Interactive CardioVascular and Thoracic Surgery 30 (2020) 249–254
doi:10.1093/icvts/ivz241 Advance Access publication 11 October 2019

ORIGINAL ARTICLE

Cite this article as: Motus IY, Bazhenov AV, Basyrov RT, Tsvirenko AS. Endoscopic closure of a bronchopleural fistula after pneumonectomy with the Amplatzer occluder: a step forward? Interact CardioVasc Thorac Surg 2020;30:249–54.

Endoscopic closure of a bronchopleural fistula after pneumonectomy with the Amplatzer occluder: a step forward?

Igor Ya Motus [a,b,*], Alexander V. Bazhenov[a], Rauf T. Basyrov[c] and Anna S. Tsvirenko[c]

[a] Department of Thoracic Surgery, Ural Research Institute for Phthisiopulmonology, the Branch of National Medical Research Centre of Tuberculosis and Inflectional Diseases, Ekaterinburg, Russia
[b] Ural State Medical University, Ekaterinburg, Russia
[c] Department of Endoscopy, Ural Research Institute for Phthisiopulmonology, the Branch of National Medical Research Centre of Tuberculosis and Inflectional Diseases, Ekaterinburg, Russia

* Corresponding author. Department of Thoracic Surgery, Ural Research Institute for Phthisiopulmonology, the Branch of National Medical Research Centre of Tuberculosis and Inflectional Diseases, 50 XXII Parts'ezda str., 620039 Ekaterinburg, Russia. Tel: +7-9122334858; fax +7-343-3334463; e-mail: igormotus@yandex.ru (I.Y. Motus).

Received 14 May 2019; received in revised form 28 August 2019; accepted 29 August 2019

Key question

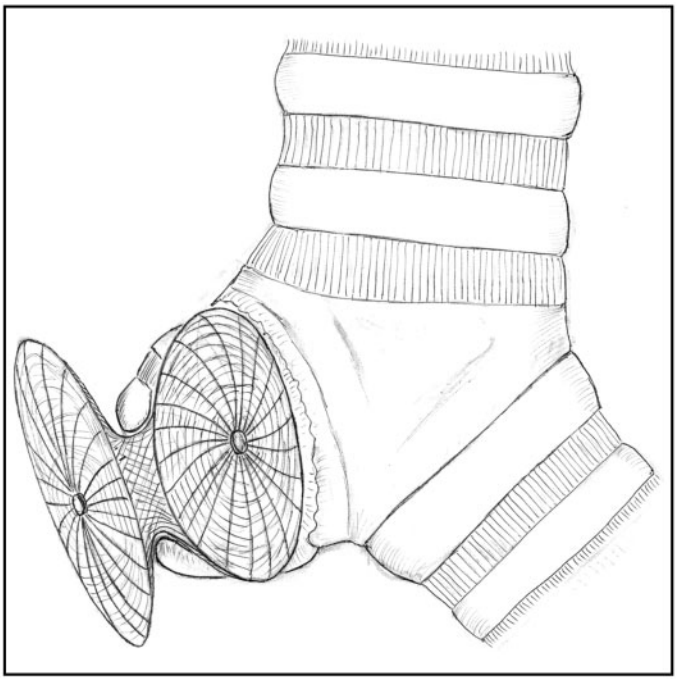
Is it possible to find an endoscopic closure method for a bronchopleural fistula (BPF) that is both safe and reliable?

Key findings

Closure of a BPF with an atrial septal defect (ASD) Amplatzer device was successful in 11 of 13 (84.6%) patients; no deaths were associated with the procedure.

Take-home message

The ASD Amplatzer device can be used for BPF closure in properly selected patients.



Abstract

OBJECTIVES: A bronchopleural fistula after pneumonectomy is a relatively rare but very serious complication. The development of endoscopic methods of treatment opens a new page in treating this condition. The goal of this paper was to confirm that the atrial septal defect Amplatzer device can be used for bronchopleural fistula closure in properly selected patients.

