

Treatment of peripheral bronchopleural fistula with interventional negative pressure drainage

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Abstract

Objectives: Bronchopleural fistula is a serious complication of pneumonectomy and lobectomy and results in a reduction in the quality of life of patients. This study aimed to evaluate the efficacy and safety of percutaneous drainage tube placement with continuous negative pressure drainage for the treatment of peripheral bronchopleural fistula.

Methods: Data of 16 patients with peripheral bronchopleural fistula were retrospectively analyzed. A percutaneous thoracic drainage tube was placed under fluoroscopy and connected with a negative pressure suction device. The drainage tube was removed when the residual cavity disappeared on computed tomography.

Results: All 16 patients underwent lobectomy, including 11 patients with lung cancer (68.8%), 4 patients with pulmonary infection (25.0%), and 1 patient with hemoptysis (6.3%). All patients underwent successful drainage tube placement on the first attempt with a technical success rate of 100%. No serious complications occurred during or after the procedure. The drainage tubes were adjusted 3.25 ± 2.24 times (range: 1–8 times). A total of 30 drainage tubes were used (average per patient, 1.88 ± 1.36 tubes). The cure time of 16 patients was 114.94 ± 101.08 days (range, 30–354 days). The median drainage tube indwelling duration was 87 days, and the 75th percentile was 117 days.

Conclusion: Interventional percutaneous thoracic drainage tube placement with continuous negative pressure drainage is an effective, safe, and feasible method for the treatment of peripheral bronchopleural fistula.

Keywords: bronchopleural fistula, interventional radiology, negative pressure drainage, residual cavity

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Introduction

Bronchopleural fistula (BPF) is an abnormal communication between the trachea, carina, bronchus, and pleural cavity. BPF is one of the serious complications of pneumonectomy and lobectomy with an incidence rate of 1.5–8% and a mortality rate of 13.4–67%.^{1,2} Treatment of BPF has improved with advancements in surgery and a broadened understanding of the mechanism of bronchial stump healing; however, BPF is still problematic for thoracic surgeons.

Classic surgical methods for BPF treatment include thoracic drainage closure, fistula repair, omental packing, and thoracoplasty. However, some patients experience traumatic shock, which is complicated by a high failure rate. Some patients are intolerant to a second operation because of long-term infection. Stents, tissue glue, spring coils, and other materials used in fiberoptic bronchoscopy have achieved successful fistula closure;^{3–8} nevertheless, it is impossible to treat peripheral BPF (PBPF) beyond the visual range of a fiberoptic bronchoscope.

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PBPF is defined as BPF without any obvious airway defect detected by bronchoscopy; it frequently originates distal to segmental bronchi. It is difficult to block the PBPF with an airway stent. According to the anatomical and pathological characteristics of PBPF, this study adopted an interventional procedure to treat PBPF in which a thoracic drainage tube was placed for continuous negative pressure drainage (CNPD) of a residual cavity.

Patients and methods

General information

In this study, we retrospectively analyzed the data of patients with PBPF treated by interventional percutaneous thoracic drainage tube placement and CNPD at our hospital from January 2012 to May 2020; the data included medical records, imaging data, surgical records, and follow-up results. Sex, age, etiology, fistula location, residual cavity size, and drainage time were recorded and analyzed. The inclusion criteria were as follows: (1) symptoms of BPF and diagnosis by chest computed tomography (CT), fiberoptic bronchoscopy, or bronchography; (2) fistula localized to the segmental bronchus, bronchioles, or part of the lobar bronchus; and (3) treatment with interventional percutaneous thoracic placement of the drainage tube and CNPD. Patients treated with stents, spring coils, or tissue glue were excluded. This study was approved by the ethics committee of the hospital, and each patient was informed in detail and signed a written informed consent form before interventional radiology treatment.

Preoperative preparation

Routine bloods, liver and kidney function, electrolytes, blood glucose, and coagulation were examined, and electrocardiography (ECG), chest CT, and fiberoptic bronchoscopy were performed before the interventional procedure. If necessary, transcatheter bronchography was performed for location and measurement of both the residual cavity and the fistula. Pre-procedure, we actively corrected water and electrolyte disorders, provided nutritional support, and facilitated anti-infection and expectorant treatment.

