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Respiratory endoscopy intervention in 12 patients with refractory persistent air leakage after pulmonary surgery: a preliminary study of case series

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Abstract

Objective To explore the value of our protocol of respiratory endoscopy intervention in the treatment of refractory persistent air leakage(PAL) after pulmonary surgery.

Method A retrospective study was conducted in 12 patients with PAL after pulmonary surgery who were successfully treated by our protocol of respiratory endoscopy intervention in the Department of Respiratory and Critical Care Medicine of the Fourth Hospital Affiliated to Soochow University and the First Hospital Affiliated to Soochow University from December 2019 to January 2024. 4 types of treatment were included in our protocol; A: chest tube drainage combined with negative pressure suction; B: medical thoracoscopy with chest tube as a path; C: stimulating bronchial mucosa hyperplasia under bronchoscopy; D: blocking of the fistula orifice with the relevant materials under the bronchoscope; And the specific treatment received by each patient was based on the condition of the patient.

Results The bronchopleural fistula was found in 7 patients; The fistula orifice was found in 5 patients and the diameter of fistula orifices were 4.0–12.0 mm, with an average of 7.2 ± 3.6 mm. Among the 7 patients with bronchopleural fistula, 1 patient received C + D, 1 patient received A + B + C, 1 patient received A + C + D, 4 patients received A + B + C + D; Among the 5 patients with fistula orifice, 2 patients received C + D, 2 patients received A + B + D, 1 patient received A + C + D. All the 12 patients were effectively treated, among which 9 patients who underwent chest tube drainage were successfully extubed. The median (interquartile distance) retention time of chest tubes before and after our protocol of respiratory endoscopy intervention were respectively 73.5(50.5,106.25) days and 29(22,38.75) days, $p < 0.05$.

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Conclusions Our protocol of respiratory endoscopy intervention can significantly shorten the retention time of the patient's chest tube and effectively treat refractory PAL after pulmonary surgery. However, it should be emphasized that individualized therapy should be provided according to the location and size of the fistula orifice.

Keywords Persistent air leakage, Respiratory endoscopy intervention, Bronchopleural fistula, Local stimulation, Bronchoscopy, Medical thoracoscopy

Introduction

PAL after pulmonary surgery is a pathological condition that leads to the mutual communication between trachea or alveoli and pleural cavity and the formation of abnormal channel [1]. Infection in the pleural cavity and hypoxia and respiratory failure due to gas exchange dysfunction are the main causes of death due to PAL after pulmonary surgery, so its therapy remains a challenge [2]. Poor tolerability, low success rate, and high mortality in the reoperation of such patients [1]. Other conventional methods of therapy including chest tube drainage and bronchoscopic interventional therapy, which can effectively treat PAL after pulmonary surgery. But for some refractory patients, the existing options of therapy may be limited. In addition, due to the location of air leakage, the size of fistula orifice and other factors, the therapy plan of PAL after pulmonary surgery should be individual rather than uniform [3].

Chest tube drainage is the basic therapy for PAL after pulmonary surgery, but the period of therapy is long, the curative effect is limited, and the intrathoracic infection is difficult to be accurately evaluated [4]. Due to the presence of chest tube, it has become possible to perform medical thoracoscopy or ultrathin bronchoscopy with the chest tube as the path to treat intrathoracic infection, which may be more effective than conventional chest tube drainage and multiple punctures required by traditional thoracoscopy can be avoided.

Management of fistula orifice is the key to the therapy of PAL after pulmonary surgery, and the medical adhesive, autologous blood, EBV valve and airway stent under bronchoscopy can effectively block the fistula orifice [2, 3]. However, in addition to postoperative fistula orifice, there is another special situation occurring in PAL, that is, the existence of postoperative residual bronchial lumen, which is defined as bronchopleural fistula. In our previous study, we took the lead in proposing a new method of therapy, that is, a case of refractory bronchopleural fistula was successfully treated with blocking material based on the stimulation of bronchial mucosa hyperplasia by brush under bronchoscopy [5], however, the current study was limited to case report. The value and selection of various respiratory interventional techniques in the therapy of PAL after pulmonary surgery were further discussed in our this case series.

Methods

Patients

A total of 12 patients with refractory PAL after pulmonary surgery were treated in the Department of Respiratory and Critical Care Medicine of the Fourth Hospital Affiliated to Soochow University and the First Hospital Affiliated to Soochow University between December 2019 and January 2024. This study was carried out with the consent of the Ethics Committee of the Fourth Affiliated Hospital of Soochow University(this study is a retrospective study using anonymized data, which is in line with the "exemption from review" regulations of the Fourth Affiliated Hospital of Soochow University). And the informed consents were obtained from the patients for this study.

