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Postoperative bronchopleural fistula repair: Surgical outcomes and adverse factors for its success

Young Ho Yang[1] | Seong Yong Park[1,2] | Ha Eun Kim[1] | Byung Jo Park[1] | Chang Young Lee[1] | Jin Gu Lee[1] | Dae Joon Kim[1] | Hyo Chae Paik[1]

[1]Department of Thoracic and Cardiovascular Surgery, Yonsei University College of Medicine, Severance Hospital, Seoul, Republic of Korea

[2]Department of Thoracic and Cardiovascular Surgery, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Republic of Korea

Correspondence
Seong Yong Park, Department of Thoracic and Cardiovascular Surgery, Sungkyunkwan University School of Medicine, Samsung Medical Center, 81 Irwon-ro, Gangnam-gu, Seoul 06531, Korea.
Email: syparkcs@gmail.com

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Abstract

Background: The purpose of this study was to investigate the results of postoperative bronchopleural fistula repair and to identify adverse factors for its success.

Methods: We retrospectively reviewed the surgical results of 39 patients who underwent surgical repair for postoperative bronchopleural fistula between January 2010 and June 2020. Success of bronchopleural fistula repair was defined as the visual closure of the bronchopleural fistula with the absence of an air leak, a recurrence of bronchopleural fistula and infection in the thoracic cavity.

Results: Twenty-five (64.1%) bronchopleural fistulas occurred after pulmonary resection and 14 (35.9%) after lung transplantation. Bronchopleural fistula was diagnosed 19 days (median) and repaired 28 days (median) after the initial operation by primary closure in 27 (69.2%) patients, and by additional resection in 12 (30.8%) patients. The overall success rate was 59% (23/39) and the overall mortality was 56.4% (22/39). Multivariable analysis revealed that the patients who were supported by mechanical ventilation at the time of repair had significantly lower success rates than those without (15.4%, 2/13 vs. 80.8%, 21/26, respectively, $p < 0.001$). The omental flap group tended to have a better success rate than the muscle flap group ($p = 0.07$).

Conclusions: There was a high overall mortality rate after bronchopleural fistula repair and a low success rate. Mechanical ventilation at the time of bronchopleural fistula repair was significantly related to the failure of bronchopleural fistula repair.

KEYWORDS
bronchopleural fistula, lung transplant, mechanical ventilation, omental flap, pulmonary resection

INTRODUCTION

A bronchopleural fistula (BPF) is a communication between the main stem, lobar, or segmental bronchus and the pleural space[1] and is one of the fatal complications after pulmonary resection. The estimated prevalence rate was reported to be 1%–4%, with a 16%–72% mortality rate.[2–4] There are certain patient characteristics and surgical techniques that can increase the incidence of BPF; these include neoadjuvant therapy, destroyed or infected lung tissue from inflammatory disease, an immunocompromised host, insulin-dependent diabetes, pneumonectomy (specifically right-sided pneumonectomy), a long bronchial stump, devascularization of the bronchial stump, residual cancer at the bronchial margin, prolonged ventilation, or reintubation after resection, and surgical inexperience.[5–8]

There are many studies regarding the risk factors for an occurrence of BPF, but few studies have focused on the factors related to the failure of surgical BPF repair. Although there have been developments in the surgical techniques and perioperative patient management, the treatment for postoperative BPF is still technically challenging for the thoracic surgeon. Various methods and techniques can be used for a BPF repair, such as primary suture, additional pulmonary resection, and reinforcement using muscle, pericardial fat, or omental flap.

However, no large study or randomized trials have been conducted to date, and as a result, there is a lack of evidence regarding the optimal treatment strategies. Therefore, the purpose of this study was to investigate the results of postoperative BPF repairs and to identify the adverse risk factors for a successful BPF repair.

METHODS

Ethical statement

This study was approved by the Severance Hospital Institutional Review Board (4–2021–1048; September 19, 2021). Informed consent was not required for this retrospective study.

