GENERAL THORACIC SURGERY

PULMONARY FUNCTION AND POSTOPERATIVE COMPLICATIONS AFTER WEDGE AND FLAP RECONSTRUCTIONS OF THE MAIN BRONCHUS

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Between 1980 and 1989, 8 wedge and 17 flap main bronchoplasties were done in 24 patients (4 carcinoid tumors, 4 benign lesions, 17 carcinomas). Bronchial anastomotic stenoses, pulmonary function, and survival were evaluated. Preoperative ventilation/perfusion scans with preoperative and postoperative spirometry were done in all patients except two who underwent a wedge bronchoplasty. Postoperative bronchoscopy was done in all patients. Follow-up was complete for the patients with carcinoma ($N = 17$). In the wedge group bronchial anastomotic stenoses occurred in three (38%) of eight patients. All three patients had serious postoperative complications (persistent atelectasis in one, prolonged ventilatory support in two); one patient died and the other two had impaired postoperative pulmonary function. Complete function recovery occurred in only three (38%) of eight patients who underwent wedge bronchoplasty. In the flap group, bronchostenosis occurred in 3 (18%) of 17 patients. The associated complications (mucus retention, minor atelectasis, partial lobar torsion) were mild. Complete pulmonary function recovery occurred in 13 (76%) of 17 patients who had flap bronchoplasty. Actuarial survival, for the patients with carcinoma, was 88%, 47%, and 41% after 1, 3, and 5 years, respectively. The local recurrence rate was 25% (4/16). In our series, flap main bronchoplasties were effective for the resection of bronchial tumors with local involvement of the adjacent main bronchus. Wedge main bronchoplasties, however, were associated with substantial postoperative complications. (J Thorac Cardiovasc Surg 1996;112:117-23)

The validity of a lobectomy with a wedge or flap main bronchus reconstruction as an alternative to a sleeve lobectomy is controversial. Several authors have successfully performed wedge resections of the main bronchus.[1-6] Others, however, abandoned these reconstructions because postoperative morbidity was high.[7] No published data are available to substantiate either of these two surgical approaches.

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We have recently published our results after complete circumferential sleeve lobectomy.[8,9] The postoperative pulmonary function, complication rates, and survival in these patients were good. In addition to those publications we now report our experience with the incomplete sleeve resections, the so-called wedge and flap main bronchoplasties. Wedge bronchoplastic procedures were done for lobar tumors with local infiltration of the cranial and the caudal parts of the adjoining main bronchus. Flap bronchoplasties were done for lobar tumors with only local involvement of either the cranial or caudal part of the adjacent main bronchus. Both constructions were then considered technically easier, although still as effective as a sleeve lobectomy.

Patients and methods

Between 1980 and 1989, 17 flap and 8 wedge bronchial resections were done in 24 patients. In all patients, the decision to perform a wedge or flap main bronchoplasty