Diagnosis of PAL after pulmonary surgery

(1)(i) The duration of air leakage after pulmonary surgery is longer than 5–7 days, which is called PAL [6]. The abnormal channel, increase of gas in the pleural cavity, the new liquid-gas level or the original liquid-gas level changes can be observed in the chest computed tomography(CT) of patients with PAL; The bubble can be observed in patients with chest tube during forced breathing. (ii) A special case in our study was that "air leakage" could not be directly observed in this patient who underwent radical resection of esophageal cancer combined with resection of pulmonary bullae because of obvious postoperative pleural adhesions. Moreover, we attempted to identify the abnormal channel by using the staining under respiratory endoscopy and digestive endoscopy because of an possible abnormal channel between the bronchi, pleural cavity and stomach was observed in the CT of this patient.

(2)The severity of the air leakage: The severity of the air leakage is classified into 4 levels according to the Cerfolio criteria [7].

(3)Classification of air leakage and diagnosis of fistula orifice: PAL after pulmonary surgery is classified into two categories based on the presence or absence of the bronchopleural fistula. (i) Presence of bronchopleural fistula (Fig. 1b): The postoperative fistula orifice is located in the distal or peripheral bronchus and cannot be reached by bronchoscopy, this residual bronchial lumen is defined as the bronchopleural fistula; Diagnosis of this type of PAL requires indirect methods such as continuous balloon occlusion, stain and Chartis system via bronchoscopy, in

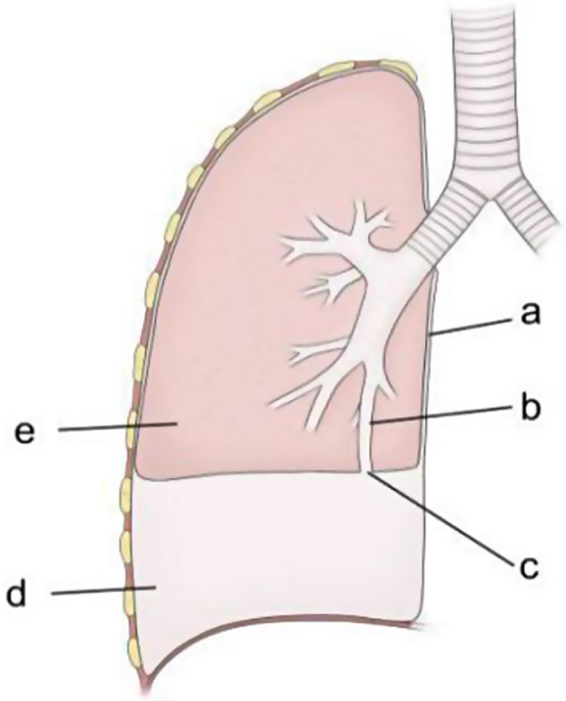

Fig. 1 (**a**) Pleural cavity, (**b**) bronchopleural fistula, (**c**) fistula orifice, (**d**) Liquid pneumothorax, (**e**) Compressed lung

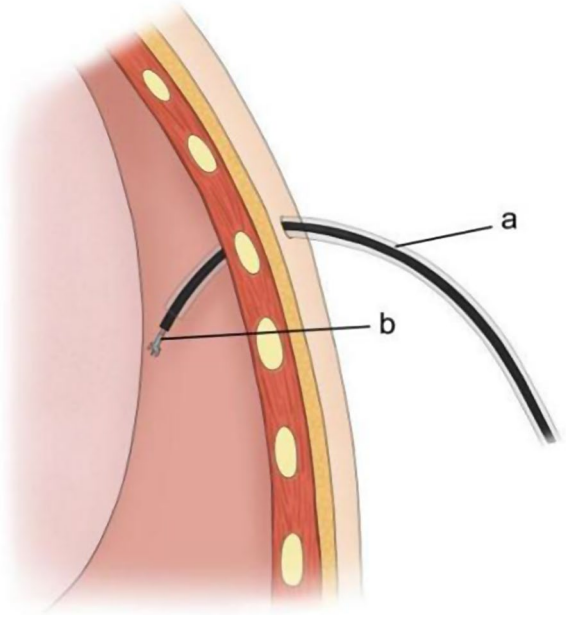

Fig. 2 (**a**) Therapy type A: chest tube drainage, (**b**) Therapy type B: medical thoracoscopy with chest tube as a path

addition, the size of the fistula orifice can not be determined in this type of PAL. (ii) Absence of the bronchopleural fistula (Fig. 1c): The fistula orifice is located in the main bronchus or surgical stump, can be diagnosed under direct vision of the bronchoscope, and the size of the fistula orifice can be measured.

