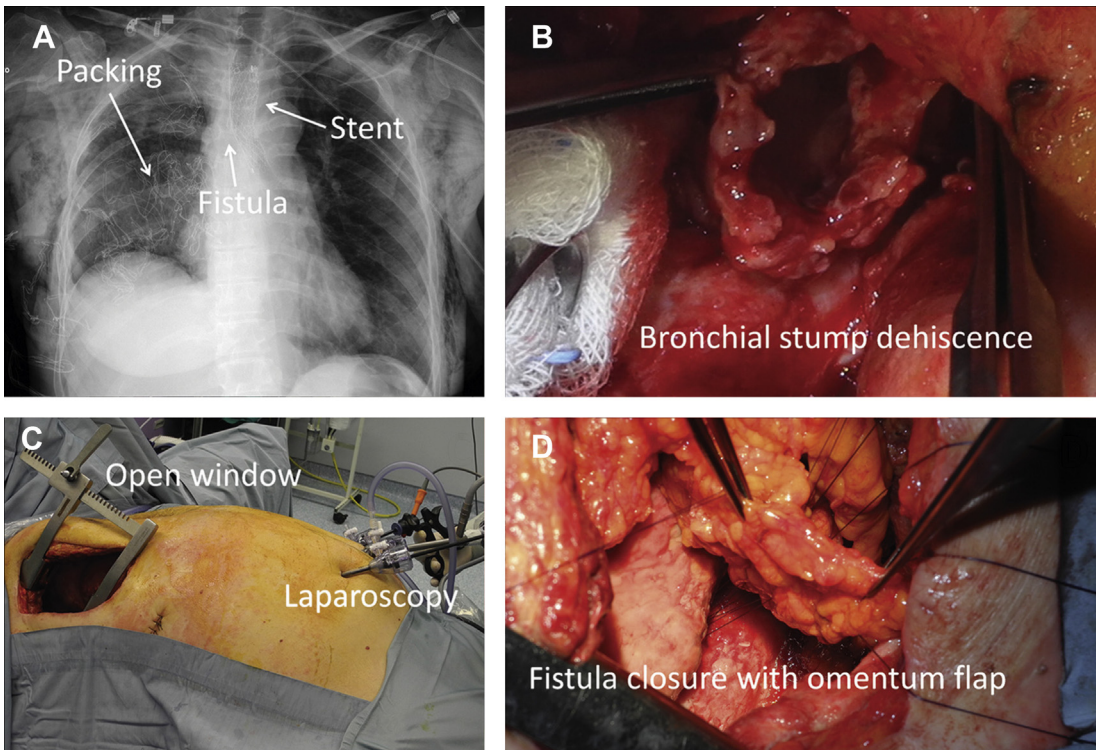
Fig. 2. Repair of a BPF in a staged fashion starting with placement of a conical stent to exclude the fistula from airflow (*A*), open thoracotomy pleural washout and packing with antibiotic-soaked gauzes (*B*), followed by laparoscopic omental harvesting (*C*) and BPF primary closure buttressed with an omental flap (*D*). (*From* Andreetti C, Menna C, D'Andrilli A, et al. Multimodal treatment for post-pneumonectomy bronchopleural fistula associated with empyema. Ann Thorac Surg. 2018;106(6):e338; with permission.)

should be performed with absorbable, monofilament, pledgeted sutures with vascularized tissue buttressing.[71] Dehiscence of greater than 50% of the bronchial stump is associated with dramatically delayed time to successful stump closure.[99] A recent South Korean case suggests empiric musculocutaneous flap coverage of any BPF with dehiscence of 1 cm or greater.[100] Repair of a late dehiscence is often impractical because extensive dissection of the stump can be risky. Tissue transfers into the pleural cavity (muscle or omental flaps) can cover the bronchial stump and eliminate the persistent pleural space (**Fig. 2**).

In patients are unable to tolerate bronchial stump revision or if early repair fails, open window thoracostomy (OWT) should be considered because adequate drainage allows most fistulae to close over time. An OWT, such as the Eloesser flap, is created by removal of a portion of 2 or 3 ribs at the most dependent portion of the empyema cavity with marsupialization of the subcutaneous tissues/skin flaps to the pleura, with success rates as high as 60% to 90%[22,101,102] (see **Fig. 1**). The original Eloesser flap was expanded to a 2-stage Clagett procedure

wherein, after adequate drainage, serial operative debridements, and local wound care, intrapleural antibiotic solution is instilled with definitive chest wall closure.[103] Obliteration of the pleural cavity can also be aided with muscular or omental flap transposition. Almost any nearby vascularized tissue pedicle can be used for buttressing, but common options include muscle flaps (latissimus dorsi, serratus anterior, intercostal),[104] parietal pleura,[105] pericardium,[106] pericardial fat,[107] pericardiophrenic graft,[107] azygos vein on the right side,[105] rectus abdominis myocutaneous flaps,[108] and omentum,[109,110] which can be harvested from a thoracotomy through a transdiaphragmatic approach.[111]

The duration of OWT is patient dependent and depends on response to antibiotic therapy, obliteration of the empyema cavity, nutrition status, and strict adherence to tobacco cessation efforts.[98] A recent Italian case series had a median duration of OWT of 5 months (range, 3–9 months) and found that early OWT creation increased the success of BPF healing.[101] Despite these encouraging results, other contemporary case series report dismal long-term survival after OWT of only 8%

at 4 years,[78] and ongoing packing of an open thoracic wound is often poorly tolerated by patients.[112]

Recently, OWT has been paired with vacuum-assisted closure devices to improve patient tolerance of wound care and healing time.[113] In addition, the recent Swiss experience has shown success in reducing mean time to OWT closure to 8 days using a modified Clagett process with povidone-iodine–soaked sponge packing changed in the operating room every 48 hours to allow for serial debridements, leading to a 100% OWT closure success rate with 0% 3-month mortality.[66] For BPF after partial lung resection, a last resort can be completion lobectomy or bilobectomy to ensure bronchial stump closure at a level of the bronchial tree with healthy tissue. Main bronchial stump revision sometimes is best accomplished through a transsternal transpericardial approach to the carina, especially for left-sided and long-stump BPFs. This approach provides an uninfected and noninflamed operative field.[114] More recent case series have shown considerable success in managing BPF with thoracoscopic debridement and stump revision, obviating OWT in many patients.[70,115,116]

Evidence on the benefit of EBV placement in aiding BPF closure is emerging, although the data are limited to small case series. These 1-way valves limit airflow into the pleural space while allowing backflow of mucus and air.[117] EBV placement is most commonly used for persistent pneumothorax secondary to PAL as opposed to BPF with concomitant empyema; however, use in BPF is gaining traction.[118] One series of 3 critically ill mechanically ventilated patients with BPF found immediate air leak resolution after EBV placement followed by BPF resolution and extubation within 5 to 13 days and good long-term survival.[119] Other case reports have shown recovery from BPF in patients on extracorporeal membrane oxygenation[120] as well as in severe cystic fibrosis as a bridge to lung transplant.[121]

SUMMARY

PAL is common after lung resection but is usually managed with continued pleural drainage until resolution. Additional management options include blood patch administration, chemical pleurodesis, and 1-way EBV placement. BPF is rarer but significant because it is associated with a high mortality caused by development of concomitant empyema. BPF should be confirmed with bronchoscopy, which may allow bronchoscopic intervention. However, early operative intervention, especially when diagnosed early, with transthoracic stump revision or OWT may ultimately expedite BPF closure and improve survival.

DISCLOSURE

The authors have nothing to disclose.

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