Bronchoplastic and Pulmonary Arterioplastic Procedures in the Treatment of Bronchogenic Carcinoma

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OBJECTIVES: Bronchoplastic and pulmonary arterioplastic procedures have become increasingly popular in recent years as an alternative to pneumonectomy, especially for patients with compromised cardiopulmonary reserve. We reviewed our experience with the procedure to determine the operative technique, indication for the procedure and long-term results.

METHODS: From January 1981 to December 2000, 65 bronchoplasties, four pulmonary arterioplasties and three combined broncho-angioplasties were performed for bronchogenic carcinoma.

RESULTS: Of the 72 patients, 31 had stage I disease, 29 had stage II and 12 had stage III disease. One patient (1.4%) died of bilateral pneumonitis postoperatively. Atelectasis occurred in two patients (2.8%), empyema in one (1.4%), and bronchial fistula in one (1.4%). There were no bronchial stenoses after bronchoplastic procedures, and no vascular complications after angioplastic procedures. The 1-, 3- and 5-year survival rates for the entire group were 86.0%, 47.0% and 29.8% respectively. The difference in survival was significant between stage I and II disease ($p = 0.0001$) and between stage I and III disease ($p < 0.0001$), but not between stage II and III disease ($p = 0.0779$).

CONCLUSIONS: Bronchoplastic, pulmonary arterioplastic and broncho-angioplastic procedures can be performed safely. Bronchoplastic procedures offer patients with bronchogenic carcinoma a long-term result comparable to that with radical lung resection. Angioplastic and combined broncho-angioplastic procedures should only be used in patients who cannot tolerate pneumonectomy due to poor cardiopulmonary reserve. [Asian J Surg 2004;27(3):192–6]
the carina were not included in this group. There were 68 men and four women ranging in age from 20 to 66 years (mean age, 54.3 years).

In the same period, a total of 1,590 patients with bronchogenic carcinoma underwent various lung resections in our department. The 72 bronchoplastic and angioplastic procedures comprised 4.5% of all operations for lung cancer. During the first 10-year period from January 1981 to December 1990, 21 bronchoplastic and angioplastic procedures were performed for bronchogenic carcinoma. In contrast, 51 patients underwent the operation in the second 10-year period from January 1991 to December 2000. Bronchoplastic and angioplastic procedures have been increasingly used in our department through the past two decades.

Preoperative examination
All patients were preoperatively evaluated with bronchoscopy and pulmonary function tests to determine the resectability and predict postoperative lung function. If the tumour was located at the lobe orifice or invaded the adjacent main bronchus, it was considered anatomically suitable for a bronchoplastic procedure. Predicted postoperative forced expiratory volume in the first second (PppFEV₁) was calculated according to the following formula suggested by Juhl and Frost: 

$$PppFEV₁ = \text{preoperative FEV}_1 \times (1 - 0.0526S)$$

where S is the number of segments resected.

From 1986 onwards, patients were also evaluated with computed tomography (CT) of the chest to identify any tumour infiltration outside the bronchial lumen that could not be detected by bronchoscopy.

Operative technique
Thoracotomy was performed through a posterolateral incision in the lateral position. Contralateral pulmonary ventilation was achieved through either a double-lumen endotracheal tube or a single-lumen tube with selective intubation of the contralateral mainstem bronchus.

The operative procedure for bronchoplasty was identical to that for standard lobectomy until the bronchus was isolated. When the major lobe orifice was infiltrated by tumour, wedge or sleeve bronchoplasty was performed. If the main bronchial wall adjacent or, especially, opposite to the lobe orifice was affected, sleeve bronchoplasty was mandatory. The bronchus was divided and resected at a distance of not less than 1.0 cm from the tumour in order to obtain a cancer-free margin. Bronchial anastomosis was performed with a single row of interrupted sutures. Non-absorbable suture material (silk or nylon) was used in most patients, and absorbable suture material (poliglactin 910) was used in only a few patients.

After completion of the bronchial anastomosis, it was checked for air leaks by inflating the lung after filling the thorax with saline solution. A well-vascularized pleural flap or pedicled fat pad from the cardiophrenic angle was used to cover the anastomotic site in order to prevent bronchial fistula and erosion of the bronchial suture line into the pulmonary artery.

The anastomosis of the pulmonary artery was performed with interrupted non-absorbable sutures (polyester or silk). Before anastomosis, 3,000 to 5,000 U of heparin was used at the anastomotic site, but no heparin was used systemically. The anastomotic site was also separated from the bronchial suture line by a pedicled pleural flap or fat pad.