METHODS: A retrospective study of 13 patients with bronchopleural fistula after pneumonectomy was performed. There were 11 men and 2 women aged 26–70 years. Right-sided fistulas occurred in 10 patients and left-sided fistulas occurred in 3. The underlying disease was lung cancer in 7 patients and pulmonary tuberculosis in 6. Video-assisted thoracoscopic surgery ($N = 7$) and open-window thoracostomy ($N = 6$) were used to treat the empyema. To treat occlusion of the bronchial fistulas, we used Amplatzer atrial septal defect occluders

Presented at the 25th European Conference on General Thoracic Surgery, Innsbruck, Austria, 28–31 May 2017.

originally intended for closure of ventricular and interatrial septal defects. The occluder was inserted from the bronchus by flexible bronchoscopy with the patient under local anaesthesia, with the help of video-assisted thoracoscopy or through a window thoracostomy from the pleural cavity.

RESULTS: We noted 3 complications after the procedure. In 2 patients, displacement of the occluders required re-installation in 1 patient and latissimus dorsi muscle coverage in the other. In the third patient, the occluder became dislodged during severe exacerbation of tuberculosis that occurred after the patient violated the treatment regimen. She died of tuberculosis 6 months after the occluder was inserted. The course in the remaining 10 patients was uneventful.

CONCLUSIONS: Our experience suggests that the use of an atrial septal defect occluder for the treatment of a bronchial fistula after pneumonectomy is a reliable option.

Keywords: Pneumonectomy • Bronchopleural fistula • Treatment • Amplatzer occlusion

ABBREVIATIONS

ASD	Atrial septal defect
BPF	Bronchopleural fistula
OWT	Open-window thoracostomy
TB	Tuberculosis
VATS	Video-assisted thoracoscopy

INTRODUCTION

The problem of a bronchopleural fistula (BPF) after pneumonectomy dates back to 1933 when Graham performed the first pneumonectomy for lung cancer that was complicated by a main bronchus stump fistula. Pneumonectomy still remains one of the main operations used to address lung cancer. It is also performed in the most severe cases of pulmonary tuberculosis (TB). The rate of BPF after pneumonectomy in lung cancer is about 2–5% [1–4]. After pneumonectomy in patients with TB, it is reported to be 4.9% [5] to 5% [6]. As we can see, this complication is not common. However, the patients with this complication are very difficult to treat, and the mortality rate is as high as 40–50% [2, 4]. There are many surgical approaches for treatment of BPF. The development of endoscopic techniques and devices have made it possible to make a new important step towards solving this problem. Our goal was to focus on the endoscopic treatment of BPF using an Amplatzer atrial septal defect (ASD) device originally intended for the transcatheter closure of ventricular and interatrial septal defects. Earlier publications showed this method to be less traumatic and at the same time promising for closing the BPF after pneumonectomy [7, 8]. The objective of this study was to present our experience in the treatment of BPF after pneumonectomy with the use of the Amplatzer ASD occluder. We have presented our data with an emphasis on long-term results.

MATERIALS AND METHODS

Written informed consent covering the use of the device for a purpose different from its original purpose was obtained from all patients. The work and the paper were reviewed and approved by the local ethics committee (protocol #33 from March 18 2015). Our single-centre retrospective study included 13 patients with BPF who were treated with the Amplatzer ASD occluder from 2015 to 2018 (Table 1). The male/female ratio was 11/2. Right-sided fistulas occurred in 10 patients; left-sided fistulas occurred in 3. Lung cancer was the underlying disease in 7 patients, pulmonary TB in 6. The time interval between the occurrence of BPF and the procedure to close it depended on the general condition of the patient, the status of the underlying disease and the situation in the pleural cavity. Five patients were initially operated on in our clinic, and 8 patients were treated in other hospitals. Four of the patients with TB had multidrug resistant and 2 had extensively drug-resistant TB. In 3 patients, TB was found at the bronchus resection line. Unsuccessful surgical attempts to close the BPF were undertaken in 4 of the patients with TB from 2011 to 2014. In 1 patient the closure of the right fistula was performed via the anterior trans-sternal approach, and in 3 patients attempts were made to cover the fistula by a muscular flap and thoracoplasty. Reactivation of the disease in the opposite lung took place in all 6 patients with TB. Multimodal treatment was carried out to prepare the patients for the occlusion. Chest tube drainage and video-assisted thoracoscopy (VATS) or open-window thoracostomy (OWT) were used for empyema treatment in 7 and 6 cases, respectively. There were no special indications for OWT or VATS. Three patients with OWT came from other hospitals. Since 2017, we have preferred VATS as an effective, significantly less traumatic procedure. VATS comprises thorough debridement of the cavity and placement of the drains under visual control. Chemotherapy was conducted in all patients with TB based on the drug susceptibility test results. In cases of endobronchitis, we administered treatment that included nebulized anticholinergic and mucolytic agents combined with local endobronchial lavage. Nutrition support was used when the body mass index was lower than 15. Endobronchial biopsy specimens from the stumps were taken from all patients before the attempt was made to close the BPF; neither TB nor cancer recurrence was found.

