Tracheobronchial reconstructions with bronchoplastic closure: An alternative method in treatment of bronchogenic carcinoma involving the carina or tracheobronchial angle

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Objective: Our objective was to summarize our experience with tracheobronchial reconstructions using bronchoplastic closure for airway defects after noncircumferential resections of bronchogenic carcinoma involving the carina or tracheobronchial angle.

Methods: From January 1990 to December 2005, all patients who underwent tracheobronchial reconstructions with bronchoplastic closure for bronchogenic carcinoma involving the carina or tracheobronchial angle were included. The clinical data for patients were collected retrospectively, including demographic characteristics, occurrences of postoperative complications, and survival.

Results: A total of 40 patients were eligible, including 23 who had right pneumonectomies, 6 who had right upper lobectomies, and 11 who had left pneumonectomies, associated with lower lateral wall of the trachea resections or with partial carinal resections for centrally localized tumors. The airway defects ranged from 0.5×2 cm to 2×4 cm and involved up to 50% of the airway circumference. Microscopic residual disease was found postoperatively at the bronchial margin in 20% (8/40). Of 40 patients, 2 (5.0%) had pulmonary atelectasis develop, 2 (5.0%) arrhythmia, 2 (5.0%) bronchopleural fistula, and 1 (2.5%) airway stenosis after operation. Thirty-day mortality was 2.5% (1/40). Median survival for 40 patients was 18.5 months with a cumulative survival of 72.2%, 26.6%, and 21.3% at 1, 3, and 5 years, respectively.

Conclusions: Tracheobronchial reconstruction using bronchoplastic closure might be a reasonable option for closing massive central airway defects for advanced bronchogenic carcinoma involving the tracheobronchial angle or carina, avoiding tracheal sleeve pneumonectomy with limited excision of the lateral wall of the trachea or carina. (J Thorac Cardiovasc Surg 2012;144:418-24)

Tracheobronchial resections and reconstructions are important methods in the treatment of lung cancer invading the trachea and bronchus. Most tracheal lesions can now be resected and then reconstructions can be performed safely. Tracheal sleeve pneumonectomy with limited excision of the lateral wall of the trachea or carina is an ideal surgical method for tumors involving the carina or tracheobronchial angle. The maximum length of tracheal-carinal resections with end-to-end anastomosis is limited to 4 cm.¹ Therefore, tracheal sleeve pneumonectomies with primary closure of airways by suture lines might be hazardous and impossible after an extended lengthy resection. In addition,

pneumonectomy is not feasible for patients with limited pulmonary function reserve. Therefore, the search for an ideal substitute and further establishing a superior operation used for patching the extensive airway defect has been a tremendous challenge to thoracic surgery.

Although the closure of airway defects has been described using vascularized autogenous tissue flaps, including pedicled extrathoracic muscle flap, intercostal muscle patch and pericardial flap,²⁻⁵ and synthetic materials,⁶ all encounter technical difficulties and various complications such as dehiscence, stenosis, infection, and rejection. In addition, these substitute materials do not possess the property of airway, such as the ciliary structure and the cartilaginous ring, which are all important to maintain normal respiratory mechanics.

A surgical alternative to sleeve pneumonectomy is the tracheobronchoplastic procedure with bronchoplastic closure described by Nohl-Oser, Fenn, and Dottori⁷ first in 1982, Sato and colleagues⁸ in 2002, and Ozcelik and Onat⁹ in 2004. Tong¹⁰ from our group also reported that 9 patients underwent the repair of massive noncircumferential airway defects with bronchoplastic closure after resections of tracheobronchial tumors and scar stenosis in 1992. All 9 patients successfully underwent airway

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Abbreviation and Acronym

CT = Computed tomography

reconstructions and survived without dehiscence and stenosis after operations. However, all reports were presented with a very limited number of cases, in the absence of long-term follow-up data, and not referring to how to select surgical procedures and reduce anastomotic complications. The purpose of this retrospective study was therefore to describe in detail this particular technique of closing large airway defects with bronchoplastic technique after extended noncircumferential resections for advanced bronchogenic carcinoma involving the carina or tracheobronchial angle and to assess the efficacy in a much larger number of patients.

