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Bronchial closure methods and risks for bronchopleural fistula in pulmonary resections: how a surgeon may choose the optimum method?

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Abstract

There is debate about which bronchial closure technique is the best to prevent bronchopleural fistulas (BPFs). We aim to assess the effect of bronchial closure procedures and patients' characteristics on BPF occurrence in pulmonary resections. Bronchial closures in 625 consecutive patients were assessed. Stumps were closed by manual suturing in 204 and by mechanical stapling in 421 cases. In the mechanical stapling group, stapling supported by manual suture was performed in 170 cases. BPFs occurred in 3.8%. Of these, stapling was used in 5.0%, whereas manual suturing was used in 1.5% ($P=0.04$). BPFs were more prevalent among patients who had undergone pneumonectomy ($P<0.01$), right pneumonectomy ($P<0.01$), stapler closure ($P<0.01$), patients with co-factors ($P<0.01$), and patients who had undergone preoperative neo-adjuvant ($P=0.01$) or postoperative adjuvant therapy ($P=0.03$). There was no difference in the frequency of BPF between patients with and without adjuvant support in the stapling group. The optimum bronchial closure method has to be chosen by considering the patient and bronchus based characteristics. This has to be assessed carefully, especially in pneumonectomy and co-factors. The manual closure seems to be the more preferable method in risky patients. An additive support suture on the bronchial stump does not decrease the risk of BPF.

Keywords: Bronchial closure; Pneumonectomy; Lobectomy; Bronchopleural fistula; Stapler; Survival

1. Introduction

Bronchopleural fistula (BPF) is observed in 1–4% of patients after a pneumonectomy or a lobectomy and less often after a segmentectomy or rarer procedures. It is more common after resections performed due to inflammatory diseases of the lung, particularly in patients with active tuberculosis and positive sputum [1]. Pomerantz noted an incidence of 10.5% after resections in 85 patients with resistant mycobacterial infection. Almost all of them occurred after right pneumonectomy in patients with multiple resistant tuberculosis despite a transposed muscle flap to cover the bronchial stump [2]. Other significant risk factors for BPFs were pneumonectomy, residual tumor at bronchial stump, preoperative irradiation, and diabetes [1]. The controversy concerning the closure of bronchial end continues among thoracic surgeons who seek the best way to prevent postoperative BPF [3]. Many centers use stapling and manual suturing methods for bronchial closure. They use additional procedures in patients who are at risk for concomitant diseases as well as BPF.

Bronchial closure procedures were reviewed in the present study. The major concern was to investigate whether bronchial closure procedures and patients' characteristics affect the frequency of BPF occurrence or not.

2. Patients and methods

2.1. Patients

Bronchial closures in 625 consecutive patients who underwent pulmonary resections, between January 2002 and December 2007 at the Department of Thoracic Surgery, Dr. Suat Seren Chest Diseases and Chest Surgery Training and Research Hospital, Izmir, Turkey, were reviewed in terms of the incidence of procedure-related BPF occurrence. Informed consent was obtained from each patient. Pulmonary resections consisted of lobectomy and pneumonectomy. Non-anatomical pulmonary resections (wedge resections) and bronchoplastic procedures, which did not include closure of the bronchial stump, were excluded from this study.

The patients' medical and operative records were critically reviewed in terms of bronchial closure method, closure related problems, postoperative occurrence of BPF,

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and the co-factors causing risk for BPF retrospectively. These co-factors have been defined as tuberculosis, diabetes mellitus, neo-adjuvant and/or adjuvant therapy.

2.2. Bronchial closure

Patients were categorized into two groups; in group 1 ($n=421$), we used (TA 30–3.5 mm or TA 30–4.8 mm) bronchial closure staplers (AUTOSUTURE, US Surgical, Norwalk, CT, USA) for mechanical closure. In group 2 ($n=204$), we used manual suturing with 2-0 monofilament polypropylene non-absorbable suture separately. Bronchi were closed transversally getting membranous and transversal parts vis-à-vis. To obtain bronchial blind end safety, the stump was not closed by absorbable suture. In group 1, regions that became weak because of free staples at the end points of the stump and recognized during stapler use were supported by suturing ($n=170$).