Patients

A total of 39 patients that had a BPF after pulmonary resection or lung transplantation were surgically treated between January 2010 and June 2020 at the Department of Thoracic Surgery, Yonsei University College of Medicine, Seoul, Republic of Korea. Their age, sex, comorbidities, indication of primary surgery, site of the BPF, requirements of mechanical ventilation (MV) at the time of the BPF repair, methods of the BPF repair, use and type of flap, failure of the BPF repair, and mortality were investigated retrospectively using medical records. A chronic steroid user was defined as a patient who had an oral prednisolone prescription of >5 mg and duration of treatment >1 month, which was based on the National Institute for Health and Care Excellence guidance for patients at risk of systemic side effects.[9]

TABLE 1 Patient baseline characteristics

Variables	Total $N = 39$
Age	60.2 ± 10.8
Male	33 (84.6%)
Comorbidity	
Diabetes mellitus	13 (33.3%)
Connective tissue disease	5 (12.8%)
Chronic steroid user	10 (25.6%)
Mechanical ventilation at the time of primary surgery	6 (15.4%)
Indication of primary surgery	
Pulmonary resection	25 (64.1%)
Lung cancer	13 (52%)
Benign lung disease	12 (48%)
Lung transplantation	14 (35.9%)
Idiopathic pulmonary fibrosis	10 (71.4%)
Bronchiectasis	1 (7.1%)
Connective tissue disease related ILD	3 (21.4%)
Site of BPF	
Bronchial anastomosis	11 (28.2%)
Bronchial stump	26 (66.7%)
Peripheral BPF	2 (5.1%)
Mechanical ventilation at the time of BPF repair	13 (33.3%)
Method of BPF repair	
Primary repair	27 (69.2%)
Additional resection	12 (30.8%)
Completion pneumonectomy	8 (66.7%)
Lobectomy or bilobectomy	2 (16.7%)
Wedge resection	1 (8.3%)
Bronchoplasty	1 (8.3%)
Failure of BPF repair	16 (41.0%)
In-hospital mortality	12 (30.8%)

Abbreviations: BPF, bronchopleural fistula; ILD, interstitial lung disease.

Surgical indications and treatment

A BPF was defined as any communication between the bronchial tree and the pleural cavity that was confirmed either clinically, by bronchoscopy or high-resolution computed tomography. Surgery was indicated when the size of the BPF was >8 mm,[10] or when a BPF was not improved with pleural drainage and conservative care. The surgical repair was performed through a posterolateral thoracotomy. The technique of surgical repair was either a primary suture closure of the bronchial stump or an additional pulmonary resection. When performing a primary repair or bronchoplasty, the necrotic tissue around the BPF was removed and the surrounding fresh tissue was manually repaired with polydioxanone 3–0 suture (Ethicon) using simple interrupted stitches. When an additional pulmonary resection was performed, more proximal part than the BPF location was additionally resected with mechanical stapler (Covidien Endo GIA Ultra Universal staplers, Medtronic). Afterwards, the air leakage test was performed. After confirming that the BPF restoration site was intact, the stump site was reinforced with a vascularized pedicle flap (e.g., omental or muscle flap) as needed.

Definition of success

The success of BPF repair was defined as discharge of the patient without a drain with visual occlusion of BPF associated with the absence of an air leak, recurrence of BPF and thoracic cavity infection. Failure included death within 3 months postoperatively, the need for a surgical procedure, or the development of a chronic fistula. In-hospital mortality was defined as death during hospitalization after surgery, and overall mortality was defined to include in-hospital mortality, mortality after readmission and death at other hospitals.

TABLE 2 Success rate of BPF repair surgery according to the reinforcement type and mechanical ventilation at the time of surgery

	Omental flap ($N = 30$)	Muscle flap ($N = 4$)	No flap ($N = 5$)	Total patients ($N = 39$)
With MV	Success 2/11 (18.2%)	Success 0/1 (0%)	Success 0/1 (0%)	Success 2/13 (15.4%)
Without MV	Success 17/19 (89.5%)	Success 1/3 (33.3%)	Success 3/4 (75%)	Success 21/26 (80.8%)
Total patients	Success 19/30 (63.3%)	Success 1/4 (25%)	Success 3/5 (60%)	Success 23/39 (59%)

Abbreviations: BPF, bronchopleural fistula; MV, mechanical ventilation.

TABLE 3 Success rate of BPF repair surgery according to the type of surgery and mechanical ventilation at the time of surgery

	Primary repair ($N = 27$)	Additional resection ($N = 12$)	Total patients ($N = 39$)
With MV	Success 1/11 (9.1%)	Success 1/2 (50%)	Success 2/13 (15.4%)
Without MV	Success 13/16 (81.3%)	Success 8/10 (80%)	Success 21/26 (80.8%)
Total patients	Success 14/27 (51.9%)	Success 9/12 (75%)	Success 23/39 (59%)

Abbreviations: BPF, bronchopleural fistula; MV, mechanical ventilation.

Statistical analysis

Continuous variables are expressed as the mean ± standard deviation or median (interquartile range, IQR), and categorical data were expressed as frequencies and percentages. The Chi-square or Fisher's exact tests were used to compare the categorical variables between the two groups. A stepwise multivariable logistic regression model was used for statistically significant variables ($p < 0.2$) in the univariate model. Multivariable analysis was performed using a logistic regression model to evaluate the effects of multiple variables on BPF repair. A p-value < 0.05 indicated statistical significance. Statistical analyses were performed using the SPSS version 25.0 (SPSS Inc.) software.