For occlusion of a bronchial fistula, we used ASD occluders from the Lepu Medical Technology Co., Ltd (Lifetech Scientific Co., Ltd., Beijing, China). This device is made of fine metallic mesh and has a waist and 2 discs (Fig. 1). The size of the fistula was measured under a C-arm by inserting the balloon into the fistula. With the patient under local anaesthesia and bronchoscopic control, the catheter with the sizing balloon was inserted into the fistula such that the x-ray plaque was set up in the centre of the BPF. The balloon was inflated by liquid contrast medium until the moment its waist was visible radiographically (Fig. 2). Once the waist appeared, inflation of the balloon was stopped, and we measured the length and width of the balloon waist in 2 projections. The waist of the occluder should be 30% wider than the diameter of the fistula.

The procedure for installing the occluder was as follows: flexible bronchoscopy was performed with the patient under local

Table 1: Patient data

Patient	Age (years)	Sex	Underlying disease	Date of PE	Date of occlusion	Fistula size (mm)	Occluder size (mm)	Pleural cavity management	Side
1	36	F	TB	X, 2010	XII, 2015	12	20	OWT	D
2	41	M	TB	VIII, 2011	VIII, 2015	10	14	OWT	D
3	55	M	TB	XII, 2012	III, 2015	8	12	OWT	D
4	60	M	CA	VI, 2014	IV, 2016	15	20	OWT	S
5	64	M	TB	X, 2014	IV, 2016	20	26	OWT	D
6	56	M	CA	VI, 2015	IV, 2016	8	14	OWT	D
7	40	F	TB	VII, 2015	III, 2017	8	12	VATS	S
8	47	M	CA	X, 2015	III, 2017	16	22	VATS	D
9	61	M	CA	XII, 2015	X, 2016	12	18	VATS	S
10	70	M	CA	I, 2017	X, 2017	20	26	VATS	D
11	68	M	CA	I, 2017	II, 2018	9	12	VATS	D
12	42	M	TB	III, 2017	VIII, 2017	24	28	VATS	D
13	64	M	CA	IV, 2017	VII, 2018	18	24	VATS	D

CA: cancer; D: right side; F: female; M: male; OWT: open-window thoracostomy; PE: pneumonectomy; S: left side; TB: tuberculosis; VATS: video-assisted thoracoscopy.

anaesthesia. The guide was inserted into the pleural cavity via the fistula. Two thoracoscopic ports were inserted, and the guide was pulled out of the pleural space through the port. The occluder was fixed to the guide and inserted back into the fistula. When the OWT took place, the necessary manipulations were performed via the thoracostomy. The unfolding and the position of the internal disk of the occluder were monitored visually with the fibrobronchoscope. The position of the external disk was assessed through the thoracoscope. Having made sure that the occluder was positioned correctly, we disconnected the guide from the occluder and removed the bronchoscope. The treatment of the empyema was continued, and the decision to close the cavity was determined depending on the patient's condition as well as on the situation with the cavity. The outcome of the treatment was monitored for 6 months to 2 years.

RESULTS

In 6 patients, symptoms of the fistula disappeared just after the placement of the occluder. In other patients, small leakages continued and decreased gradually during the formation of granulations and scar tissue around the occluder. Further observation of the patients showed that the occluder was gradually overgrown with granulation tissue from both sides, and epithelialization first began from the tracheobronchial tree and then spread to the pleural cavity (Fig. 3). The average time for cessation of all symptoms of the fistula was 3 weeks to 2 months.