PATIENTS AND METHODS

Patient Population

This study was approved by the Ethics Committee of Shanghai Pulmonary Hospital of Tongji University. Between 1990 and 2005, patients who underwent the closure of extensive intrathoracic airway defects after non-circumferential resections for advanced bronchogenic cancers using bronchoplastic closure were enrolled in the study. Those patients who received additional resection procedures, such as resections of thoracic walls or great vessels, were not excluded from the study. The clinical data of patients were collected and reviewed, including demographic characteristics, types of surgery, TNM stage, survival, and incidences of complications.

Preoperative Assessment

All patients underwent a battery of examinations before the operation, including plain chest x-ray film, chest computed tomography (CT), abdominal ultrasound scan, brain magnetic resonance imaging and bone emission CT, spirometry, and fiberoptic bronchoscopy. Bronchoscopy is done to reveal the location of a mass and discern the suspected areas on tracheal walls possibly involved. Those patients with airway defects involving more than 50% of the airway circumference were excluded from the present study. Cervical mediastinoscopy, with biopsy of stations 2, 4 (both left and right), and 7, was performed only in patients with bulky nodes or to exclude N3 disease detected by CT scan, because it may decrease the blood supply of the airway. Patients with N2 or N3 disease detected by mediastinoscopy or CT scan were excluded from this study. The size, location, and involvement of the tumor are all major factors in determining the type of operation. According to the findings of chest CT and fiberoptic bronchoscopy, the feasibility of the procedure could be determined. All patients were assessed by the same medical and surgical teams from our tertiary care hospital.

Surgical Technique

All procedures were performed through a standard posterolateral thoracotomy. On the left side, the aortic arch was mobilized and drawn apart to expose the left lower trachea and the carina after division of the arterial ductus ligament. On the right side, the azygos vein and level 4 lymph node were mobilized and excised to expose the right lower trachea and tracheobronchial angle. Before the involved airway was opened, the endotracheal tube was retracted into the midportion of the trachea.

For tumors that arose from the right upper lobe bronchus and extended upward to the right lateral wall of the trachea, the invaded lateral wall of trachea was opened above the bifurcation, and this incision was then

carried downward both in front and at the back, continuing onto the right main bronchus and bronchus intermedius. Finally, the bronchus was cut obliquely above the middle lobe bronchus, followed by the inferior pulmonary ligament being ligated and divided.⁶ The normal wall of the right main bronchus and bronchus intermedius was then left for trachea reconstruction (Figure 1, A).

For tumors that arose from the upper lobe bronchus or main bronchus and extended upward to the lateral wall of the trachea as well as downward to the bronchus intermedius or left lower lobe bronchus, usually tracheal sleeve pneumonectomy was essential. The invaded lateral wall of trachea was opened above the bifurcation, and this incision was then carried downward, both in front and at the back, continuing onto the bronchus intermedius or left main bronchus. Finally, the bronchus was cut obliquely above the distal end of bronchus intermedius or left main bronchus. The normal wall was left for tracheal reconstruction (Figure 1, B and C).

For lesions that arose from the medial lateral wall of the left main bronchus and extended upward to the carina, partial carinal resection and tracheal sleeve pneumonectomy were usually essential. The lateral wall of the involved main bronchus was opened beneath the bifurcation, and the incision was then carried upward along the trachea both in front and at the back for about 1.5 cm above the carina, then downward along the trachea and the contralateral main bronchus with an inverted V shape. The normal wall was left in continuity with the contralateral main bronchus (Figure 1, D).