In patients with the risk for BPF occurrence, autologous fibrin glue (VIVOSTAT, Fibrin Sealent, Denmark), intercostal muscle flap, and pleural tissue were used on the stapled stump line in addition to suture support. The patients who used suture support were included in the statistical analysis. Other support materials, non-homogenous ones, were not assessed as an effective factor in analysis.

Patients, in whom massive air flow, abundant and bloody expectoration, high fever and dyspnea developed during the postoperative period, were examined for BPF.

The study was approved by the Hospital Ethics Committee.

2.3. Statistical analysis

All statistical analyses were performed using SPSS software, version 9.0 statistical package program (SPSS Inc, Chicago, IL, USA). Fisher's exact test or Pearson χ^2-test and binary logistic regression test via backward stepwise method were used in statistical analysis, and a *P*-value of 0.05 or less was considered significant.

3. Results

Six hundred and twenty-five patients were included in the study. The mean age of the patients was 55.9 ± 13.7 (10–83) years. One hundred and thirteen (18.1%) of the patients had co-factors that might be risky for BPF occurrence (Table 1). The distribution of patients and surgical procedures according to the bronchial closure method is shown in Table 2.

BPF developed totally in 24 (3.8%) patients. Of the patients with BPF, 23 were male and 16 were under the age of 60 years. Twenty-two patients had undergone surgical operation because of malignancy.

The incidence of BPF was 5.0% (21/421) in the stapling group, and 1.5% (3/204) in the manual group ($P=0.04$). Twenty-one patients had undergone pneumonectomy, of which 15 were right pneumonectomy. The incidence of BPF was significantly higher in pneumonectomies than lobectomies. The occurrence of BPF was determined to be significantly high in right pneumonectomies compared with the left ones. The incidence was also higher in patients with co-factors and in patients who had had neo-adjuvant therapy and adjuvant therapy. Of the patients with BPF, two had a history of hyperglycemia, three had a history of tuberculosis, eight had a history of neo-adjuvant therapy, and seven had a history of adjuvant therapy (Table 3).

Table 1. The general characteristics of patients and the surgical procedures performed

Parameter	*n*	%
Age (years)	55.9 ± 13.7 (10–83)	
≤60	338	54.1
>60	287	45.9
Gender		
Male	526	84.2
Female	99	15.8
Co-factors for BPF		
No	512	81.9
Yes	113	18.1
Adjuvant therapy	86	13.8
Neo-adjuvant therapy	85	13.6
Diabetes mellitus	27	4.3
Tuberculosis	24	3.8
Pulmonary diseases		
Malignant	511	81.8
Benign	114	18.2
Surgical procedure		
Lobectomy	419	67
Pneumonectomy	206	33
Bronchial closure		
Stapling	421	67.4
Manual	204	32.6

BPF, bronchopleural fistula.

In logistic regression analysis, in which the effect of surgical procedure, bronchial closure method, neo-adjuvant therapy, adjuvant therapy, diabetes mellitus, tuberculosis and one of co-factors on the development of BPF was investigated, surgical procedure and co-factors were determined to be independent variables that affect BPF incidence (Table 4).

In comparison of two subgroups of group 1 (with or without manual suture support), the frequency of BPF in patients with manual suture support was 4.7% (8/170) whereas it was 5.2% (13/251) in patients without manual suture support ($P=1.0$). The patients' characteristics and performed closure methods (stapling with or without support) are listed in Table 5.

Table 2. The closure methods performed in patients

Parameter	Stapling *n* (%)	Manual *n* (%)	Total	*P*-value
Overall	421–67.4	204–32.6	625	
Age (years)				
>60	194–67.6	93–32.4	287	0.93
<60	227–67.2	111–32.8	338	
Pulmonary diseases				
Malignant	349–68.3	162–31.7	511	0.32
Benign	72–63.2	42–36.8	114	
Surgical procedure				
Lobectomy	260–62.1	159–37.9	419	**<0.01**
Pneumonectomy	161–78.2	45–21.8	206	
Right	67–77.9	19–22.1	86	1.0
Left	94–78.3	26–21.7	120	
Co-factors				
(+)	94–83.2	19–16.8	113	**<0.01**
(−)	327–63.9	185–36.1	512	

Bold values indicates the significant results.