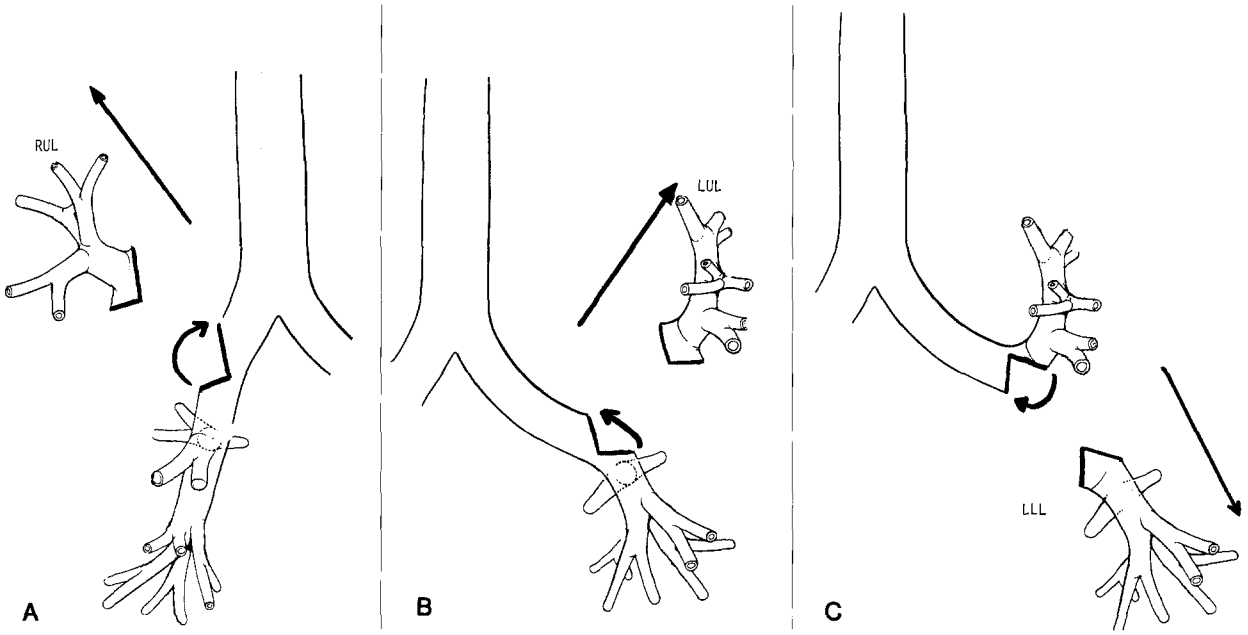

Fig. 1. A, B, and C, Wedge bronchoplasty with lobectomy of right upper lobe *(RUL),* left upper lobe *(LUL),* and left lower lobe *(LLL).*

was made intraoperatively after the unexpected finding of local tumor involvement of the main bronchus. In all cases, after standard lobectomy, the margins at the line of resection showed macroscopic or microscopic local tumor invasion. A complete circumferential sleeve lobectomy was ruled out because this resection was considered too drastic and excessive. Therefore the alternative of a wedge or flap main bronchoplasty was chosen.

The lungs were ventilated with a double-lumen bronchotracheal cannula in all patients. A standard posterolateral thoracotomy was done. The pleural space was entered through the fourth or fifth intercostal space. Lymph node sampling was done. The segmental arteries and vein were divided.

Wedge technique. The tumor was palpated and a bronchotomy was made to assess the precise intraluminal tumor location. Local tumor infiltration of the cranial and the caudal parts of the adjoining main bronchus was the indication for wedge bronchoplasty. The affected lung lobe and a part of the main bronchus were excised with two oblique bronchial incisions in the main bronchus (wedge resection). In this way between one third and one half of the main bronchus circumference was resected. The medial bronchial wall was preserved. The bronchial edges were then approximated. The cartilaginous part was sutured with interrupted 3-0 or 4-0 Vicryl polyglactin 910 sutures in six patients, Prolene polypropylene sutures in one patient, and PDS polydioxanone sutures in one patient (all sutures manufactured by Ethicon, Inc., Somerville, N.J.). The sutures were placed and tied from the medial direction to the lateral to avoid any traction. The membranous part was reconstructed with 5-0 Prolene polypropylene sutures. The anastomosis was covered with a pedicled pleural flap in seven patients and a pericardial flap in one patient. The different types of wedge reconstructions are shown in Fig. 1.

Flap technique. A lobar bronchotomy was made and the tumor location was determined. A flap bronchoplasty was only indicated if either the cranial or caudal part of the adjacent main bronchus was affected. A lobectomy and partial main bronchus wall resection were made in such a way that approximately 2 to 3 cm of the unaffected side of the lobar bronchus was preserved. Obviously, the continuity between this lobar bronchial remnant and the main bronchus was kept intact. The lobar remnant was spread out and used as a flap to cover the defect in the main bronchus. The remnant was fixed in place with interrupted 3-0 or 4-0 Vicryl polyglactin 910 sutures. The bronchial anastomosis was covered with a pedicled pleural flap in 16 cases and sealed with tissue glue in 1 case. The right- and left-sided flap bronchoplasties are shown in Figs. 2 and 3.

Postoperative bronchoscopy was done in all patients to assess bronchial patency.

Evaluation methods. Follow-up was obtained for all patients from patient files and referring physicians. To assess the postoperative recovery of pulmonary function the predicted postoperative forced expiratory volume in 1 second (FEV_1) was calculated and compared with the measured postoperative FEV_1. Results of preoperative spirometry and split pulmonary radionuclide ventilation/perfusion (V/Q) scans were used to calculate the predicted postoperative FEV_1. Preoperative spirometry and split pulmonary radionuclide V/Q scans were done in all patients. The V/Q scan was done with either xenon 133 or krypton 81m with the use of large-field projections from the anterior and dorsal side. Spirometry was done with a computerized spirometer.