Frozen section of resection margins was carried out during the procedure routinely. If the results of the frozen section were negative (negative margins), 2 traction sutures were initially placed around the full-thickness cartilaginous ring at the distal end of bronchial flap and the corresponding end of the defect airway, which could be used for alignment and be pulled to decrease the tension during tying of the sutures. The reconstruction was commenced by suturing the remaining portion of the bronchus into the tracheal defect with interrupted 4-0 Vicryl absorbable sutures (Ethicon, Inc, Somerville, NJ), which were positioned approximately 3 mm apart and at a depth of 2 mm. The sutures were started from the corner and continued upward or downward until the bronchial flap patched the defect. During several brief periods of apnea (the endotracheal tube was retracted into the midportion of the trachea), the involved wall was removed and all anastomotic sutures were placed between the bronchial flap and the contralateral defect airway. Then the proximal endotracheal tube was advanced into the contralateral main bronchus. Sutures were tied from the cartilaginous wall inasmuch as the membranous wall tears more easily. If the results of the frozen section were positive (positive margins), the bronchial flap was not enough to patch the defect, and the gap between the distal trachea and the proximal main bronchus was less than 4 cm after circumferential resection of airway, the procedure should be extended, such as by sleeve pneumonectomy and carinal resection with right upper lobectomy.

The bronchial anastomosis was then checked for air leakage with a sustained airway pressure of 30 cm H₂O. In all these patients, the bronchial anastomosis had been covered with some type of tissue, such as pedicle pleural flaps, intercostal muscle flaps, or anterior serratus muscle flaps. Radical dissections of mediastinal and hilar lymph nodes were performed.

In 1 patient, an additional superior vena cava resection procedure was performed without cardiopulmonary bypass.

Follow-up

Follow-up data were obtained from telephone calls, letters, or direct outpatient examinations. Patient follow-ups were completed and lasted until study terminations or deaths. All patients underwent follow-up at 3-month intervals for the first year, 6-month intervals for the second year postoperatively, and yearly thereafter to monitor disease progression and evaluate the appearance of bronchial flaps with chest CT and fiberoptic bronchoscopy.

FIGURE 1. Patterns of tracheocarinal airway defects closed by autologous bronchial flaps. A, Closure of right lower lateral trachea defects after noncircumferential resection associated with right upper lobectomy. B and C, Closure of lower lateral trachea defects after noncircumferential resection associated with pneumonectomy for centrally located pretreated tumors. D, Closure of medial lateral main bronchus defects after noncircumferential resection associated with pneumonectomy and partial carinal resection for centrally located pretreated tumors.

Statistical Analysis

Statistical analyses were performed using SPSS 13.0 (SPSS, Inc, Chicago, Ill). Continuous variables are presented as means $\pm$ standard deviation or medians (range), and categorical variables are presented as counts or rates. A χ^2 test or Fisher exact test was used to compare dichotomous variables. The analysis of survival was performed using the Kaplan-Meier method. Survival curves were compared using the log-rank test. All tests were 2-sided.

RESULTS

Demographics

From January 1990 to December 2005, a total of 6811 patients underwent lung resections for primary lung cancer (including 91 sleeve pneumonectomies) at the Thoracic Surgery Department of Shanghai Pulmonary Hospital affiliated to Tongji University. Of them, 40 (0.6%) patients received tracheobronchial reconstructions using bronchoplastic closure. There were 35 (87.5%) men and 5 (12.5%) women with a mean age of 56.4 ± 9.3 years.

Adjuvant Treatments

None of the 40 patients received neoadjuvant therapies. Adjuvant treatment strategies and protocols for patients varied widely, possibly owing to the long study period. Some patients were transferred to different local hospitals after the operation for adjuvant treatments. Of 40 patients, 29 (72.5%) received some form of postoperative adjuvant therapies (irradiation and chemotherapy, either alone or in various combinations). Postoperative irradiation therapy with a total dose of 50 to 60 Gy was given to 8 patients who were confirmed to have a positive bronchial resection margin by pathologic examinations. The postoperative chemotherapy was given to 29 patients (8 in combination with

irradiation). The other 11 patients refused any adjuvant therapy.