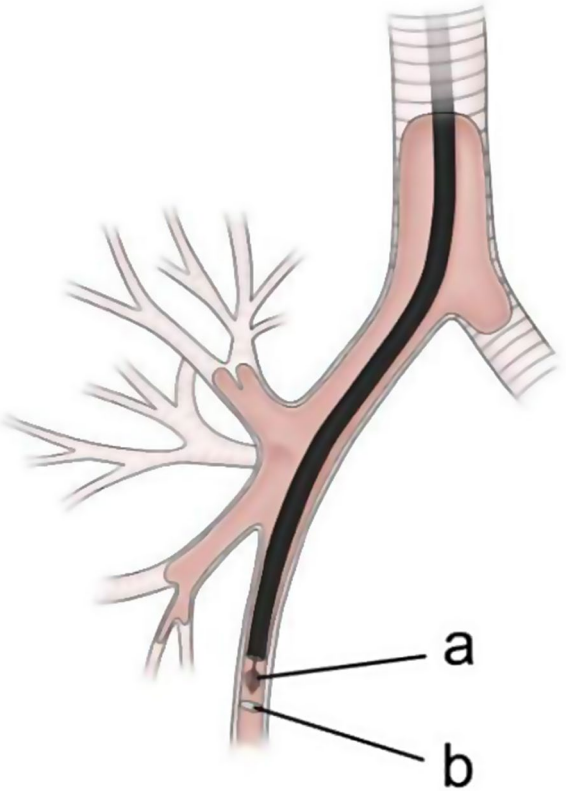

Fig. 3 (**a**) Therapy type C: local stimulation under bronchoscopy, (**b**) Therapy type D: blocking of the fistula orifice with the relevant materials under the bronchoscope

Our protocol for the treatment of PAL after pulmonary surgery

4 types of treatment(A, B, C and D) were included in our protocol and the specific treatment(the combination of A, B, C or D) received by each patient was based on the condition of the patient. And the details of the 4 types of treatments are as follows:

A: Chest tube drainage combined with negative pressure suction (Fig. 2a): The thoracentesis was performed on the patients and the chest tubes were placed into the chest cavity of the patients; The chest tubes were connected to the water seal bottles and the negative pressure suction was performed on the patients. B: Medical thoracoscopy with chest tube as a path (Fig. 2b): In contrast to conventional medical thoracoscopy, we examined the patients along the chest tubes by using the thoracoscopy or the ultra-thin bronchoscope; And the removing of necrotic tissues, the releasing of adhesions and the pleurl lvge with saline were performed on the patients. C: Stimulating bronchial mucosa hyperplasia under bronchoscopy (Fig. 3a): In patients with bronchopleural fistula, the brush was applied under bronchoscopy to rub the lumen above the fistula orifice, and with the help of proliferating granulation tissue to promote the occlusion of the bronchus above the fistula orifice. D: Blocking of

the fistula orifice with the relevant materials under the bronchoscope (Fig. 3b): The autologous blood, absorbable gelatin sponge, EBV valve etc. were used to block the fistula orifice.

Principles of treatment after pulmonary surgery for PAL

(1) Management of complications: (i) Chest tube drainage combined with negative pressure suction was performed for patients with PAL and pleural cavity infection. If the symptoms of infection such as cough, expectoration, fever, etc., were repeated, and the purulent drainage fluid continued to not decrease or increase, the medical thoracoscopy or ultra-thin bronchoscope was used to perform thoracoscopy through the chest tube and local therapies were performed, such as the removing of necrotic tissues and the releasing of adhesions. (ii) Empirical anti-infective therapy or anti-infective therapy was based on the results of sputum culture and pleural effusion culture.

(2) Therapy of fistula orifice: (i) Presence of the bronchopleural fistula: The brush was used to stimulate bronchial mucosa hyperplasia combined with the use of individualized blocking materials(including autologous blood, absorbable gelatin sponge, EBV valve, etc.) through bronchoscopy to block the bronchopleural fistula. (ii) Absence of the bronchopleural fistula: Brushing to stimulate bronchial mucosa hyperplasia or medical adhesive or sclerosing agent were used separately to block the fistula orifice when the diameter of fistula orifice was ≤3 mm; The brush was used to stimulate bronchial mucosa hyperplasia combined with the use of individualized blocking materials through bronchoscopy to block the fistula orifice when the diameter of the fistula orifice was >3 mm but ≤6 mm; The airway stent was placed when the diameter of the fistula orifice was >6 mm.

Table 1 Clinical baseline characteristics of the patients

Variables	Total *N* = 12
Age	53.0 ± 17.0(25–75)
Gender(M/F)	7/5
Past medical history(%)	
healthy	11(91.7%)
Breast tumor surgery	1(8.3%)
BMI(%)	
< 25 kg/m^2	11(91.7%)
≥ 25 kg/m^2	1(8.3%)
Site of surgery(%)	
Right	8(66.7%)
Left	4(33.3%)
Method of Surgical (%)	
Lobectomy	6(50.0%)
Segmentectomy	4(33.4%)
Wedge resection	1(8.3%)
surgery of esophageal and pulmonary bullae	1(8.3%)
Postoperative Pathology (%)	
Lung cancer	9(75.0%)
Benign disease	3(25.0%)

M: Male, F: Female

Evaluation of efficacy

(1)(i)The chest tube was successfully removed: when there are no bubble spilling out or only a small amount of bubbles spilling out during forced coughing, reduced or stable fluid pneumothorax was observed on the CT or X-ray after 24 h of clamping chest tube. (ii) The gradual absorption or disappearance of the remaining dead space was observed on imaging in patients during the follow-up(including the patients who without chest tube drainage). The basis for judging that PAL is effectively treated is that both 1 and 2 are met.