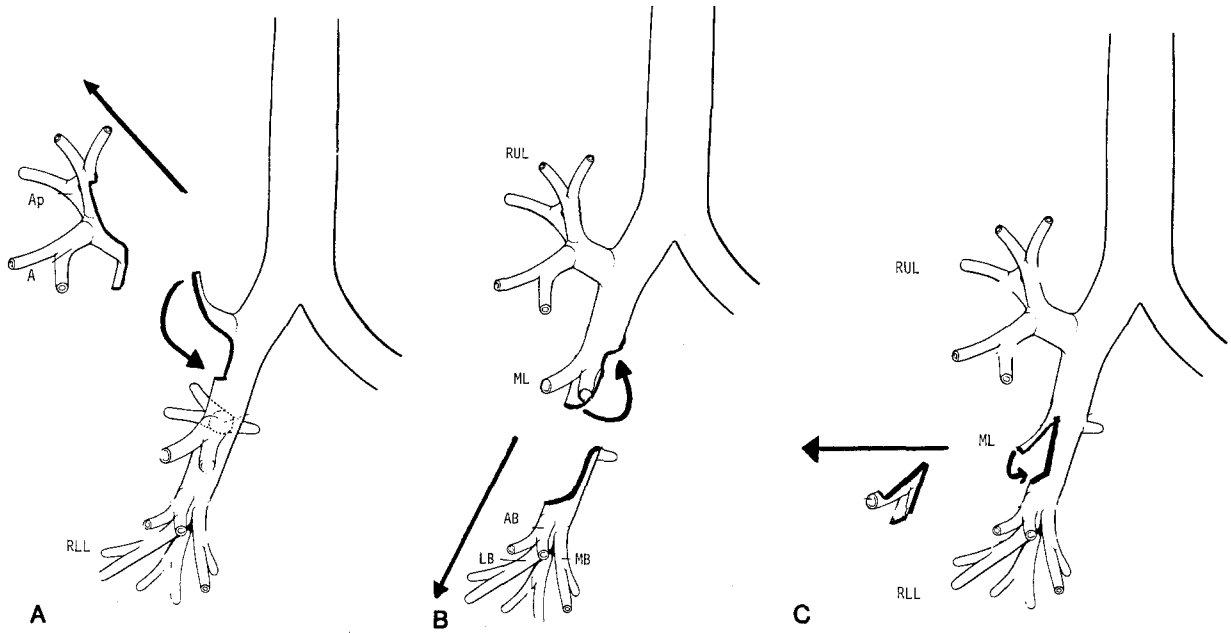

Fig. 2. A, B, and C, Flap bronchoplasty with lobectomy of right upper lobe *(RUL),* right lower lobe*(RLL),* and middle lobe *(ML). Ap,* Apical; *A,* anterior; *AB,* anterior basal; *MB,* medial basal; *LB,* lateral basal.

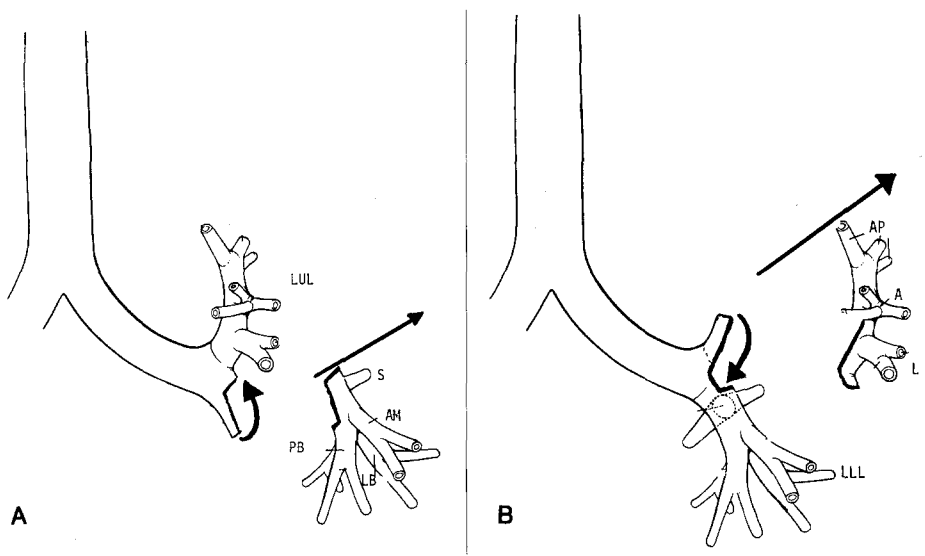

Fig. 3. A and B, Flap bronchoplasty with lobectomy of left upper lobe *(LUL)* and left lower lobe *(LLL). S,* Superior, *AM,* anteromedial, *PB,* posterior basal, *LB,* lateral basal; *AP,* apicoposterior; *A,* anterior; *L,* lingula.