Problems with the occluder occurred in 3 patients: In a male patient (patient no. 3; Table 1), dislocation of the occluder occurred 2 months after its placement because of inexact measuring of the fistula size. The occluder was removed via a thoracostomy, and the new one was installed after thorough repeated measuring. The further course was uneventful, and the fistula healed. The patient visited the clinic in 2017; his general physical condition was satisfactory. In a female patient (no. 7; Table 1), severe exacerbation of TB occurred after violation of the treatment regimen. The fistula progressed and the occluder dropped into the pleural cavity. She died of TB 6 months after the occlusion. Closure of the largest fistula (no. 12; Table 1) was also unsuccessful because the occluder did not fit tightly in such a wide fistula, and we had to remove it by bronchoscopy. This also happened during exacerbation of the TB and the accompanying progression of the fistula. After the exacerbation had been cured, the fistula was closed by coverage with the latissimus dorsi muscle.

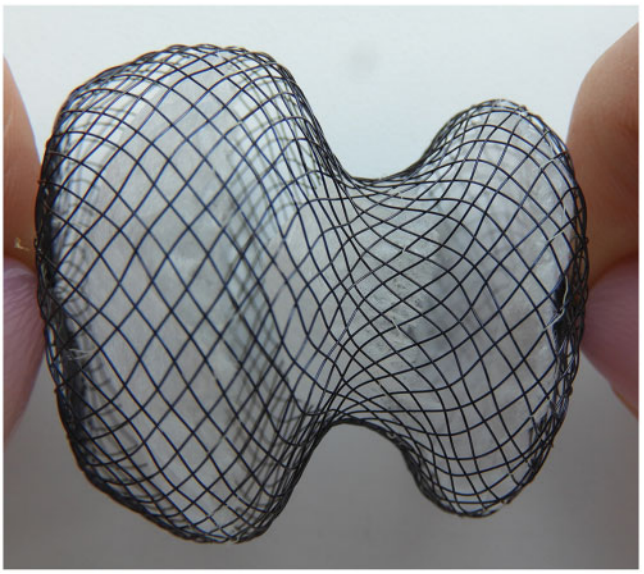


Figure 1: Amplatzer atrial septal defect occluder.

The remaining 10 patients experienced no complications associated with the installation of the occluder. They are still under supervision at regional clinics. Their condition has so far remained satisfactory except for 1 patient (no. 4; Table 1) in whom the lung cancer recurred. He has since had several courses of chemotherapy. At the same time, no symptoms of the recurrence of the BPF were noted in this patient. No deaths were associated with the procedure. A computed tomography scan 1 year after the procedure is shown in Fig. 4 (patient no. 2; Table 1).

DISCUSSION

Several surgical approaches are available for the treatment of BPF. When choosing the method of radical surgery for BPF, the

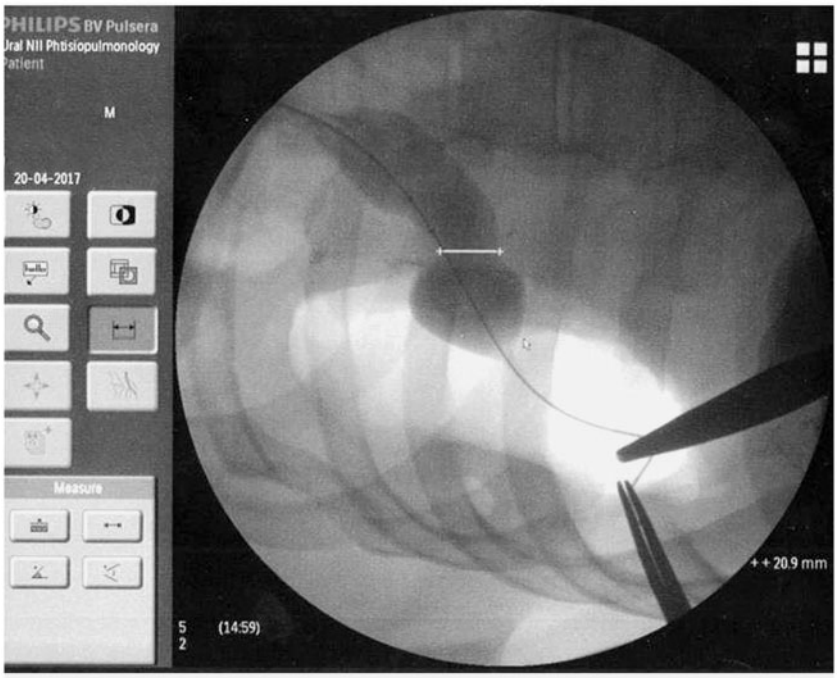


Figure 2: Measuring the size of the bronchopulmonary fistula by inserting the sizing balloon into the fistula. Line points to the waist of the fistula.