(2)Due to "air leakage" could not be accurately evaluated and an abnormal channel between the bronchi, pleural cavity and stomach may be present in this patient who underwent radical resection of esophageal cancer combined with resection of pulmonary bullae, the successful blocking of the abnormal channel was confirmed with the use of combined respiratory and digestive endoscopy.

Statistical method

SPSS 27.0 statistical software was used to analyze the data. Wilcoxon signed rank test was used to compare the retention time of chest tubes before and after therapy with respiratory endoscopy intervention, and the difference was statistically significant with $p<0.05$.

Results

The characteristics of the patients (Table 1)

In our study, 7 were males and 5 were females, aged 25–75 years (53.0 ± 17.0 years), and 5 were older than 65 years. The mean Body Mass Index(BMI) was 20.5 ± 3.0 kg/m^2, and 11 (91.7%) patients had a BMI of less than 25 kg/m2. A history of breast tumor surgery in 1 patient, and all the other patients were healthy.

Lung surgery was performed on all 12 patients. The indication for surgery was pulmonary nodules detected by physical examination in 11 patients (91.7%), and the diameter of pulmonary nodules ranged from 6.0 to 41.0 mm(22.3 ± 12.7 mm); The indication for surgery was pulmonary bullae in 1 patient(8.3%)(radical resection of esophageal cancer was performed at the same time as resection of pulmonary bullae in this patient). 6 patients underwent lobectomy, 4 patients underwent segmentectomy, 1 patient underwent wedge resection, 1 patient underwent wedge resection, 1 patient underwent radical resection of esophageal carcinoma combined with resection of pulmonary bullae.

The pathological findings were pulmonary malignancy in 9 patients(75.0%), and benign disease in 3 patients(25.0%). Carcinoma in situ with microinfiltration

was found in 3 patients; Squamous cell carcinoma in 3 patients, among them, stage IA, IIB and IIIA were in 1 patient respectively; Adenocarcinoma in 3 patients, among them, stage IA, IIA and IIIA were in 1 patient respectively. In 3 patients with benign pulmonary disease, 1 patient underwent radical resection of esophageal carcinoma and resection of pulmonary bullae at the same time.

Diagnosis of PAL after pulmonary surgery

All the 12 patients were observed with newly emerging symptoms of cough, sputum, fever, and dyspnea, as well as abnormal channel or increased gas in the pleural cavity or the new liquid-gas level on chest CT, and were diagnosed with PAL after pulmonary surgery with the help of bronchoscopy. The bronchopleural fistula were found in 7 patients under bronchoscopy, of which the location of fistula orifices were determined indirectly by Chartis system, continuous continuous balloon occlusion and stain in 3, 2 and 2 patients, respectively; And 1 of these patient was diagnosed with the fistula of bronchi, pleural cavity and stomach by bronchoscopy and gastroscopy. The fistula orifice were found in 5 patients under bronchoscopy directly with the diameter of 4.0–12.0 mm(7.2±3.6 mm), of which fistula orifice was located above the tracheal carina in 1 patient, and the fistula orifices were located at the surgical stump in 4 patients (Table 2).

Therapy of PAL after pulmonary surgery

(1)Therapy of complications: (i) Chest tube drainage combined with negative pressure suction: Of the 12 patients, 9 patients were performed chest tube drainage, and 3 patients were not performed chest tube drainage; In patients undergoing chest tube drainage, chest tubes (size of chest tube: 18f(french)-26f) were performed in 8 patients when PAL were identified immediately, and chest tube was performed 1 patient (size of chest tube: 8f) during the respiratory endoscopy intervention; According to the Cerfolio criteria, the severity of air leakage was all grade 4 in patients with chest tube drainage. (ii) Medical thoracoscopy with chest tube as a path: At least once medical thoracoscopy(with chest tube as a path) was performed in 7 patients with large diameter of chest tubes (Table 2).

(2)Therapy of fistula orifice (Fig. 4a-f): Among the 7 patients with bronchopleural fistula, 1 patient received C+D, 1 patient received A+B+C, 1 patient received the A+C+D, 4 patients received A+B+C+D; Among the 5 patients with fistula orifice, 2 patients received C+D, 2 patients received A+B+D, 1 patient received A+C+D (Table 2). The course of therapy is shown below in this special patient who underwent radical resection of esophageal cancer combined with resection of pulmonary bullae (Fig. 5a-f).