The expected pulmonary function loss was calculated from the following equation.[10, 11]

$$\text{Preoperative } FEV_1 \times \frac{\text{Number of functional segments in the lobe to reresected}}{\text{Total number of segments in both lungs}}$$

The number of functional segments was derived from the V/Q scans. Complete absence of radioactivity in a specific lung lobe that was to be surgically resected was interpreted as total dysfunction of that particular area, indicating that the predicted postoperative FEV_1 (in milliliters) should be considered equal to the postoperative measured FEV_1 (in milliliters).

If, on the contrary, the lobar bronchus proved to be patent with even V/Q distribution, lobar function was presumed to be adequate and the predicted postoperative FEV_1 (in milliliters) was calculated by subtracting the

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Table I. *Characteristics of patient population*

	Group	
	Wedge (n = 8)	*Flap (n = 16)*
No. of bronchoplasties	8	17
Age (yr)	57.8	55.6
Age range (yr)	37.2-71.6	16.7-74.6
Men:women	6:2	15:2
Histologic type		
Squamous	7	9
Nonsquamous		1
Carcinoid	1	3
Benign		4
Site		
RUL	4	2
RML		2
RLL		4
LUL	2	2
LLL	2	7
Stage (only patients with carcinoma; $n = 17$)		
T1 N0		1
T2 N0	2	5
T2 N1	3	2
T2 N2	2	2
Curative operation	3	8
Palliative operation	4	2

RUL, Right upper lobe; *RML,* right middle lobe; *RLL,* right lower lobe; *LUL,* left upper lobe; *LLL,* left lower lobe.

amount of anticipated function loss as a result of surgical resection of the diseased lobe. The predicted postoperative FEV_1 value was adapted in accordance with the estimated number of involved segments if incomplete bronchial obstruction was visualized on the V/Q scans. Spirometry was repeated after operation.

To facilitate analysis, the measured postoperative FEV_1 (in milliliters) of each patient was expressed as a fraction of the predicted postoperative FEV_1 (in milliters). This index, measured FEV_1/predicted FEV_1, reflected the postoperative recovery of pulmonary function. The survival rate for the patients with carcinoma was calculated with the SPSS PC version 5.0 software program (SPSS Inc., Chicago, Ill.).

Results

Patient characteristics are summarized in Table I. In five patients the flap or wedge bronchoplasty was the second lung operation. The predicted postoperative FEV_1 value was adapted for these patients.

Seven patients who had wedge bronchoplasty and 10 who had flap bronchoplasty had bronchial carcinoma. Three patients in the wedge group and eight in the flap group had a curative resection. A palliative resection, with tumor-positive margins at the line of resection or N2 lymph nodes, was done in six patients. Postoperative radiotherapy was administered in five patients. Postoperative complications, follow-up, and recovery of pulmonary function are shown in Tables II and III.

Table II. *Postoperative complications and follow-up*

	Group	
	Wedge (n = 8)	*Flap (n = 16)*
Postoperative complications		
Anastomosis related		
30-day mortality	1	
Bronchial stenosis/ kinking/torsion	3	3
Not anastomosis related	1	3
Follow-up (yr)*	3.0	6.4
Range	13 dy-10.3 yr	1.2-12.6 yr
Death	5	10
Causes of death (no. of patients)		
Local recurrence	1	1
Local recurrence with metastases	1	1
Metastases	1	3
Cardiac		4
Other	2	1

*All patients; September 1994.

Table III. *Pulmonary function recovery*

	Index			
Type of resection	*<0.80*	*0.80 < × < 0.95*	*>0.95*	*NA*
Wedge ($n = 8$)	1	2	3	2
Flap ($n = 17$)	2	2	13	

Index, Measured FEV_1/predicted FEV_1; *NA,* not available.

Wedge bronchoplasty. Three patients who underwent wedge bronchoplasty had bronchial kinking at the anastomosis site: one patient had persistent lobar atelectasis of the reimplanted lobe and two had respiratory distress that necessitated prolonged mechanical ventilatory support. In all three patients the bronchial anastomosis had a slitlike orifice. Just distal from the anastomotic orifice the bronchus showed sharp angulation.