RESULTS

Patient baseline characteristics

The mean age of patients was 60.2 ± 10.8 years and there were 22 male patients (84.6%; Table 1). During the study period, 63 (0.7%) of the 8 635 patients who underwent pulmonary resection surgery developed BPF. The BPF was developed in 16 (4.9%) of the 324 lung transplant patients. Among them, 25 patients (4 pneumonectomies, 18 lobectomies, and 3 sublobar resections) in pulmonary resection surgery and 14 patients (1 single lung, 9 bilateral lungs, and 4 bilateral lungs with lobectomy of the donor lung) in lung transplantation received surgical treatment for BPF. The indication for pulmonary resection and lung transplantation before the diagnosis of BPF were lung cancer (13 patients), benign lung disease (12 patients), and end-stage lung disease (14 patients; 10 with idiopathic pulmonary fibrosis, 1 with bronchiectasis, and 3 with connective tissue disease-related interstitial lung disease). BPF was diagnosed 19 days (median; IQR, 14 and 41 days) and repaired 28 days (median; IQR, 17 and 55 days) after the initial operation. The BPF repair was done within 2 days (median; IQR, 1 and 9 days) after diagnosis.

Outcomes of BPF repair

The BPFs were repaired by primary closure in 27 patients, and by additional resection in 12 patients (8 completion pneumonectomies, 1 completion lobectomy, 1 completion bilobectomy, 1 wedge resection, and 1 bronchoplasty; Table 1). Thirty patients required reinforcement with an omental flap and four patients with a muscle flap (1 pectoralis major and 3 latissimus dorsi; Table 2). There was only one abdominal complication of a diaphragmatic hernia related to the omental harvest. The in-hospital mortality rate was 30.8% (12/39), and the overall mortality rate was 56.4% (22/39). Eleven patients died due to septic shock, six of pneumonia, two of chronic respiratory failure, one of lung cancer, and two of unknown causes. The overall success rate of BPF repair was 59% (23/39). The patients that required MV at the time of BPF repair had a significantly lower success rate when compared to those without (15.4%, 2/13 vs. 80.8%, 21/26, respectively; $p < 0.001$; Table 3).

Risk factors for surgical BPF repair

In the univariate analysis, chronic steroid use (hazard ratio [HR], 5.19; 95% confidence interval [CI]: 1.16–28.7; $p = 0.039$), MV at the time of BPF repair (HR, 23.1; 95% CI: 4.5–185.6; $p < 0.001$), and additional resection at the time of BPF repair (HR, 0.36; 95% CI: 0.07–1.51; $p = 0.183$) were independent prognostic factors. Furthermore, in the multivariable analysis, MV at the time of BPF repair (HR, 16.65; 95% CI: 3.02–140.43; $p = 0.003$) remained independent prognostic factors (Table 4).

TABLE 4 Univariate and multivariate analysis for surgical BPF repair

Variables	Univariate		Multivariate	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Age	1.04 (0.98–1.12)	0.215		
Sex	1.47 (0.25–11.72)	0.678		
Diabetes mellitus	0.52 (0.12–2.04)	0.360		
Chronic steroid use	5.19 (1.16–28.7)	0.039	3.20 (0.46–24.01)	0.233
Lung transplantation (vs. lung resection)	1.12 (0.29–4.27)	0.862		
MV at the time of BPF repair	23.10 (4.5–185.6)	<0.001	16.65 (3.02–140.43)	0.003
Additional resection at the time of BPF repair	0.36 (0.07–1.51)	0.183	0.53 (0.06–3.68)	0.530
Reinforcement with flap	1.05 (0.15–8.77)	0.960		
Time to surgery from diagnosis of BPF	1.00 (0.99–1.01)	0.741		

Abbreviations: BPF, bronchopleural fistula; CI, confidence interval; MV, mechanical ventilation; OR, odds ratio.

Comparison between omental and muscle flaps

At the time of BPF, the success rates in all patients of the omental and muscle flap groups were 66.7% and 25%, respectively; in patients without MV, the success rates in each group were 89.5% and 33.3%, respectively. When comparing the two types of flaps in patients without MV, the omental flap tended to have a better success rate, although it was not statistically significant ($p = 0.07$; Table 2).