Dyna CT-guided percutaneous thoracic puncture and drainage tube placement

Patients were requested to lay on the Dyna CT (Artis zeego; Siemens Healthineers, Forchheim,

Germany) examination table when conscious. Oxygen was administered, and ECG monitoring was performed. A Dyna CT scan was performed to determine the skin puncture point and puncture route. In general, the puncture point should be selected on the affected side of the chest wall or anterior chest wall as convenient. The skin puncture point should be as close to the top of the residual cavity as possible to enable the drainage tube to be placed from top to bottom (Figure 1).

The puncture site was disinfected, and local anesthesia was induced by administration of 2% lidocaine. Then, an 18G puncture needle was used to puncture the residual cavity. Purulent liquid or bloody pleural effusion was aspirated, and 3–5 ml was used for bacteriology and drug sensitivity testing. The Dyna CT images were reexamined to confirm that the puncture position and route were correct. A 0.035-inch hydrophilic membrane guidewire was introduced through the puncture needle, and a multi-lateral hole external drainage tube (8.5 F, 10.2 F; Cook Medical, Bloomington, Indiana, USA) was introduced through exchange. The drainage tube was placed at the bottom of the pleural effusion on the affected side, and the drainage tube was fixed after smooth suction was achieved. The patients typically carried a surgical drainage tube. If the surgical drainage tube was in the appropriate position, another external drainage tube (10.2 F or 12 F) was replaced through the guide wire; if the percutaneous position of the surgical drainage tube was too low, it was necessary to replace the interventional drainage tube, and make a thoracic puncture and place a second tube under the guidance of Dyna CT.

Postoperative management

Because the fistula did not heal, the air leakage was persistent. In order to ensure that the extraction volume of the residual cavity was greater than the leakage volume, the end of the drainage tube(s) was connected with the hospital central negative pressure system on the wall (pressure range, 0.03–0.06 MPa) for 24 h every day for CNPD by using a three-way valve, to promote residual cavity closure. Expectorant and antibiotic treatment were administered (sensitive antibiotics were used according to the results of bacterial culture and drug sensitivity testing). According to laboratory results, patients were treated for symptoms by correction of water and