At postoperative histologic examination one patient with postoperative respiratory distress had a tumor-positive bronchial margin at the line of resection. A complete circumferential sleeve resection was done; however, the patient died after 13 days. Another patient had a pinpoint tumor-positive bronchial margin at the line of resection. This patient and another two patients with lymph nodes positive for N2 disease received postoperative radiotherapy.

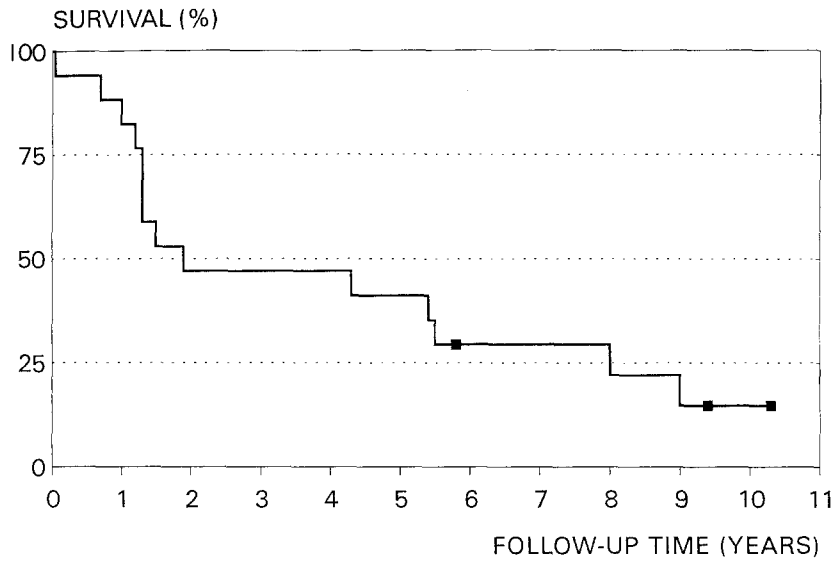

Fig. 4. Cumulative survival of patients with carcinoma ($N = 17$).

Postoperative complications unrelated to the bronchoplasty occurred in one patient (prolonged parenchymal air leak).

Complete postoperative recovery of pulmonary function occurred in 38% (3/8) of all patients who underwent wedge bronchoplasty. Four patients in the wedge group had an uneventful postoperative period. Three showed complete postoperative pulmonary recovery (indices ≥0.95) 52, 43, and 148 days after operation. In one patient impaired postoperative pulmonary function developed 41 days after operation (index 0.83). Spirometry could not be obtained in two patients in the wedge group.

Flap bronchoplasty. Three patients in the flap group had bronchoscopically confirmed bronchial anastomotic stenosis: one patient had a brief period of mucus retention, another had a partial lobar torsion, and one had minor atelectasis. Two of these patients eventually had complete recovery of pulmonary function with respective indices of 0.95 and 1.02 at 78 and 33 days after operation. One patient had persistently impaired pulmonary function with an index of 0.82.

Postoperative complications unrelated to the bronchoplasty occurred in three patients: prolonged parenchymal air leak, contralateral pneumonia, and left diaphragmatic paralysis. Two patients eventually had complete functional recovery. The patient with left diaphragmatic paralysis had persistantly impaired pulmonary function with an index of 0.84 at 41 days after operation. Eleven patients in the flap group had uncomplicated postoperative recovery; however, two patients had impaired postoperative pulmonary function with respective indices of 0.83 and 0.59 at 19 and 90 days after operation. Complete recovery of pulmonary function occurred in 76% (13/17) of all patients who underwent flap bronchoplasty. Two patients in the flap group with lymph nodes positive for N2 disease received postoperative radiotherapy.

Local recurrence and survival. Actuarial survival of the patients with carcinoma ($N = 17$) was 88%, 47%, and 41% after 1, 3, and 5 years (Fig. 4). Local recurrences occurred in 29% (2/7) of the patients who had wedge bronchoplasty and in 20% (2/10) of those who had flap bronchoplasty. Our overall 30-day mortality rate was 4%; one patient died after 13 days.

Discussion

Sleeve, flap, and wedge bronchial reconstructions are three different surgical techniques to resect lesions of the main bronchus. After sleeve resections the morbidity rate is acceptable[9] and the postoperative pulmonary function is good.[8] Nonetheless, flap and wedge bronchoplasties are used as alternatives to sleeve resection. This approach remains a matter of debate.