Statistical analyses
Postoperative survival rates were calculated by Kaplan-Meier analysis, and statistical significance was assessed using the log rank test. Differences were considered statistically significant when \( p \) was less than 0.05.

Results
Indication for bronchoplasty and angioplasty
A total of 68 bronchoplastic procedures were performed. Of these, 63 patients were anatomically suitable for the procedure, as shown by preoperative bronchoscopy. Endobronchial tumour was identified at the lobe orifice in 51 patients, in the lobe bronchus with invasion of the adjacent main bronchial wall in 11, and in the left mainstem bronchus in one. For the remaining five patients, the decision for bronchoplasty was made intraoperatively, due to metastatic lymph node adhesion to the origin of the lobe bronchus in three patients and extension of tumour onto the wall of the bronchus in two.

Seven angioplastic procedures were performed; the pulmonary artery was involved through metastatic node adhesion in five patients and direct tumour extension in two. All angioplastic procedures were decided intraoperatively.

In all patients, PppFEV₁ was not less than 1.0 L. However, if pneumonectomy had been performed, PppFEV₁ would have been less than 1.0 L in 11 patients. Standard pneumonectomy was contraindicated in these patients.

Type of procedures
Forty-five patients underwent sleeve bronchoplasty. Right upper sleeve lobectomy was performed in 30 patients, includ-
ing one with simultaneous middle lobectomy. Ten patients underwent sleeve lobectomy of the left upper lobe, two of the right upper and middle lobes, one of the right middle lobe and one of the left lower lobe. One patient underwent sleeve resection of the left mainstem bronchus without removal of the lung parenchyma.

Twenty patients underwent wedge resection of the main bronchus. Fourteen patients underwent right upper lobectomy with wedge resection of the main bronchus, including two cases of concomitant middle lobectomy. Wedge resection of the main bronchus was associated with left upper lobectomy in two patients, left superior segmentectomy in two, right middle lobectomy in one and left lower lobectomy in one.

Four patients underwent an angioplastic procedure with standard lobectomy. Wedge resection of the pulmonary artery with conventional left upper lobectomy was performed in two patients, and with right upper lobectomy in one. The remaining patient underwent sleeve resection of the pulmonary artery with standard left upper lobectomy.

Three patients underwent combined broncho-angioplasty including sleeve right upper lobectomy with sleeve resection of the pulmonary artery (n = 1), wedge left upper lobectomy with wedge resection of the pulmonary artery (1), and wedge right upper lobectomy with wedge resection of the pulmonary artery (1).

Thus, a total of 46 sleeve bronchoplastic, 22 wedge bronchoplastic and seven pulmonary arterioplastic procedures were performed in the 72 patients.

Pathology and classification
Histopathological diagnosis was squamous cell carcinoma in 58 patients, adenocarcinoma in four, small cell undifferentiated carcinoma in four, mucopidermoid carcinoma in three, and adenosquamous carcinoma, carcinoid and malignant histiocytoma in one each. According to the pTNM classification proposed by the International Union Against Cancer, 31 patients had stage I disease, 29 had stage II and 12 had stage III disease. Postoperative pathological examination showed that bronchial stump carcinoma was present in five patients (6.9%).

Postoperative mortality and morbidity
There were no intraoperative deaths. One patient died of bilateral pneumonitis 10 days after surgery (postoperative mortality rate, 1.4%). Four patients (5.6%) developed postoperative complications; atelectasis occurred in two patients (2.8%), and empyema and bronchial fistula in one each (1.4%). All patients with complications recovered through appropriate postoperative treatment and care. No bronchial stenosis developed after bronchoplasty, and the postoperative course was uneventful in all seven patients who underwent arterial reconstruction.

Long-term survival
Overall, the survival rate for the entire group was 86.0% 47.0% and 29.8% at 1, 3 and 5 years, respectively (Figure 1). Three-year survival rates for patients with stage I, II and III disease were 69.4%, 32.3% and 25.0%, respectively. There was no 5-year survival in patients with stage III disease, whereas 5-year survival rates in patients with stage I and II disease were 48.6% and 10.8%, respectively (Figure 2). In the seven patients who had undergone pulmonary artery reconstruction, five died within 2 postoperative years, and the remaining two were alive at 1 year and 4 months, respectively.