Table 3. The incidence of bronchopleural fistulas in patients who had undergone pulmonary resection

Parameter	*n*	BPF	%	*P*-value
Overall	625	24	3.8	
Gender				
Male	526	23	4.4	0.15
Female	99	1	1.0	
Age (years)				
>60	287	8	2.8	0.22
≤60	338	16	4.7	
Pulmonary diseases				
Malignant	511	22	4.3	0.28
Benign	114	2	1.8	
Surgical procedure				
Lobectomy	419	3	0.7	**<0.01**
Pneumonectomy	206	21	10.2	
Pneumonectomy				
Right	86	15	17.4	**<0.01**
Left	120	6	5.0	
Co-factors				
(+)	113	11	9.7	**<0.01**
(−)	512	13	2.5	
Diabetes mellitus				
(−)	598	22	3.7	0.28
(+)	27	2	7.4	
Tuberculosis				
(−)	601	21	3.5	0.06
(+)	24	3	12.5	
Neo-adjuvant therapy				
(−)	540	16	3.0	**0.01**
(+)	85	8	9.4	
Adjuvant therapy				
(−)	539	17	3.2	**0.03**
(+)	86	7	8.1	
Adjuvant therapy				
Chemotherapy	45	0	0	**0.01**
Radiotherapy	31	5	16.1	
Chemoradiotherapy	10	2	20.0	
Method of bronchial closure				
Stapling	421	21	5.0	**0.04**
Manual	204	3	1.5	

BPF, bronchopleural fistula.

Of the 24 patients with BPF, two died of fistula-related complications, such as pneumonia, sepsis or respiratory failure in the early postoperative period, whereas four patients died of late postoperative period fistula-related reasons and other secondary reasons for BPF occurrence. The overall fistula related mortality was 0.96%.

4. Discussion

BPFs are often fatal or morbid. Patient- and disease-related co-factors, as well as operation-related technical problems, may cause BPFs. Thoracic surgeons search for the most appropriate, reliable and safe bronchial closure methods. This is of vital importance for patients' survival as well as quality of life. The risk factors: hyperglycemia, chronic obstructive pulmonary disease, neo-adjuvant therapies applied for lung cancer, hypoalbuminemia, and previous steroid therapy, may negatively affect the surgical closure techniques [4, 5]. The surgeon should either preoperatively or peroperatively make the decision about the technique and the strengthening that he is going to perform during bronchial closure. It may be decided to use either manual or stapling methods. Controversy continues regarding the relative merits of sutured versus stapled closure of the bronchus, with many advocating the superiority of stapling [6]. Some authorities prefer routine stapler use, some prefer and suggest manual closure [7]. It is important to determine the efficacy and reliability of stapling on bronchial closure as well as to identify its superiority on other techniques in the prevention of BPF occurrence. The possible advantages of using staplers in pulmonary resections are as follows: the contamination of operation area can be minimized, the time required for closure can be markedly reduced, staplers can also be used safely in vascular division [3, 6, 8]. The first advantage is particularly important for pulmonary resections performed for infectious lung diseases (such as tuberculosis, bronchiectasis) as well as the tumors with extensive necrosis. Methods and materials for strengthening will be required. We routinely performed the strengthening of stump in patients having such risk factors. The surgical team decided the stapler or manual closure technique via patient specific evaluation. Routine strengthening was performed regardless of the closure technique.

In the present series, the vast majority of the resections had been done because of lung cancer, and the most frequently performed resection was lobectomy. The incidence of fistula among patients who had undergone pneumonectomy because of malignity was significantly higher than those who had undergone lobectomy. The incidence of BPF occurrence was low among patients who had undergone lobectomy and pneumonectomy for certain reasons. In general, BPF was observed as being significantly higher in right pneumectomies compared with the left ones. These results show that the surgical team should be more careful and attentive while choosing and performing bronchial

Table 4. Logistic regression analysis

Parameter	OR	*P*-value
Surgical procedure (pneumonectomy/lobectomy)	13.2	**<0.01**
Co-factors (+)/(−)	2.5	**0.04**

OR, odds ratio.