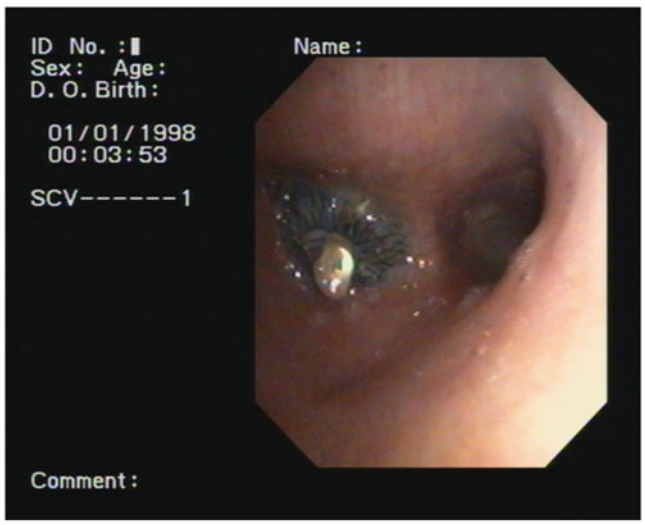


Figure 3: Patient no. 7 in Table 1. Endoscopic view 2 months after insertion of the occluder.

size of the fistula, the length of the bronchial stump, the side on which the lesion occurs and the general condition of the patient are taken into account [1, 9–12]. However, it should be emphasized that surgical closure of BPF is often technically difficult and is followed by a rather high mortality rate (16–27%) [10, 11] and can be tolerated by only 68.7% [9] and 75% [4] of patients with BPF. Our experience showed that only 66.3% of patients with BPF could undergo radical surgery. Therefore, attempts to treat fistulas with the help of endoscopic methods are understandable.

Conservative treatment does not directly affect the fistula but is aimed at resolving pleural empyema and correcting the patient's homeostasis. If these problems are solved successfully, the small fistulas (>3 mm) heal spontaneously or with endoscopic assistance, namely the use of glue or fibrin [1, 9, 13, 14]. Endoscopic treatment with a silver–human albumin complex was successfully used for early fistulas with a size equal to or smaller than 5 mm [15]. Application of tissue glue adhesive (methyl-2-cyanoacrylate) was successful in 8 out of 10 cases. Both patients with failures had fistulas of 0.5 cm or larger [16]. Our data showed that endoscopic treatment in patients with BPF >3 mm was effective in 27 of 32 cases (84.4%).

There are descriptions in the literature of closure of right BPF via mediastinoscopy [17, 18]. We share the opinion of Moreno *et al.* [12], who stressed the technical complexity of mediastinoscopic closure of BPF. The technique is practically applicable only in the treatment of right-sided fistulas. The technique is unlikely to be effective in patients with short stumps.

The development of endoscopic methods and devices contributed to the further evolution of new approaches that proved to be suitable for treatment of such difficult patients. A modified Dumon stent was promising [19–21], but the stent migrated in some patients [22]. A metallic ring coil combined with fibrin glue was suggested as a method of treatment of BPF including large fistulas [23–26]. But the treatment of large fistulas, especially in patients with short stumps, is still the most challenging because of the unreliable anchoring of the device in large fistulas [8, 13]. Kramer *et al.* [7] described a novel technique for endobronchial closure of postpneumonectomy BPF by implantation of the Amplatzer ASD occluder in 2008. They reported the successful treatment of 2 patients with fistulas 5 mm in diameter. The authors stressed the advantage of this device, which had a waist and 2 discs closing the fistula from both sides, as opposed to the use of glue, which was applied only to the internal aspect [7]. In some instances, ASD occluders were buttressed by the addition of glue [27]. Encouraging initial results contributed to the progress of this method, and Kramer *et al.* [8] published a new report in 2014. In their study, BPF closure by Amplatzer ASD occluder was successful in all 14 patients with postpneumonectomy fistulas.