Type of Surgery and Pathology

Among 40 patients who underwent this tracheoplastic procedure, the underlying diseases were primary lung cancer in 92.5% ($n = 37$) and low-grade neoplasm in 7.5% ($n = 3$). The locations of tumors were as follows: 29 in right upper lobes, 9 in left upper lobes, and 2 in medial lateral walls of the left main bronchus. Accordingly, there were 23 right pneumonectomies, 6 right upper lobectomies, and 11 left pneumonectomies plus tracheobronchial reconstruction.

The pathologic examinations disclosed 27 squamous cell carcinomas, 5 adenocarcinomas, 3 adenosquamous carcinomas, 3 adenoid cystic carcinomas, 1 large cell carcinoma, and 1 squamous cell carcinoma combined with small cell carcinoma. The lymph node involvements were classified N0 in 7 patients, N1 in 8 patients, and N2 in 25 patients. According to the 2007 revision of the TNM classification, 4 were in stage IIa, 8 in stage IIb, 14 in stage IIIa, and 14 in stage IIIb. Because of technical and anatomic difficulties, there were 8 patients with positive resection margins who did not receive extended resection during the early portion of this clinical experience. The types of disease were as follows: 6 squamous cell carcinomas, 1 adenocarcinoma, and 1 adenosquamous carcinoma. We think that the relatively large percentage of R1 resections was related to our limited experience in airway surgery, airway disease, and chest CT diagnosis during the early portion of this clinical experience. Because of the limit of CT diagnosis in the early of 1990s, we could not assess the invaded lateral wall of the bronchus intermedius correctly in 3 patients with limited

FIGURE 2. A, Cumulative survivals of 40 patients after tracheobronchoplasty. B-D, The differences in survival between patients with aged 60 years and older versus younger than 60 years, T1-3 versus T4, and stage IIIa versus IIIb were significant (all $P < .05$).

lung function reserve before the operation. They just received right upper lobectomies plus tracheobronchial reconstruction. Owing to the anatomic difficulties, there was not enough space for radical surgery even after mobilization of the aortic arch. The other 2 patients with more than 1.5-cm invaded lateral wall of left lower trachea just received the left pneumonectomies plus tracheobronchial reconstruction. There were 3 other patients with negative frozen section test results during the surgery, but they refused the extended radical surgery even after positive paraffin section test results were reported.

Perioperative Mortality and Complications

Of 40 patients who underwent tracheobronchoplastic procedures, 1 died of sepsis owing to bronchopleural fistula and empyema 24 days after the operation. Accordingly, the 30-day mortality was 2.5%. Major perioperative

complications occurred in 6 (15.0%) patients as bronchopleural fistula (2/40), pulmonary atelectasis (2/40), and arrhythmia (2/40, 1 case of ventricular premature contraction [>5 beats/min] and 1 of atrial fibrillation, respectively). Postoperative recoveries of these patients were uneventful, except for complicated bronchopleural fistula in 1 patient.

Long-Term Outcome

The median follow-up time was 18.5 months (range, 1-121 months). The cumulative survival was 72.2% at 1 year, 26.6% at 3 years, and 21.3% at 5 years (Figure 2, A). Three patients with adenoid cystic carcinomas all survived longer than 5 years. Eleven patients showed a local relapse and 22 showed distant metastases. The local recurrence in 9 cases was at the resection margin (all 8 patients with positive bronchial resection margin had local relapses) and in 2 at the ipsilateral intrathoracic lymph node. The

FIGURE 3. A, Bronchoscopy revealed lesions arose that from the right upper lobe bronchus and extended upward to the lateral wall of the trachea. B, Bronchoscopy revealed airtight, stable, and epithelialized airways 6 months after right pneumonectomy plus tracheobronchial reconstruction.

overwhelming cause of death was distant metastasis. There were significant differences in the survivals between patients 60 years or older versus those younger than 60 years, T1-3 versus T4, and stage IIIa versus IIIb (all $P < .05$) (Figure 2, B to D). There was a trend toward longer survival time in patients with lymph node involvement status N0/N1 than those with N2 (median, 31.7 vs 20.9 months), as well as in patients with negative bronchial resection margins than those with a residual tumor at the bronchial stump (median, 19 vs 12 months), but the differences did not reach significance. The probability of survival did not significantly correlate with the histologic type, residual bronchial resection margin disease, and adjuvant therapies.