Table 5. The closure methods performed in patients

Parameter	Stapling without support *n* (%)	Stapling with support *n* (%)	Total	*P*-value
Overall	251−59.6	170−40.4	421	
Age (years)				
>60	111−57.2	83−42.8	194	0.37
<60	140−61.7	87−38.3	227	
Pulmonary diseases				
Malignant	206−59.0	143−41.0	249	0.60
Benign	45−62.5	27−37.5	72	
Surgical procedure				
Lobectomy	154−59.2	106−40.8	260	0.92
Pneumonectomy	97−60.2	64−39.8	161	
Right	37−55.2	30−44.8	67	0.33
Left	60−63.8	34−36.2	94	
Co-factors				
(+)	46−48.9	48−51.1	94	**0.02**
(−)	205−62.7	122−37.3	327	

closure procedures in patients with malignancy as well as in all patients who had undergone right pneumonectomy.

In the present series, patients were examined in two groups according to the stump closure method. The groups consisted of patients with malignant and benign lesions. Lobectomies and pneumonectomies were non-homogeneously distributed in all groups. The incidence of fistulas in the group with closure applied by stapler was similar with the data given in the literature. We have expected a difference between the closures in which the stump line was supported with sutures and with other materials. The difference between two methods is as minimal as negligible (5.2% vs. 4.7%). The necessity of support of viable tissue has been stressed in many studies [6, 9, 10]. We also, share similar opinions and apply these. However, the results of the present study did not indicate a significant difference. The rate of fistulas being significantly high particularly in right pneumonectomies (left 5%, right 17.4%) corroborates the opinion about the necessity of strengthening by tissue support in patients who also have other risk factors, and in right pneumonectomies in particular. Similarly, it was reported in the study by Darling et al. [11] that right pneumonectomies cause fistula with higher proportion, and fistula and complication related mortality was higher in right pneumonectomies. In total three (1.5%) fistulas were determined in 204 patients in group 2 where closure had been performed by manual suturing. The frequency of BPF in group 1 was higher than group 2. The incidences reported in the literature, which reached up to 2%, 3.1% and 5.4% via manual suturing, seem to be similar with the closures applied by stapling [4, 6, 9]. However, in those studies, the numbers of the patients in the groups were not similar with each other as those in the present series. In their series including 209 pneumonectomies performed because of malignant disease, Hubaut et al. [12] highlighted that the rate of BPF occurrence was quite low in bronchial closures applied by manual suturing. When manual and stapling methods were compared, the difference between the BPF incidences was found to be significantly in favor of manual suturing.

In the course of the application period, we observed that certain minor technique problems have caused microfistulas. We determined that the end points of stapler application line are the weakest parts of the line, and the staple incompletely closed the tissue particularly at the end point where the staple line of the stapler has exceeded the length of the bronchus. We assessed that detachment of a staple in this site during postoperative period is a cause for microfistulas. We also observed that these microfistulas can be the causes of large BPFs with the accompaniment of infections. This was a required factor to provide stump safety with the support by lateral suturing to these weak and risky stump end points. We had thought that the use of suture support in the stapling group might cause a decrease in the incidence of BPF, however, the difference was not statistically significant.

When it is considered that co-factors would not change, the quality and reliability of closure methods will come into prominence. In addition to the high risks, which the concomitant diseases bring, neo-adjuvant therapy regimens applied in malignant patients prior to the resection also cause a high risk for BPF development [13]. In the present study as well, it was seen that neo-adjuvant therapy regimens used prior to the operation had a negative effect on bronchial healing. Fistula occurred in 9.4% of the patients who had undergone intervention ($P=0.01$). Whichever technique for bronchial closure is used in such patients (manual or stapling) the surgeon will absolutely be in need of a supportive method. This support should particularly be performed when stapling is applied. Nevertheless, fistula incidence was not found to be significantly different in patients in whom stapling was used.

Pneumonectomy, right pneumonectomy, co-factors, neo-adjuvant and adjuvant therapies, and the use of a stapler are risk factors for the occurrence of BPF. The incidence becomes higher when stapling is preferred instead of manual bronchial closure. A choice of manual suture may be useful in a patient group with right pneumonectomy and risk factors.

Despite many components concerning patients and diseases that threatens bronchial healing, precision in the bronchial closure method, as well as the preferred method, is of vital importance. The present study showed that closure with a stapler, despite its various advantages, causes more fistulization than manual closure particularly in patients with risk factors. It was also observed that supportive applications do not make a significant contribution to stapling applications. It can be said that manual closure methods are more convenient for bronchial healing. However, all of the closure methods have acceptable roles in terms of BPF occurrence. The choice of closure method has to be made by considering the patient- and bronchus-based characteristics.