(3)Empirical anti-infective therapy or anti-infective therapy was based on the results of sputum culture and pleural effusion culture.

Table 2 Diagnosis, therapy, and prognosis of patients with PAL

No	Age Gender	broncho-pleural fistula	Location of fistula orifice	Size of fistula orifice(mm)	Dimension of chest tube	Therapy	Retention time of chest tube(d)	Follow-up(m) and result(air leakage)
1	48 F	N	Surgical stump of the upper lobe of the left lung	5	N	C+D	/	9.4, N
2	75 M	N	Surgical stump of the left main bronchus	5	N	C+D	/	11.4, N
3	67 M	Y	Apical and anterior segments of the upper lobe of the right lung	Not determined	N	C+D	/	0.9 N
4	32 F	Y	Posterior segment of the upper lobe of the left lung	Not determined	Y 26f	A+B+C+D	155	18.9, N
5	60 M	Y	Inner basal segment of the lower lobe of the right lung	Not determined	Y 24f	A+B+C+D	121	11.4, Relapse
6	65 M	Y	Posterior segment of the upper lobe of the right lung	Not determined	Y 21f	A+B+C+D	94	12.1, N
7	25 F	N	Surgical stump of the dorsal segment of the right lower lobe	4	Y 8f	A+C+D	10	8.7, N
8	28 F	Y	Basal segment of the lower lobe of the right lung	Not determined	Y 24f	A+B+C	72	19.5, N
9	69 M	N	Surgical stump of the upper lobe of the left lung	10	Y 24f	A+B+D	173	28.1, N
10	53 M	Y	Posterior segment of the upper lobe of the right lung	Not determined	Y 24f	A+B+C+D	78	9.2, N
11	65 M	N	Above the tracheal carina	12	Y 24f	A+B+D	125	7.6, N
12	49 F	Y	Dorsal segment of the lower lobe of the left lung	Not determined	Y 18f	A+C+D	65	37.4, N

A: chest tube drainage combined with negative pressure suction; B: medical thoracoscopy with chest tube as a path; C: stimulating bronchial mucosa hyperplasia under bronchoscopy; D: blocking of the fistula orifice with the relevant materials under the bronchoscope. M: Male, F: Female, Y: Yes, N: None, d: Day, m: Month