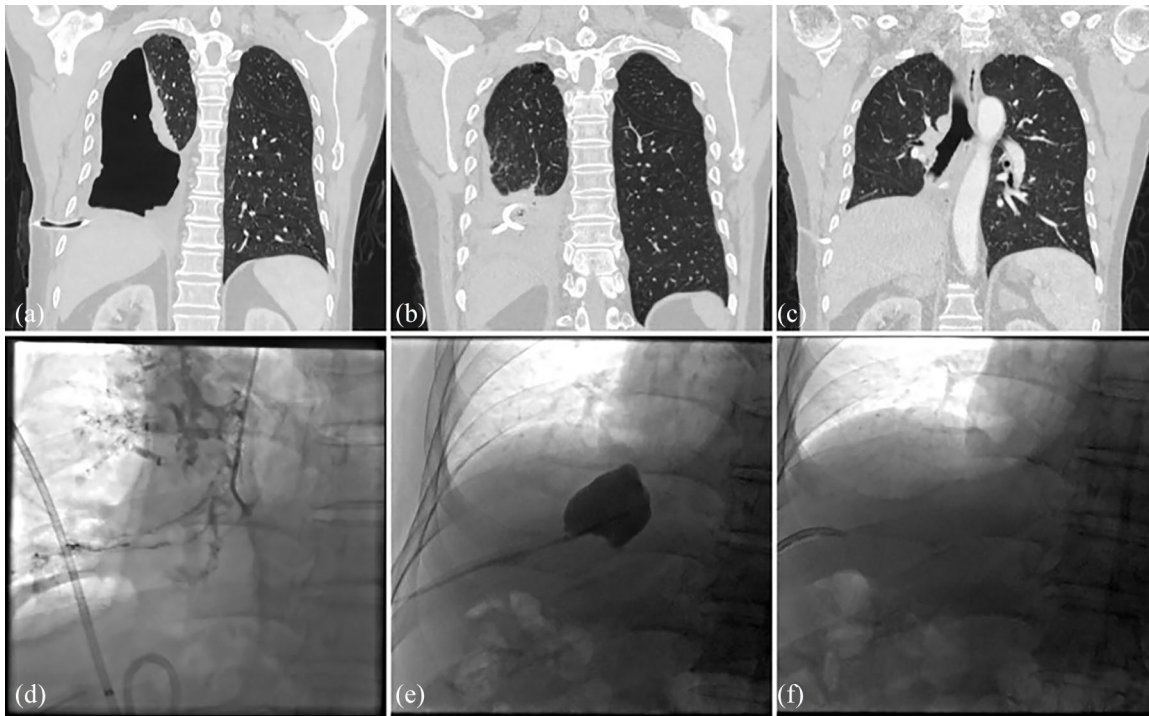


Figure 1. A 57-year-old male underwent thoracoscopic right inferior lobectomy. A postoperative pathological examination revealed invasive lung adenocarcinoma. Two weeks later, the patient underwent closed thoracic drainage for bronchopleural fistula. (a) Chest CT before the interventional procedure showed a large encapsulated gas shadow in the right chest and the surgical drainage tube in the right lower chest. (b) After 82 days of negative pressure drainage, chest CT showed that the abscess cavity had significantly decreased in size. (c) After 116 days of negative pressure drainage, chest CT reexamination showed disappearance of the pus cavity. (d) Fluoroscopy shows the residual cavity drainage tube inserted by interventional technique. Small fistula formation in the stump of the lower right bronchus was shown by tracheography. (e) Eighty-three days after drainage tube placement, the pyogenic cavity was significantly smaller. (f) One hundred seventeen days after drainage tube placement, the residual cavity disappeared, and the drainage tube was partially retracted.

electrolyte disorders and by provision of support for intravenous nutrition. Patients were observed for about 1 week. Chest CT was performed to observe a reduction in residual cavity size. If necessary, drainage tube angiography was performed under fluoroscopy guidance, and the position of the drainage tube was adjusted. In order to achieve good patient compliance, a portable negative pressure suction device that did not restrict patients' mobility was provided for use during the out-of-hospital period. Patients attended the hospital for reexamination every 2–4 weeks. Chest CT was performed to evaluate the nutritional status and the size and position of the residual cavity. If necessary, drainage tube angiography was performed again, and the position of the drainage tube was adjusted. The head of the drainage tube was always kept at the lowest point of the residual

cavity. The drainage tube was replaced after 3 months or it was blocked.

The treatment was considered to be successful (1) if there was no effusion or gas in the drainage tube for more than 1 week or (2) if chest CT showed residual cavity closure. The drainage tube was removed after the above criteria were met (Figure 1).

Results

A total of 16 patients (14 males and 2 females) aged 18–69 years (mean, 54.8 ± 12.2 years) were enrolled in this study (see Table 1). All patients underwent lobectomy or sublobar resection, including 11 patients with lung cancer (68.8%), 4 patients with pulmonary infection (25.0%), and 1 patient with hemoptysis (6.3%). According to the onset time, BPF was divided into three types: two

cases of early fistula occurred within 1 week after surgery; eight cases of intermediate fistula occurred within 1 week to 1 month after surgery; and six cases of late fistula occurred more than 1 month after surgery. In 16 patients, it was confirmed by bronchography that the fistulas were located in the bronchus rather than the lung parenchyma. The fistulas were in the upper right lung in one case, in the upper left lung in two cases, in the middle right lung in three cases, and in the lower right lung in nine cases. There were 2 cases of lobobronchial fistula, 1 case of segmental bronchial fistula, and 13 cases of bronchiole fistula.

All patients underwent successful drainage tube placement under Dyna CT guidance on the first attempt with a technical success rate of 100%. No serious complications, such as massive hemoptysis, hemothorax, and asphyxia, occurred during or after puncture. The drainage tubes were adjusted 3.25 ± 2.24 times (range: 1–8 times). A total of 30 drainage tubes (1.88 ± 1.36 tubes per patient) were used, including 12 patients (75.0%) with no more than 2 drainage tubes and 4 patients (25.0%) with more than 2 drainage tubes.

The average cure time was 114.94 ± 101.08 days (range, 30–354 days). The median drainage tube indwelling duration was 87 days, and the 75th percentile was 117 days. Four patients (25.0%) had fistula and residual cavity closure within 40 days after CNPD. The patient's symptoms disappeared, and they gradually recovered. Furthermore, the patients gained weight, and quality of life improved significantly. Nine patients (56.3%) underwent drainage of 20–80 ml of purulent fluid every day within 120 days (>40 days). Cough, expectoration, and other symptoms disappeared, and closure of the fistula and residual cavity was observed. Three patients (18.8%) were treated with drainage tube for 120 days, and the residual cavity was gradually reduced. The volume of purulent fluid drained was approximately 70–150 ml per day.