Toledo and colleagues[5] did not find any bronchial narrowing in 11 flap and wedge resections. Ayabe and colleagues[3] reported one postoperative death, caused by myocardial infarction, in 15 patients who

underwent wedge bronchoplasty. Naruke and associates[2] had one granulation bronchial stenosis among seven patients who underwent wedge bronchoplasty. Postoperative complications were not specified in patients who underwent wedge bronchoplasty in the reports of Paulson and colleagues[1] (n = 14) and Belli and colleagues[4] (n = 6). Salminen and associates[6] found good postoperative pulmonary function in three patients who underwent wedge bronchoplasty.

Bronchostenosis. In our wedge group there tended to be a relationship between the presence of a bronchial stenosis and the development of postoperative complications with reduced pulmonary function recovery.

Bronchial anastomotic stenosis was observed in three (38%) of eight patients in the wedge group. At bronchoscopy all three patients had severe deformation of the anastomotic orifice with serious postoperative complications (persistent atelectasis in one, respiratory distress in two). One patient died of sepsis. The two surviving patients showed incomplete postoperative recovery of function (indices 0.69 and 0.88, respectively).

In contrast to findings in the wedge group, the relationship between bronchial stenosis, postoperative complications, and reduced postoperative recovery of pulmonary function was not clear for the flap group. Bronchostenosis with associated postoperative complications related to the bronchoplasty occurred in 3 (18%) of 17 patients. These complications (mucus retention, minor atelectasis, partial lobar torsion) were mild and treated successfully. The patient with lobar torsion had incomplete recovery of function, and recovery of function in the other two patients was complete.

Compared with previously published results of sleeve lobectomy,[9] the prevalence of bronchostenosis tended to be higher in the wedge group. In a group of patients who underwent sleeve lobectomy, bronchostenosis occurred in 13 (8.9%) of 145 patients.[9] In our wedge group bronchostenosis was noticed in 3 (38%) of 8 patients. In the flap group bronchostenosis occurred in only 3 (18%) of 17 patients.

Morbidity. The 30-day mortality rate in the wedge/flap bronchoplasty and sleeve lobectomy groups was similar: 4% (1/25) versus 4.8%[9] (7/145).

Pulmonary function recovery. The postoperative pulmonary function in the flap group appeared to be as good as the pulmonary function after sleeve lobectomy. In a previously published series of 109 patients[8] who underwent circumferential sleeve lobectomy, 65 patients (60%) showed complete postoperative recovery of pulmonary function, which was defined as an index of 0.95 or greater. In the flap group in the current series, 13 (76%) of 17 patients had an index of 0.95 or greater.

Only four patients who underwent flap bronchoplasty had an index of less than 0.95: one patient had left diaphragmatic paralysis and persistently impaired pulmonary function; one patient had bronchial stenosis; and in two patients, who had uneventful postoperative recovery, the predicted postoperative FEV_1 level was not reached. In the latter two patients it was speculated that either interruption of the parasympathetic nerves, lymphatic vessels, or bronchial circulation contributed to the reduced pulmonary function, as was suggested by Wood and colleagues,[12] or the calculation of the predicted postoperative FEV_1 of these two patients was biased because of misinterpretations of the V/Q scan.

In the wedge group only three (38%) of eight patients had an index of 0.95 or greater.

Radiotherapy and postoperative complications. We could not demonstrate any relationship between postoperative radiotherapy and postoperative complications or failure to achieve the predicted level of FEV_1 . Three patients in the wedge group and two in the flap group had postoperative radiotherapy. Only one patient in the wedge group had a postoperative complication with reduced recovery of pulmonary function. This complication, however, was probably related to the bronchial stenosis. Two patients in the flap group had postoperative complications before radiotherapy was delivered. In both these patients postoperative FEV_1 levels eventually reached the predicted values.

Survival and local recurrence. The survival and local recurrence rates for the patients with carcinoma who underwent wedge and flap bronchoplasty were not adversely affected in comparison with the reported long-term follow-up after sleeve resections.[9] The 5-year survival after sleeve lobectomy was 49%,[9] and in this series the rate was 41%. Local recurrence rates for the sleeve lobectomy and wedge/flap groups were 17.9%[9] (26/145) and 25% (4/16).

In our series the postoperative oncologic results after both resections were good. The wedge main bronchoplasties, however, were associated with serious postoperative complications related to the anastomosis. Flap bronchoplasties, on the other hand, were very effective. The technical feasibility of creating an adequate lobar flap that could be used to close the

bronchial defect was a major drawback of the flap bronchoplasty. The small number of patients in this series restricts statistical analysis. Therefore these data should be interpreted with care.

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