Stenosis of the bronchial anastomosis occurred in 1 patient who underwent stenting 2 months postoperatively. In other patients, bronchoscopy revealed airtight, stable, and epithelialized airways during the follow-up (Figure 3). There was no case of late bronchopleural fistula and empyema during the entire outpatient follow-up period.

COMMENT

Under some circumstances, the carina or tracheobronchial angle was invaded by bronchogenic carcinoma of the upper lobe and main bronchus, but the contralateral wall of the main bronchus was free of disease. The healthy wall of the bronchus could be used for airway reconstruction. However, limited information is available regarding this procedure using bronchoplastic closure, only described in the case reports.⁷⁻¹⁰ In this study, we wanted to further describe this particular tracheobronchoplastic procedure using bronchoplastic closure and assess short- and long-term outcome in a series of 40 patients.

Previous reports of this procedure with bronchoplastic closure were almost completely confined to right tracheobronchoplasty for bronchogenic carcinoma. In this study, there were 4 different types of reconstruction based on the location of the lesion and extent of resection.

When the right upper bronchogenic carcinoma invaded the right lateral wall of the trachea, carinal resection and

right upper lobectomy were done most frequently. Using this tracheobronchoplastic technique (Figure 1, A), the procedure became simpler than the conventional procedure, because we did not have to perform the end-to-end anastomosis between the trachea and the left main bronchus and the more difficult end-to-side anastomosis between the bronchus intermedius and the medial wall of the left main bronchus. Elevation of the bronchus intermedius to the side of trachea will create excessive extension if the length of involved right lateral lower trachea is greater than 2.0 cm. On the basis of our experiences, this approach is safely feasible in cases in which no more than 2.0 cm of the right lower trachea is involved.

Nohl-Oser and his colleagues⁷ argued that this procedure was applicable only in those cases in which the extension of tumor involvement in the trachea is less than the length of the remaining bronchus flap. Our experience showed that the transversus V-shaped trimming of the lateral of trachea could reduce lateral tracheal defects markedly; thus this tracheobronchial reconstruction using bronchoplastic closure might be feasible in some cases in which the involved airway wall is longer than the flap. If the aforementioned bronchogenic carcinoma extended downward to the bronchus intermedius, resection of the tracheobronchial angle with right lung should be done (Figure 1, C). Under this circumstance, we think that this approach is safely feasible in cases in which no more than 3.0 cm of the right lower trachea is involved.

However, of 40 patients, only 9 underwent left pneumonectomy plus tracheobronchial reconstruction, and none underwent left upper lobectomy plus tracheobronchial reconstruction. Several reasons may account for these statistics. First, carcinoma of the left lung rarely extends to the carina or tracheobronchial angle, given the length of the left main bronchus. Second, the approach to the carina or tracheobronchial angle via a left thoracotomy is quite difficult, even after mobilization of the aortic arch. In this constricted subaortic space, the resection of the distal trachea and the proximal right main bronchus and the subsequent end-to-end anastomosis become difficult. Using this tracheobronchoplastic technique (Figure 1, B to D), we think that noncircumferential resection of invaded airway and subsequent coverage of the defect may be easier. On the basis of our experiences, this approach is safely feasible only in cases in which a limited length of trachea is involved, generally speaking, no more than 1.5 cm of the left lower trachea.