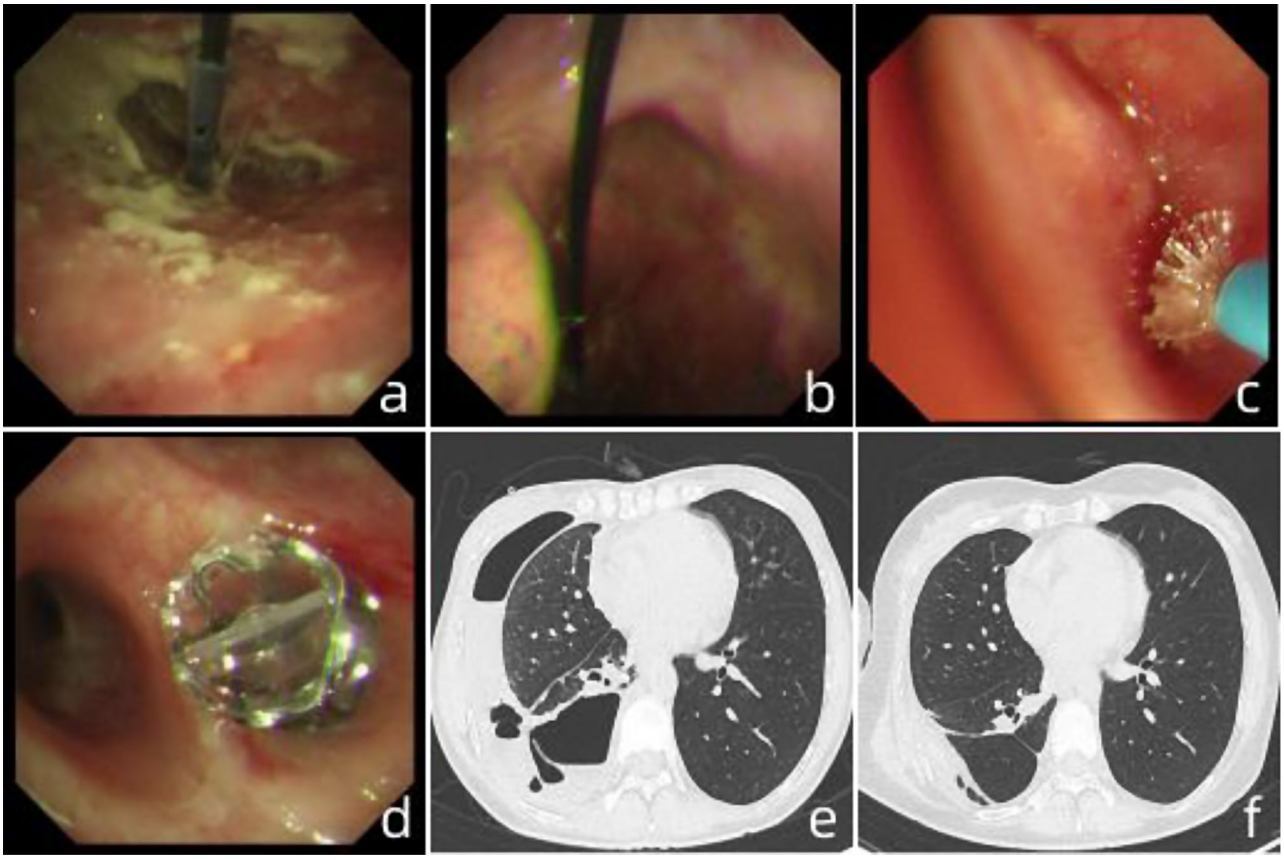

Fig. 4 (**a**) Before the medical thoracoscopy with chest tube as a path, (**b**) After the medical thoracoscopy with chest tube as a path, (**c**)Brushing to stimulate bronchial mucosa hyperplasia under a bronchoscope, (**d**) Placing of the EBV valve, (**e**) PAL and fluid pneumothorax in the right lung after surgery in this patient, (**f**) A repeat CT scan showed that the right lung fluid pneumothorax was basically absorbed after successful removal of the chest tube and follow-up for 10 months in this patient

Effect of therapy

(1)From the time of last respiratory endoscopy intervention to 8 April 2024, the 3 patients without chest tube drainage were followed up for 9.4 months, 11.4 months and 0.9 months, respectively; In addition, gradual resorption or blocking of the fistula orifice under endoscope or gradual absorption of the residual dead space under examination of imaging were observed in these 3 patients. 9 patients who underwent chest tube drainage were successfully extubed, the retention time of the chest tubes was 10–173 days, with a median (interquartile distance) of 94 (72,124) days, and the follow-up was 7.6-37.4months after extubation; Among these 9 patients, only 1 patient relapsed after receiving programmed cell death protein 1(PD-1), and gradual absorption or vanish of the residual dead space under examination of imaging were observed in remaining 8 patients during the follow-up (Table 2).

(2)Chest tube drainage were performed in 8 patients when PAL were identified at once, and the median (interquartile distance) retention time of chest tubes before and after our protocol of respiratory endoscopy intervention were respectively 73.5(50.5,106.25) days and 29(22,38.75) days, $p<0.05$ (Fig. 6).

Discussion

PAL is a common complication after pulmonary surgery, the chest infection and gas exchange disorder caused by PAL after pulmonary surgery will prolong the hospital stay of patients, and even threaten their lives [1, 8]. Pulmonary surgery is the most common cause of PAL, the incidence of PAL after pneumonectomy is approximately 4.5–20%, whereas the incidence of PAL after lobectomy is about 0.5-1%, other causes include necrotizing infections such as tuberculosis, pneumonia, empyema, etc [3, 9]. In the study of Hoeijmakers F et al. [10], it was shown that lobectomy (compare with segmental resection), right lung surgery, were independent predictors of PAL after lung surgery. In our study, all 12 patients had PAL caused by pulmonary surgery, including 6 cases of lobectomy (54.5%) and 8 cases of right lung surgery (66.7%). In addition, there are many other risk factors for PAL after lung surgery, including advanced age (>65 years), low BMI (<25 kg/m2), underlying lung diseases, decreased lung