Patients usually underwent puncture and placement of interventional drainage tube and CNPD treatment was started at the time of first hospitalization. The hospitalization cost is about RMB 8000, and the hospitalization period is 1–2 weeks. Reexamination of CT and adjustment of drainage tube were usually carried out in the outpatient department, and the cost was about RMB 2000.

Discussion

At present, BPF is treated as follows: drainage tube placement to fully drain the residual cavity, prevent pus from flowing into healthy lung tissue, and prevent aggravation of pulmonary infection; fistula blockage to isolate the communication between the bronchus and the residual cavity; and residual cavity closure. These approaches improve quality of life for patients and prolong survival.

Surgical treatments are complex and are associated with considerable trauma, a high disability rate, a high mortality rate (29%), and a high recurrence rate (38%).⁹ As a result, many patients do not opt for surgery after a diagnosis of BPF.

There are reports in the literature about non-surgical treatments for BPF, but these methods are generally suitable only for small fistulas that are less than 1 mm in size.¹⁰ These methods for the treatment of BPF have the following characteristics: (1) All the procedures are performed under fiberoptic bronchoscopy, but enlargement of the fistula during the treatment is a common complication of plugging of the fistula under bronchoscopy.¹¹ With bronchoscopy, a variety of plugging materials (such as stent) and plugging agents can be injected into the fistula for plugging, but placement of the stent or Amplatzer device is associated with problems such as inaccurate positioning and inability to observe expansion of the distal occluder;^{12,13} (2) Another characteristic of the known BPF treatment methods is that the fistula usually heals quickly, but healing of the residual cavity is difficult and takes longer. Boudaya *et al.* reported conservative treatment of 17 patients with BPF. The patients in their group underwent drainage tube placement, povidone-iodine pleural irrigation, and multiple bronchoscopy procedures with silver nitrate injections into 0.1–0.9 cm of the BPFs. This strategy was used to successfully close 16 of the 17 BPFs (the fistula size was 0.1–0.6 cm). Unfortunately, during the 6-month follow-up, no relief from empyema occurred in any of the patients.¹⁴

The application of airway stents to seal the fistula under interventional radiology is also an option for the treatment of BPF,^{12,15,16} but the healing of the residual cavity is still a problem. Han *et al.* reported customized and individualized airway stent placement under fluoroscopy for BPF treatment. The clinical symptoms of 95.3% of patients

Table 1. Patient population.

Patient	Gender	Age (years)	Etiology	Onset time (days)	Original surgery	Fistula location	Residual cavity size (LR × FB × UD, cm)	Duration of hospitalization (days)	Indwelling tube duration (days)	Number of tube adjustments
Patient 1	M	64	LA	35	Right middle and lower lobectomy	Upper right lobe	2.43 × 2.37 × 3.58	5	192	6
Patient 2	M	54	Lung cancer	40	Wedge resection of right upper lobe	Upper right lobe	6.47 × 3.95 × 5.93	5	346	7
Patient 3	M	62	Lung cancer	5	Right lower lobectomy	Lower right lobe	6.82 × 5.82 × 7.94	11	98	3
Patient 4	M	51	SCC	6	Right middle and lower lobectomy	Middle right lobe	3.85 × 8.29 × 5.51	16	69	2
Patient 5	M	60	Hemoptysis	30	Right lower lobectomy	Lower right lobe	3.76 × 5.26 × 6.75	7	89	2
Patient 6	M	64	LA	42	Right lower lobectomy	Lower right lobe	4.87 × 9.45 × 10.06	13	97	3
Patient 7	M	52	Mucinous adenocarcinoma of lung	97	Right lower lobectomy	Lower right lobe	2.89 × 5.68 × 7.55	8	35	1
Patient 8	M	57	LA	14	Right lower lobectomy	Lower right lobe	7.57 × 8.78 × 10.64	7	117	4
Patient 9	M	56	LA	42	Right lower lobectomy	Lower right lobe	7.01 × 6.46 × 5.85	13	30	1
Patient 10	M	62	SCC	210	Right lower lobectomy	Lower right lobe	6.09 × 6.51 × 8.33	4	31	1
Patient 11	F	69	Pulmonary infection	8	Left upper lobectomy	Upper left lobe	3.87 × 3.66 × 8.50	10	128	4
Patient 12	M	18	Tuberculous empyema	25	Wedge resection of right upper lobe	Middle right lobe	4.74 × 4.77 × 7.68	6	31	1
Patient 13	M	38	Post traumatic infection	30	Left upper lobectomy	Lower right lobe	5.64 × 7.48 × 13.12	8	354	8
Patient 14	M	59	SCC	8	Left lower resection	Upper left lobe	5.32 × 10.13 × 7.63	14	57	5
Patient 15	M	51	LA	30	Right lower lobectomy	Lower right lobe	6.61 × 5.75 × 6.23	11	78	2
Patient 16	F	60	Pulmonary infection	26	Left upper lobectomy	Upper left lobe	3.85 × 2.79 × 5.98	8	87	2
F, female; FB, front and back; LA, lung adenocarcinoma; LR, left and right; M, male; SCC, squamous cell carcinoma of lung; UD, up and down.										