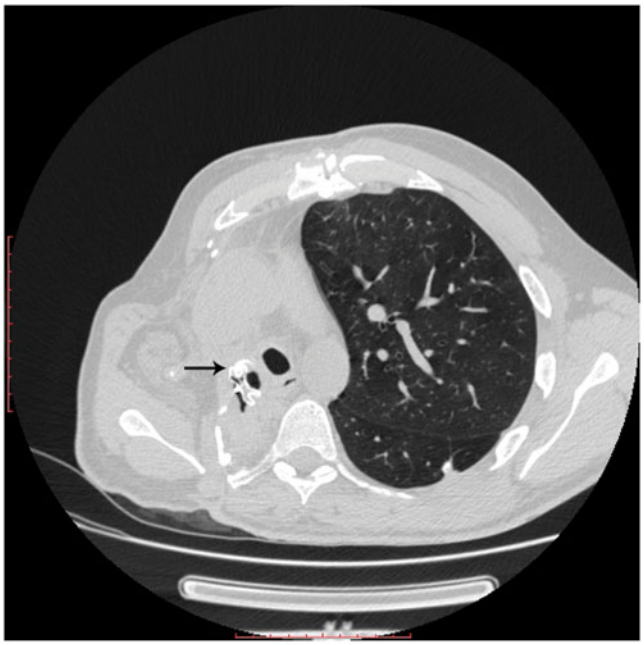


Figure 4: Patient no. 2 in Table 1. Computed tomography scan 1 year after the installation of the occluder. Arrow points to the occluder.

Analysing our initial experience, we consider it necessary to emphasize the following important points: the underlying disease in our patient population was lung cancer in 7 patients and pulmonary TB in 6. Unfavourable outcome of pulmonary TB, especially multidrug resistant TB, results in lung destruction requiring pneumonectomy. This condition is always accompanied by severe immune disorders, which are a serious risk factor for development of postoperative complications including BPF. In our study all complications after BPF occlusion took place in 3 patients initially operated on for TB. In 2 of them, the relapse of TB resulted in an increase of the fistula and loss of the occluder and eventually in the death of the third patient. Previously, we had repeatedly observed an increase in the size of the BPF with the progression of the TB. Thus, it can be assumed that the underlying disease, especially TB, can affect the outcome of the procedure. Stabilization of the underlying disease and stabilization of the size of the fistula are important conditions affecting the reliability of the occlusion of the fistula.

Successful application of the ASD occluder to close a BPF in a patient with multidrug resistant TB who underwent pneumonectomy has already been described [28]. The debridement of an empyema is also of importance for relieving acute symptoms and for stabilizing the size of the fistula. When the cavity is drained by the chest tube, irrigation can be continued just after the occlusion. The healing of the fistula and the subsequent elimination of the residual cavity were important for recovery and the prevention of recurrence of the TB. This association was observed not only in this group of patients but also earlier in other patients who had bronchial fistulas. Five of our patients with TB, including those who endured complications with the occluder, are now free of the disease. Hence, we do not see any problems using the prosthetic material for the treatment of BPF in patients initially operated on for TB. On the other hand, no problems after the BPF was occluded were noted in patients operated on for lung cancer. In 1 patient, the cancer progressed, but the occluder remained in place, and there was no recurrence of the fistula. In addition, for reliable anchoring of the occluder, it is important that the fistula be completely formed and has no tendency to progress. Therefore, there is no need to hurry with the installation of the occluder. Fruchter *et al.* [8] did not notice any association between timing of intervention in relation to BPF occurrence and success rate. We did not find an association either.

Measuring the size of the fistula with the help of the sizing balloon and the X-ray C-arm appeared to be the most accurate method. We did not observe displacements of occluders at later stages, which proved the reliability of the method when the occluders had been installed properly. The size of the fistula is important when choosing a treatment strategy. Data from the literature [1, 9, 13–16] and our own experience show that for fistulas <5 mm, attempts at endoscopic treatment are justified, as indicated previously. Larger fistulas can be successfully treated with Amplatzer ASD occluders, because we can accurately measure the size of fistula and select an occluder of the required size. As our experience has shown, occluder dislocation occurs during the progression of the fistula or if the initial measurement is inaccurate. Spontaneous displacement of the occluder into the trachea leads to tracheal obstruction. In such cases, the occluder should be removed. The occluder can be easily removed either by bronchoscopy or by VATS if it is not fixed firmly in the stump.