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eComment: Bronchial stapled suture versus manual closure: does the choice depend on the surgeon or on the patient?

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We have read with great interest the article by Uçvet et al. [1] reporting on the methods and risk factors related to bronchopleural fistula (BPF) in pulmonary resections.

In recent years, despite the advances in surgical technology, BPFs still occur and have a difficult management and outcome. Right pneumonectomy and postoperative barotrauma due to mechanical ventilation are the main factors related to BPF [2]. Furthermore, Sonobe et al. showed the high incidence of BPF in patients who had undergone re-thoracotomy or induction therapy [3].

The factors listed above are in agreement with those described by Uçvet et al. and, to our knowledge, should be analyzed before performing any bronchial resection. In our department, the closure method of choice is stapler suture because of the advantages related to lower air leakage, bleeding rates and reduced operative trauma. In the literature, incidences of BPFs range from 2.1% to 4.4% [1–4], while, in our series, we reported 0.72% demonstrating the efficacy and safety of stapled sutures [5]. However, we agree with the conclusion of Uçvet et al. [1] that the optimum bronchial closure method has to be chosen by considering the patients' risk factors and bronchus characteristics, as in case of neoadjuvant therapy or reoperation.

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eComment: Post pneumonectomy bronchopleural fistula: is it the closure technique or the operative side that really matters?

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We read with interest Uçvet et al.'s report regarding bronchial closure (BC) to minimise postlung resection bronchopleural fistula (BPF) [1]. The authors conclude that a manual BC is preferable to mechanical stapling in risky patients (such as right pneumonectomy resections). This recommendation is presumably based on their overall BPF incidence of 5% (21/421) in the stapled group vs. 1.5% (3/204) in the manual group ($P<0.04$). However, in the pneumonectomy subgroup ($n=206$ patients) performed primarily for malignancy, the BPF incidence was 10.2% (17.4% for a right pneumonectomy vs. 5% for the left side). The percentage of stapled BC was similar irrespective of the side [right pneumonectomy ($n=86$ patients): 67 stapled BC (78%) vs. 19 manual BC and similarly left pneumonectomy ($n=120$ patients): 94 stapled BC (78%) vs. 26 manual BC]. Hence, it is difficult to conclude that a manual BC offers any significant advantage in this patient subgroup.

It has long been recognized that a right pneumonectomy carries a higher BPF risk and may have confounded this study's findings. It would be useful to know how many of the 15 right pneumonectomy patients (15/86) who developed a BPF had a manual BC and, similarly, which of the six left pneumonectomy patients (6/120) who developed a BPF had a manual BC. Indeed from their multivariate logistic regression analysis, technique of BC was not an independent risk predictor for development of a BPF.

The relative merits of sutured vs. stapled BC remains a contentious issue as thoracic surgeons seek to prevent the much dreaded postlung resection BPF. Numerous clinical studies suggest superiority of a stapled BC over a hand-sewn manual BC [2]. Advantages include a more rapid closure with less soiling of the operative field although this is less important for non-infective pathology like lung cancer. Several randomized laboratory animal studies with histological analysis (of the bronchial stump) have demonstrated equivalence of either BC technique in terms of avoidance of BPF and resistance to pressure of the stump [3]. The authors observed that additional applications including glue, muscle flaps and suturing to support the stapled BC stump in high-risk patients did not confer any significant benefit. However, use of vascularized tissue such as a pedicled *latissimus dorsi* muscle flap or pericardial flap is highly effective in preventing postpneumonectomy BPF [4, 5]. In our opinion prophylactic interventions with viable biological tissues should be considered in high-risk patients.

If performed competently, the actual BC technique is less important, provided general surgical principles are adhered to. This includes achieving clear oncological resection margins, not leaving too long a stump, especially on the right side, and avoiding excessive diathermy or sharp dissection that may denude the epithelium predisposing to stump devascularization. Hence, a stapled BC should remain part of the thoracic surgeon's armamentarium for the higher risk right-sided pneumonectomy. Despite meticulous surgical technique, however, in a subset of high-risk patients including those with neoadjuvant chemoradiotherapy, a BPF may be inevitable even with prophylactic measures in place regardless whether a stapled or manual BC is performed.

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