were relieved 30 days after treatment; however, 50.7% of the patients did not achieve closure of the residual cavity even after 10 weeks of stent placement.¹⁶

In the treatment of BPF, closing the fistula is as important as closing the residual cavity. PBPF is beyond the scope of fiberoptic bronchoscopy because it is difficult to determine the location of the fistula. In the present cohort, 30% water-soluble iodine agent (3–5 ml) was injected through the catheter under bronchography. The bronchography accurately depicted the entry of the contrast medium into the residual cavity through the small fistula.

Conventional vacuum-assisted closure (VAC) involves a special wound drape and a tube connected to an electric pump that applies continuous or intermittent controlled subatmospheric pressure to the wound. VAC promotes thoracic wound healing by reducing interstitial edema and increasing tissue perfusion and oxygenation. It can also cause an increase in the amount of granulation tissue and reduce the colonization of anaerobic bacteria. Intrathoracic VAC applications are mostly described as case reports.¹⁷ For example, Karapinar *et al.*¹⁸ reported the efficacy of VAC in the treatment of six cases of postpneumectomy empyema with open window thoracostomy that included one case of BPF. Since this group of patients cannot tolerate surgery, we used CNPD as an interventional radiology method. With CNPD, the residual cavity volume is reduced until it is closed through the induction of negative pressure by ensuring that the extraction volume of the residual cavity is greater than the air leakage volume.

A closed thoracic drainage tube is usually a rubber tube with a diameter of 8–10 mm that is inconvenient to carry. This method is referred to as passive drainage. The head of the surgical drainage tube is often located above the residual cavity, but cannot effectively drain low-level liquid in the residual cavity. The puncture point of the interventional drainage tube is the anterior chest wall or the lateral chest wall. In the upper-pole skin of the residual cavity, the head of the interventional drainage tube is in the lower pole of the residual cavity. CNPD achieves active drainage, and the drainage effect is good. With the help of regular reexamination according to the size of the residual cavity and use of the guidewire and catheter technology under

fluoroscopy, the position of the tube can be adjusted or it can be replaced while ensuring that the head end of the drainage tube is always at the lowest point of the residual cavity. The drainage tube can fully and continuously drain the residual cavity, reduce retention of effusion and gas, remove the source of infection, promote expansion of normal lung tissue on the affected side, displace the mediastinum, narrow the rib space, lift the diaphragm, and accelerate residual cavity closure.

The intervention proposed here is simple, and it can rapidly improve the symptoms of patients and shorten the duration of hospitalization. Follow-up reexamination is usually carried out in the outpatient department, and this can further reduce the cost to the patients.

Limitations

Our study is limited in that it adopted a retrospective design with a small sample size; thus, further large-sample prospective studies are needed. Although this group of patients was cured, they were required to carry the drainage tube on their person for a long time. This is still an inconvenience, so further research is needed to improve the healing of the residual cavity and shorten the treatment cycle.

Conclusion

In conclusion, CNPD is an effective and safe method to treat PBPF through targeting the residual cavity. This easy, safe, and economically friendly approach can quickly improve symptoms and quality of life for patients.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee and Medical Records Management Department of the First Affiliated Hospital of Zhengzhou University, Henan, China (Registration No. 2015-07).

Consent for publication

Written informed consent for publication of their clinical details and/or clinical images was obtained from the patient. A copy of the consent form is available for review by the Editor of this journal.

Author contributions

Xiaobing Li: Formal analysis; Writing – original draft; Writing – review & editing.