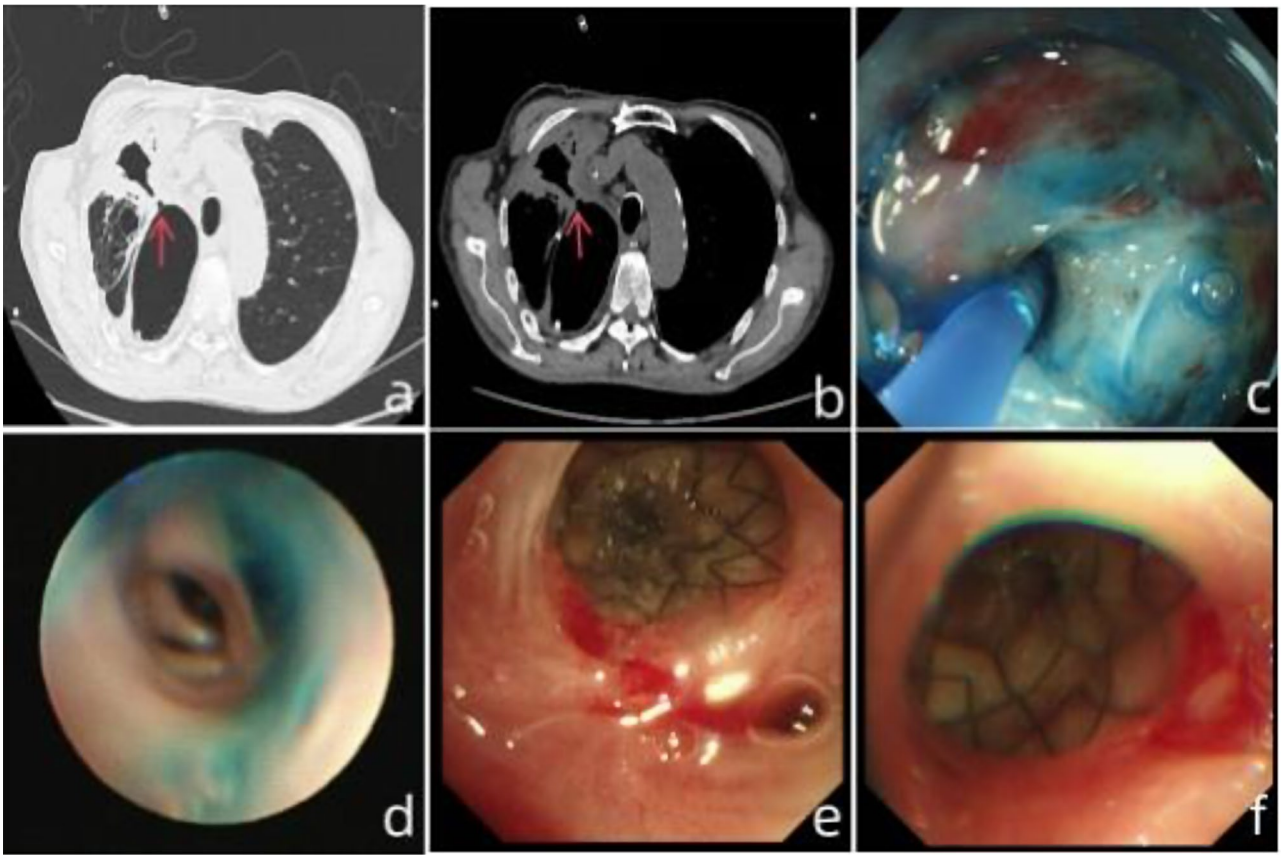

Fig. 5 The course of therapy of the patient with the fistula of bronchi, pleural and stomach after radical resection of esophageal cancer and resection of pulmonary bullae. (**a**) An abnormal channel of bronchi, pleural cavity and stomach in the lung window of chest CT; (**b**) An abnormal channel of bronchi, pleural cavity and stomach in the mediastinum mediastinum window of chest CT; (**c**) A gap in the stomach can be seen under gastroscopy and stain was released through the gap under gastroscopy; (**d**) The outflow of staining from the apical and anterior segments of the upper lobe of the right lung was observed under bronchoscopy; (**e**, **f**) Inverse EBV valves were retrofitted into the apical and anterior segments of the right upper lobe, respectively, and successful blocking of the fistula orifice was confirmed under combined bronchoscopic and gastroscopic examination

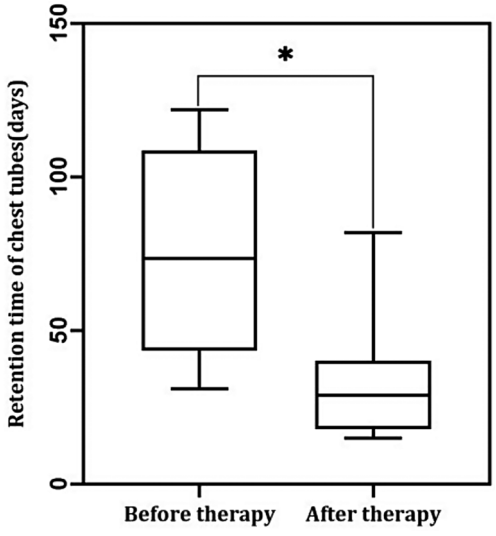

Fig. 6 Comparison of the retention time of chest tubes before and after respiratory endoscopy intervention(*: $p < 0.05$)

function, pleural adhesion, chemotherapy or radiotherapy, immunodeficiency and diabetes [8]. In our study, 5 patients (41.7%) were older than 65 years and 11 patients (91.7%) had BMI < 25 kg/m2.