CONCLUSION

It is known that candidate patients are weakened by the underlying disease, a major operation and the potential subsequent complications. Therefore, the BPF treatment selected must be reliable and safe and result in minimal trauma. Endoscopic treatment meets these requirements. It must be noted and emphasized that the application of Amplatzer ASD occluders for the treatment of BPF is an off-label use. At the same time, the published data and our experience suggest that this technique is a reliable method for the treatment of BPFs after pneumonectomy. This procedure has practically no contraindications, and it is easily tolerated by patients. Our experience suggests that the use of Amplatzer ASD occluders for the treatment of bronchial fistulas after pneumonectomy is a reliable option for solving this difficult problem.

Conflict of interest: none declared.

Author contributions

Igor Ya Motus: Conceptualization; Investigation; Methodology; Supervision; Writing - Original Draft. **Alexander V. Bazhenov:** Conceptualization; Data curation; Investigation; Methodology; Visualization. **Rauf T. Basyrov:** Data curation; Methodology; Visualization. **Anna S. Tsvirenko:** Data curation; Formal analysis; Investigation; Methodology; Visualization.

REFERENCES

[1] Cardillo G, Carbone L, Carleo F, Galluccio G, Di Martino M, Giunti R *et al.* The rationale for treatment of postresectional bronchopleural fistula: analysis of 52 patients. Ann Thorac Surg 2015;100:251–7.

[2] Hubaut JJ, Baron O, Al Habash O, Despins P, Duveau D, Michaud JL. Closure of the bronchial stump by manual suture and incidence of