Shuai Wang: Data curation; Software.

Meipan Yin: Funding acquisition; Investigation; Methodology; Validation.

Xiangnan Li: Conceptualization; Supervision.

Yu Qi: Validation.

Yaozhen Ma: Data curation; Methodology; Visualization.

Chunxia Li: Data curation.

Gang Wu: Conceptualization; Project administration; Resources; Writing – review & editing.

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Competing Interests

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Availability of data and materials

The data is available from the corresponding author on reasonable request.

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References

- Deschamps C, Bernard A, Nichols FC 3rd, *et al.* Empyema and bronchopleural fistula after pneumonectomy: factors affecting incidence. *Ann Thorac Surg* 2001; 72: 243–247; discussion 248.
- Pförr A, Pagès PB, Baste JM, *et al.* A predictive score for bronchopleural fistula established using the French database epithor. *Ann Thorac Surg* 2016; 101: 287–293.
- Klotz LV, Gesierich W, Schott-Hildebrand S, *et al.* Endobronchial closure of bronchopleural fistula using Amplatzer device. *J Thorac Dis* 2015; 7: 1478–1482.
- Podgaetz E, Andrade RS, Zamora F, *et al.* Endobronchial treatment of bronchopleural fistulas by using intrabronchial valve system: a case series. *Semin Thorac Cardiovasc Surg* 2015; 27: 218–222.
- Akulian J, Pathak V, Lessne M, *et al.* A novel approach to endobronchial closure of a bronchial pleural fistula. *Ann Thorac Surg* 2014; 98: 697–699.
- Andreotti C, D'Andrilli A, Ibrahim M, *et al.* Effective treatment of post-pneumonectomy bronchopleural fistula by conical fully covered self-expandable stent. *Interact Cardiovasc Thorac Surg* 2012; 14: 420–423.
- Chae EY, Shin JH, Song HY, *et al.* Bronchopleural fistula treated with a silicone-covered bronchial occlusion stent. *Ann Thorac Surg* 2010; 89: 293–296.
- York JA. Treating bronchopleural fistulae percutaneously with N-butyl cyanoacrylate glue. *J Vasc Interv Radiol* 2013; 24: 1581–1583.
- Bribriescio A and Patterson GA. Management of postpneumonectomy bronchopleural fistula: from thoracoplasty to transsternal closure. *Thorac Surg Clin* 2018; 28: 323–335.
- Lois M and Noppen M. Bronchopleural fistulas: an overview of the problem with special focus on endoscopic management. *Chest* 2005; 128: 3955–3965.
- Stratakos G, Zuccatosta L, Porfyridis I, *et al.* Silver nitrate through flexible bronchoscope in the treatment of bronchopleural fistulae. *J Thorac Cardiovasc Surg* 2009; 138: 603–607.
- Han X, Wu G, Li Y, *et al.* A novel approach: treatment of bronchial stump fistula with a plugged, bullet-shaped, angled stent. *Ann Thorac Surg* 2006; 81: 1867–1871.
- Fruchter O, El Raouf BA, Abdel-Rahman N, *et al.* Efficacy of bronchoscopic closure of a bronchopleural fistula with amplatzer devices: long-term follow-up. *Respiration* 2014; 87: 227–233.
- Boudaya MS, Smadhi H, Zribi H, *et al.* Conservative management of postoperative bronchopleural fistulas. *J Thorac Cardiovasc Surg* 2013; 146: 575–579.

15. Wu G, Li ZM, Han XW, *et al.* Right bronchopleural fistula treated with a novel, Y-shaped, single-plugged, covered, metallic airway stent. *Acta Radiol* 2013; 54: 656–660.
16. Han X, Yin M, Li L, *et al.* Customized airway stenting for bronchopleural fistula after pulmonary resection by interventional technique: single-center study of 148 consecutive patients. *Surg Endosc* 2018; 32: 4116–4124.
17. Matzi V, Lindenmann J, Porubsky C, *et al.* Intrathoracic insertion of the VAC device in a case of pleural empyema 20 years after pneumonectomy. *Ann Thorac Surg* 2007; 84: 1762–1764.
18. Karapinar K, Saydam Ö, Metin M, *et al.* Experience with vacuum-assisted closure in the management of postpneumonectomy empyema: an analysis of eight cases. *Thorac Cardiovasc Surg* 2016; 64: 258–262.

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