The diagnosis of PAL after pulmonary surgery is mainly based on the patient's symptoms, chest CT and bronchoscopy, and it is very important to determine the location and size of fistula orifice as soon as possible [3]. The abnormal channel can even be directly observed on CT when the fistula orifices were obvious in some patients [11]. In 1 patient in our study, the fistula orifice was located 1centimeter above the tracheal carina and could be directly observed on CT, and the abnormal channel between the bronchi, pleural cavity and stomach was directly observed on chest CT in 1 patient with radical resection of esophageal cancer and resection of pulmonary bullae. However, most cases of PAL after pulmonary surgery still need to be diagnosed by bronchoscopy [12, 13]. In our study, we propose the concept of "bronchopleural fistula" and "fistula orifice" and the bronchopleural fistula were found in 7 patients under bronchoscopy,

of which the locations of fistula orifice were determined indirectly by Chartis system, continuous continuous balloon occlusion or stain; The fistula orifice were found in 5 patients under bronchoscopy directly and the size of the fistula orifices were accurately measured.

The therapy of PAL after pulmonary surgery mainly includes the management of complications and the fistula orifice; It is the first step for treating PAL to manage related complications such as fluid pneumothorax, intrathoracic infection, and chest tube drainage plays an important role in assessing the degree of air leakage and controlling intrathoracic infection [14]. It has also been shown that simply drainage and controlling the infection can make the fistula orifice heal when the fistula orifice is small enough [15]. The large diameter of chest tubes(>18f) were placed in most patients in our study. Medical thoracoscopy is mostly used for the diagnosis of pleural effusion and pleural diseases, but it is rarely reported to be used for the therapy of PAL after pulmonary surgery [16]. In our study, we creatively used medical thoracoscopy or ultra-thin bronchoscope through the chest tube and performed local therapy in 7 patients with large diameter of chest tubes. In 1 young female patient with PAL and pleural adhesion, the fistula orifice was healed only after chest tube drainage, medical thoracoscopy through chest tube and systemic anti-infection. This suggests that medical thoracoscopy through chest tube may be helpful for the therapy of PAL after pulmonary surgery, but data from a larger sample are needed to support it.

The management of fistula orifice is the key to the therapy of PAL after pulmonary surgery, however, the management of fistula orifice is different due to the location and size of fistula orifice and a unified standard is difficult to establish [2, 3]. Some studies have shown that autologous blood, absorbable gelatin sponge and EBV valve can effectively treat PAL after lung surgery, but there is a certain failure rate, especially for some refractory PAL after lung surgery [5, 17, 18]. In addition, the Food and Drug Administration (FDA) does not recommend the use of metallic stents for the treatment of benign airway diseases because of the limitations of complications [19]. However, in the therapy of PAL, the placement of covered metal stents can theoretically cover the fistula orifice, and stent-related complications can be avoided if the fistula orifice can be healed and the stents can be removed for a short time [20]. Any airway intervention device will cause local inflammatory response and may lead to granulation proliferation, such as airway stent in the therapy of airway stenosis, which will cause granulation proliferation and lead to airway restenosis [21]. However, the granulation proliferation caused by the intervention device may be beneficial in the therapy of PAL after pulmonary surgery, because the granulation proliferation caused by the intervention device may promote the healing of the fistula orifice. In one of our previous animal experiment, we found that stimulation of the tracheal mucosa by applying a brush resulted in the granulation proliferation at 2 weeks and airway stenosis at 4 weeks [22]. In our study, we proposed the concept of "bronchopleural fistula", and made the therapy plan of fistula orifice according to the presence or absence of bronchopleural fistula and the size of fistula orifice. The results showed that all the 12 patients were effectively treated. During the follow-up, only 1 patient relapsed due to anti-tumor therapy, PAL did not recur by endoscopic and chest CT follow-up in the remaining patients. All patients with chest drainage tube were successfully extubated, and the retention time of chest tubes can be shorten significantly by our protocol of therapy.

And the limitation in our study need to be noted. Our study is a preliminary study of case series and the results need to be further supported by clinical studies with larger samples.

Conclusion

In conclusion, we put forward the concept of "bronchopleural fistula" and performed medical thoracoscopy through the chest tube in patients with large diameter chest tubes, and advocated local stimulation to promote fistula orifice healing. The results showed that our protocol was feasible for the therapy of refractory PAL after pulmonary surgery, however, just as our protocol includes multiple treatments and the individualized measures of respiratory endoscopy intervention should be emphasized in therapy of PAL.

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Author contributions

ZYY: Data curation, Formal Analysis, Investigation, writing—original draft; XLZ: Data curation, Investigation, writing—review and editing; WYP: Data curation, writing—review and editing; YJL: Formal Analysis, writing—review and editing; DXZ: Conceptualization, Methodology, writing—review and editing, supervision. JHJ: Conceptualization, Methodology, writing—review and editing, supervision, project administration.

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Data availability

The data in this study is available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

This study was carried out with the consent of the Ethics Committee of the Fourth Affiliated Hospital of Soochow University(this study is a retrospective study using anonymized data, which is in line with the "exemption from review" regulations of the Fourth Affiliated Hospital of Soochow University).

Consrnt for publication
All list authors consent to the submission and all data are used with the consent of the person generating the data.

Competing interests
The authors declare no competing interests.

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