Discussion
A bronchoplastic procedure is an optimal choice for patients with lung cancer who cannot survive pneumonectomy due to compromised pulmonary reserve. Luketich and Ginsberg reported that patients who had a PpaFEV1 of less than 1.0 L were less likely to tolerate pneumonectomy than patients with better predicted lung function. Preservation of lung tissue in these patients is of paramount importance; thus, sleeve or wedge lobectomy is the ideal option. In the present study, this procedure provided an opportunity for tumour resection in patients with compromised pulmonary function. Eleven patients were considered unable to tolerate pneumonectomy due to a PpaFEV1 of less than 1 L. However, they tolerated the
bronchoplastic procedure well. Suitable anatomic location of the tumour was the major indication for the procedure in the present study. A sleeve or wedgeresection of the bronchus was indicated when the tumour involved the lobe orifice or the adjacent main bronchus, so that a standard lobectomy would inevitably leave a positive bronchial resection margin. Sixty-one patients who had normal pulmonary reserve underwent bronchoplastic or angioplastic procedures. Thus, an anatomically suitable tumour location and reduced pulmonary reserve were the indications for bronchoplastic procedure in the present study. In our experience, combined use of bronchoscopy and CT scan is helpful for designing bronchoplastic procedures.

Intraoperative frozen-section analysis of the resected bronchial margin must be emphasized in all cases because postoperative pathological examination showed that bronchial stump carcinoma existed in five patients (6.9%) in the present study. Results from other series revealed that a positive bronchial margin could be avoided by intraoperative frozen-section examination.1,3–10 Bronchial stump carcinoma is definitely the cause of local tumour recurrence, and may be the reason why stage II and stage III patients' survival was poorer than expected in the present study.

Atelectasis is a common complication occurring in the early period following bronchoplasty. Maggi and associates reported that the incidence of postoperative atelectasis was 10.9% in 1985,2 whereas Gaiassert and associates' corresponding figure was 5.6% in 1996.11 In our group, however, only 2.9% (2/68) of patients who underwent bronchoplastic procedures developed postoperative atelectasis, which was cured through removal of endobronchial clots and secretions by repeated bronchoscopy. Anastomotic fistula occurs occasionally after bronchoplasty. Belli and associates reported one (5.3%) in 19 patients undergoing bronchoplastic procedures.9 In the present study, however, only one anastomotic fistula (1.4%) was observed. Anastomotic dehiscence and bronchovascular fistula can be effectively prevented by wrapping the anastomotic site with a pedicled pleural flap or fat pad. Bronchial stenosis is one of the most common complications occurring in the late period after bronchoplasty.1,9,10 Thrombosis occasionally occurs in the pulmonary artery after angioplasty.1,9 However, these late complications were not seen in the present study. In our experience, bronchial stenosis can be prevented by using small doses of steroids (fludrocortisone 5 mg/day for 10 days) in the early postoperative period. In the process of performing angioplastic procedures, the use of heparin at the anastomotic site may prevent thrombosis in the pulmonary artery.

In recent years, sleeve lobectomy has been reported to be associated with a lower incidence of postoperative morbidity and mortality and similar long-term survival compared with standard pneumonectomy. Yoshino and colleagues demonstrated that the incidence of postoperative complications was 13.7% with sleeve lobectomy and 24.1% with pneumonectomy (p > 0.05); the 3-year survival was 67.5% with sleeve lobectomy and 58.5% with pneumonectomy (p = 0.05).3 Gaiassert et al reported that the hospital mortality following sleeve lobectomy was 4% compared with 9% following pneumonectomy (p < 0.05), whereas the 5-year survival rates for the two groups were 42% and 44% respectively (p > 0.05).11 In our series, the morbidity and mortality were 5.6% and 1.4% respectively, and overall 5-year survival rate was 29.8%.

Dù and associates summarized the long-term survival of 259 patients who underwent various lung resections for lung cancer in their department between 1968 and 1979.12 The 5-year survival rates for conventional lobectomy and pneumonectomy were 23.8% and 13.3%, respectively. Thus, bronchoplastic procedures are safe and have acceptable short-term and long-term results.

In our experience, resection and reconstruction of the pulmonary artery is not a very difficult operation. However, disappointing long-term results limit its use. For this reason, we suggest that angioplastic and combined bronchoplastic procedures be used only in patients who cannot survive pneumonectomy because of compromised cardiopulmonary reserve.

References
angioplasty technique in the treatment of bronchogenic carcinoma. 