bronchopleural fistula in a series of 209 pneumonectomies for lung cancer. Eur J Cardiothorac Surg 1999;16:418–23.
[3] Mansour Z, Kochetkova EA, Santelmo N, Meyer P, Wihlm J-M, Quoix E *et al*. Risk factors for early mortality and morbidity after pneumonectomy: a reappraisal. Ann Thorac Surg 2009;88:1737–44.
[4] Wright CD, Wain JC, Mathisen DJ, Grillo HC. Postpneumonectomy bronchopleural fistula after sutured bronchial closure: incidence, risk factors, and management. J Thorac Cardiovasc Surg 1996;112:1367–71.
[5] Shiraishi Y, Katsuragi N, Kita N, Tominaga Y, Hiramatsu M. Different morbidity after pneumonectomy: multidrug-resistant tuberculosis versus non-tuberculous mycobacterial infection. Interact CardioVasc Thorac Surg 2010;11:429–32.
[6] Vashakidze S, Gogishvili S, Nikolaishvili K, Dzidzikashvili N, Tukvadze N, Blumberg HM *et al*. Favorable outcomes for multidrug and extensively drug resistant tuberculosis patients undergoing surgery. Ann Thorac Surg 2013;95:1892–8.
[7] Kramer MR, Peled N, Shitrit D, Atar E, Saute M, Shlomi D *et al*. Use of Amplatzer device for endobronchial closure of bronchopleural fistulas. Chest 2008;133:1481–4.
[8] Fruchter O, El Raouf AB, Abdel-Rahman N, Saute M, Bruckheimer E, Kramer MR. Efficacy of bronchoscopic closure of a bronchopleural fistula with Amplatzer devices: long-term follow-up. Respiration 2014;87:227–33.
[9] Hollaus PH, Lax F, Janakiev D, Lucciarini P, Katz E, Kreuzer A *et al*. Endoscopic treatment of postoperative bronchopleural fistula: experience with 45 cases. Ann Thorac Surg 1998;66:923–7.
[10] Porhanov V, Poliakov I, Kononenko V, Selvaschuk A, Bodnya V, Semendiaev S *et al*. Surgical treatment of 'short stump' bronchial fistula. Eur J Cardiothorac Surg 2000;17:2–7.
[11] de la Riviere AB, Defauw JJ, Knaepen PJ, van Swieten HA, Vanderschueren RC, van den Bosch JM. Transsternal closure of bronchopleural fistula after pneumonectomy. Ann Thorac Surg 1997;64:954–9.
[12] Moreno P, Lang G, Taghavi S, Aigner C, Marta G, De Palma A *et al*. Right-sided approach for management of left-main-bronchial stump problems. Eur J Cardiothorac Surg 2011;40:926–30.
[13] Ranu H, Gatheral T, Sheth A, Smith EEJ, Madden BP. Successful endobronchial seal of surgical bronchopleural fistulas using BioGlue. Ann Thorac Surg 2009;88:1691–2.
[14] Lang-Lazdunski L. Closure of a bronchopleural fistula after extended right pneumonectomy after induction chemotherapy with BioGlue surgical adhesive. J Thorac Cardiovasc Surg 2006;132:1497–8.
[15] Andreetti C, D'Andrilli A, Ibrahim M, Poggi C, Maurizi G, Vecchione A *et al*. Submucosal injection of the silver–human albumin complex for the treatment of bronchopleural fistula. Eur J Cardiothorac Surg 2010;37:40–3.
[16] Scappaticci E, Ardissone F, Ruffini E, Baldi S, Mancuso M. Postoperative bronchopleural fistula: endoscopic closure in 12 patients. Ann Thorac Surg 1994;57:119–22.
[17] Azorin JF, Francisci MP, Tremblay B, Larmignat P, Carvaillo D. Closure of a postpneumonectomy main bronchus fistula using video-assisted mediastinal surgery. Chest 1996;109:1097–8.
[18] Groth SS, D'Cunha J, Rueth NM, Andrade RS, Maddaus MA. Mediastinoscopy-assisted minimally invasive closure of a bronchopleural fistula: a new technique to manage an old problem. J Thorac Cardiovasc Surg 2010;140:244–5.
[19] Madden BP, Sheth A, Ho TBL, McAnulty GR, Sayer RE. A novel approach to the management of persistent postpneumonectomy bronchopleural fistula. Ann Thorac Surg 2005;79:2128–30.
[20] Tayama K, Eriguchi N, Futamata Y, Harada H, Yoshida A, Matsunaga A *et al*. Modified Dumon stent for the treatment of a bronchopleural fistula after pneumonectomy. Ann Thorac Surg 2003;75:290–2.
[21] Tsukada H, Osada H. Use of a modified Dumon stent for postoperative bronchopleural fistula. Ann Thorac Surg 2005;80:1928–30.
[22] Jones NC, Kirk AJB, Edwards RD. Bronchopleural fistula treated with a covered wallstent. Ann Thorac Surg 2006;81:364–6.
[23] Watanabe S, Watanabe T, Urayama H. Endobronchial occlusion method of bronchopleural fistula with metallic coil and glue. Thorac Cardiovasc Surg 2003;51:106–8.
[24] Clemson LA, Walser E, Gill A, Lynch JL, Zwischenberger JB. Transthoracic closure of a postpneumonectomy bronchopleural fistula with coils and cyanoacrylate. Ann Thorac Surg 2006;82:1924–6.
[25] Shimizu J, Takizawa M, Yachi T, Arano Y, Hirano Y, Waseda R *et al*. Postoperative bronchial stump fistula responding well to occlusion with metallic coils and fibrin glue via a tracheostomy: a case report. Ann Thorac Cardiovasc Surg 2005;11:104–8.
[26] Sivrikoz CM, Kaya T, Tulay CM, Ak I, Bilir A, Döner E. Effective approach for the treatment of bronchopleural fistula: application of endovascular metallic ring-shaped coil in combination with fibrin glue. Ann Thorac Surg 2007;83:2199–201.
[27] Akulian J, Pathak V, Lessne M, Hong K, Feller-Kopman D, Lee H *et al*. A novel approach to endobronchial closure of a bronchial pleural fistula. Ann Thorac Surg 2014;98:697–9.
[28] Yang L, Kong J, Tao W, Song Y, Huang T, He F *et al*. Tuberculosis bronchopleural fistula treated with atrial septal defect occluder. Ann Thorac Surg 2013;96:e9–11.