Bronchial anastomosis complication is a major cause of morbidity after tracheobronchial surgery. Excessive anastomotic tension has been reported to be the single greatest cause of anastomotic complication after tracheobronchial operations.³ Two bronchopleural fistulas occurred, 1 in the right upper lobectomy and the other in the right pneumonectomy in the primary stage, respectively. The right main

bronchus is shorter and more vertical than the left main bronchus. When the defect in the lateral wall of the lower trachea was covered with the normal wall of right main bronchus and bronchus intermedius, the anastomotic tension could be greater than other types. Besides conventional maneuvers to reduce anastomotic tension, our subsequent experience showed that it was of crucial importance to alleviate the anastomotic tension that transverses V-shaped trimming of the lateral trachea and wedge-shaped trimming of the diverticular part formed at the corner of the bilateral healthy airway wall after they were connected. Second, shortage of adequate blood supply to the airway is another major cause of anastomotic complication. Therefore, avoiding excessive long-segment mobilization of the trachea or bronchi to minimize possible injury to the blood supply of the airway is an important measure to ensure sufficient blood supply to the anastomosis. On the other hand, cutting the excessive length of the bronchial flap is useful for eliminating dead space where sputum retention contributed to anastomosis fistula.

As reported by some authors, pleural flaps, pericardial flaps, intercostal muscle pedicle flaps, and intrathoracic muscle transposition flaps might be useful for bronchial coverage and suture line reinforcement.^{2-4,10} However, it remains controversial that a viable tissue used for the tracheobronchial anastomosis coverage can reinforce the anastomosis.⁶⁻⁸ We routinely supported the tracheobronchial anastomosis line with pedicled pleural flaps, intercostal muscle flaps, or anterior serratus muscle flaps. Despite careful patient selection and meticulous bronchial coverage technique, the development of fistula of the anastomosis still could not be avoided in 2 cases in this study.

The perioperative mortality and 5-year survival in this study (2.5% and 21.3%) are comparable with those figures of sleeve pneumonectomy in our institution¹¹ and with those in other centers,^{1,12-16} too. As is reported, the N status is a key prognostic factor. In our study, all patients with bronchial resection margin infiltration had N2 disease. We think, therefore, that the involvement of metastatic mediastinal nodes may be a potential contraindication for this surgery. Despite the intuitive opinion that incomplete resections are detrimental, some recent studies have surprisingly concluded that long-term survival was not affected per se.¹⁷⁻²⁰ The present study showed that patients with negative resection margins survived longer (median survival, 19 months) than those with positive resection margins (median survival, 12 months), but the figures did not reach a significant difference in 5-year survival.

The primary limitation of this study is that it is retrospective and from a long time span when enormous advances were made in anesthetic and critical care management. Our approach to tracheobronchial reconstruction, including

the anastomotic techniques and the reconstructive options, also advanced from 1990 to 2005. Nevertheless, we consider this technique to have some distinct advantages. This procedure ensures rigidity of the repaired wall and a normal respiratory epithelial lining. The autogenous airway flap with the vertical longitudinal blood supply is helpful to healing of the suture line. Using this tracheobronchoplastic technique, the vertical tension would be less than the conventional one, owing to the absence of the circumferential excision of the long segmental airway. Airway management of anesthesia is simpler than that of conventional anesthesia. The cross-field ventilation by the endotracheal tube is not essential. It simplifies the tracheobronchial plastic procedure but also accomplishes acceptable operative mortality rates and long-term survival with conventional extended resections. Therefore, we think that it seems to be a safe and applicable method for selected bronchogenic carcinoma and a surgical alternative for sleeve pneumonectomy and carinal resection with right upper lobectomy.