DISCUSSION

BPF is one of the most serious complications after pulmonary resection that has been reported to occur in approximately 0.4%–1.5% after lobectomy and 1.5%–15% after pneumonectomy.[11] A BPF may develop at any point of time during the course of illness.[12,13] Although the incidence of BPF has decreased with the development of surgical techniques and perioperative management, patients with BPF have a relatively high mortality rate that remains a challenge for thoracic surgeons. Surgical treatment is indicated for both early (within 2 weeks) and late (after 2 weeks) postoperative patients under infection control.[14] In the case of small BPF (<8 mm), the BPF can be blocked using endoscopic procedures. Several endoscopic procedures that have been proposed to close a BPF, including the application of glues, sclerosant agents, plugs placement and endoscopic prosthesis (Amplatzer devices, Dumon silicone stent, and self-expandable metallic stents). However, in the case of large BPF (>8 mm), the surgical method is strongly recommended.[10,15]

Several studies have suggested risk factors for developing a postoperative BPF.[11,16] However, little is known about the related adverse factors of a successful BPF repair. In our study, multivariable analysis showed that MV at the time of BPF repair had a negative effect on the success of the BPF repair. Furthermore, there was no statistical significance reached for the presence of diabetes mellitus and chronic steroid use, the type of primary surgery, additional resection required at the time of BPF repair, bronchial stump reinforcement with flap, and time between surgery and diagnosis of BPF.

The patients who were on MV at the time of BPF repair were more likely to require a ventilator after surgery. On this basis, continuous positive pressure ventilation, with high airway pressure being applied to the BPF repair site, was thought to interfere with and impede the healing of the BPF repair site. Therefore, the possibility of weaning the patient off MV after surgery should be determined and considered when the timing of the surgery is planned. In patients who require continued ventilatory care postoperatively for hypoxia or hemodynamical instability, it would be preferable to delay surgery until extubation is possible. In the event that ventilator weaning is not possible after BPF surgery, it is suggested to reduce the mean airway pressure, positive end expiratory pressure (PEEP) to reduce the peak airway pressure, tidal volume to reduce the peak inspiratory pressure, and the proportion of minute ventilation provided by the ventilator.[17] Intermittent mandatory ventilation modes with low tidal volumes, PEEP, respiratory rates, and shorter inspiratory times are appropriate.[18]

In a BPF repair, vascularized tissue is often used to buttress the stump. Satisfactory results have been reported with the use of omental, muscular,[19–21] pericardial,[22,23] and diaphragmatic[24] flaps for BPF repair. We prefer to use an omental flap to reinforce the stump site after a postoperative BPF repair. The omental flap has several advantages. First, omentum tissue has the ability to induce angiogenesis and enhance neovascularization.[25–28] Second, omentum tissue has immunological benefits, such as an increase in local lymphocytes, which aid in the elimination of infection. Third, because the omentum is large and atypical, it is suitable for filling irregular spaces and attaching to stumps.[29] However, a disadvantage is that an additional incision is required. The omental flap group demonstrated a greater trend toward the success of BPF repair than the muscle flap group in the patients without MV at the time of repair ($p = 0.07$). Despite the theoretical advantages of the omental flap, there was no statistically significant difference in our study. This is thought to be because the small number of patients in the muscle flap group, and that the ventilator factor had a great influence. Therefore, additional studies are needed regarding the appropriate flap for BPF repair.

This study had some limitations. First, this was a retrospective, single-center study with a relatively small sample due to the low incidence of postoperative BPF with only some of them treated surgically. Second, the type of BPF repair was performed mainly on the surgeon's preference. Nevertheless, our study is considered meaningful as it offers novel suggestive factors related to the success of BPF repair in the current situation where little is known about the risk factors related to prognosis after surgical treatment of postoperative BPF.

There was a high overall mortality after BPF repair and a low success rate of BPF repair. The use of mechanical ventilation at the time of BPF repair was significantly related to the failure of BPF repair, whereas etiology, chronic steroid usage, and additional pulmonary resection were not related. The omental flap group demonstrated a greater trend toward a successful BPF repair when compared to the muscle flap group.

CONFLICT OF INTEREST

The authors declare no conflicts of interest for this article.

ORCID

Young Ho Yang https://orcid.org/0000-0002-0977-0525
Seong Yong Park https://orcid.org/0000-0002-5180-3853
Ha Eun Kim https://orcid.org/0000-0001-9240-2215
Chang Young Lee https://orcid.org/0000-0002-2404-9357
Jin Gu Lee https://orcid.org/0000-0003-2767-6505
Dae Joon Kim https://orcid.org/0000-0002-2182-010X
Hyo Chae Paik https://orcid.org/0000-0001-9309-8235

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