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References

- Mitchell JD, Mathisen DJ, Wright CD, Wain JC, Donahue DM, Moncure AC, et al. Clinical experience with carinal resection. *J Thorac Cardiovasc Surg.* 1999;117:39-52.
- Sfyridis PG, Kapetanakis EI, Baltayiannis NE, Bolanos NV, Anagnostopoulos DS, Markogiannakis A, et al. Bronchial stump buttressing with an intercostal muscle flap in diabetic patients. *Ann Thorac Surg.* 2007;84:967-71.
- Meyer AJ, Krueger T, Lepori D, Dusmet M, Aubert JD, Pasche P, et al. Closure of large intrathoracic airway defects using extrathoracic muscle flaps. *Ann Thorac Surg.* 2004;77:397-404.
- Taghavi S, Marta GM, Lang G, Seebacher G, Winkler G, Schmid K, et al. Bronchial stump coverage with a pedicled pericardial flap: an effective method for prevention of postpneumonectomy bronchopleural fistula. *Ann Thorac Surg.* 2005;79:284-8.
- Anderson TM, Miller JJ Jr. Use of pleura, azygos vein, pericardium, and muscle flaps in tracheobronchial surgery. *Ann Thorac Surg.* 1995;60:729-33.
- Teng MS, Malkin BD, Urken ML. Prefabricated composite free flaps for tracheal reconstruction: a new technique. *Ann Otol Rhinol Laryngol.* 2005;114:822-6.
- Nohl-Oser HC, Fenn A, Dottori V. Tracheobronchoplastic procedure in the treatment of advanced carcinoma of the right upper lung. *Ann Thorac Surg.* 1982;33:396-9.
- Sato M, Hasegawa S, Shoji T, Wada H. Tracheobronchoplasty for resection of lung cancer arising from a tracheal bronchus. *Ann Thorac Surg.* 2002;73:310-2.
- Ozcelik C, Onat S. Nohl-Oser type tracheobronchoplastic procedure in the treatment of advanced carcinoma of the right upper lobe. *Interact Cardiovasc Thorac Surg.* 2004;3:277-9.
- Tong WP. Autogenous bronchial pedicle flap for tracheoplastic procedures. *Zhonghua Wai Ke Za Zhi.* 1992;30:623-4.
- Chen X, Zhang P, Jiang G, Ding J, Tong W, Jiang L, et al. Tracheal and carinal resection and reconstruction in the treatment of lung cancer. *Zhongguo Fei Ai Za Zhi.* 2006;9:14-7.
- Jensik RJ, Faber LP, Kittle CF, Miley RW, Thatcher WC, El-Baz N. Survival in patients undergoing tracheal sleeve pneumonectomy for bronchogenic carcinoma. *J Thorac Cardiovasc Surg.* 1982;84:489-96.

13. Tsuchiya R, Goya T, Naruke T, Suemasu K. Resection of tracheal carina for lung cancer: procedure, complications, and mortality. *J Thorac Cardiovasc Surg*. 1990;99:779-87.
14. Rea F, Marulli G, Schiavon M, Zuin A, Hamad AM, Feltracco P, et al. Tracheal sleeve pneumonectomy for non small cell lung cancer (NSCLC): short and long-term results in a single institution. *Lung Cancer*. 2008;61:202-8.
15. Roviato GC, Varoli F, Rebuffat C, Scalambra SM, Vergani C, Sibilla E, et al. Tracheal sleeve pneumonectomy for bronchogenic carcinoma. *J Thorac Cardiovasc Surg*. 1994;107:13-8.
16. Dartevielle PG, Macchiarini P, Chapelier AR. Tracheal sleeve pneumonectomy for bronchogenic carcinoma: report of 55 cases. *Ann Thorac Surg*. 1995;60:1854-5.
17. Snijder RJ, Brutel de la Rivière A, Elbers HJ, van den Bosch JM. Survival in resected stage I lung cancer with residual at the bronchial resection margin. *Ann Thorac Surg*. 1998;65:212-6.
18. Massard G, Doddoli C, Gasser B, Ducrocq X, Kessler R, Schumacher C, et al. Prognostic implications of a positive bronchial resection margin. *Eur J Cardiothorac Surg*. 2000;17:557-65.
19. Hofmann HS, Taege C, Lautenschläger C, Neef H, Silber RE. Microscopic (R1) and macroscopic (R2) residual disease in patients with resected non-small cell lung cancer. *Eur J Cardiothorac Surg*. 2002;21:606-10.
20. Ghiribelli C, Voltolini L, Paladini P, Luzzi L, Di Bisceglie M, Gotti G. Treatment and survival after lung resection for non-small cell lung cancer in patients with microscopic residual disease at the bronchial stump. *Eur J Cardiothorac Surg*. 1999;16:555-9.