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Functional Advantage of Parenchymal-Sparing Surgery for Early Hilar Lung Cancer

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WATANABE, Y., ODA, M., SHIMIZU, J., HAYASHI, Y., OHTA, Y., IWA, T., TONAMI, N. and HISADA, K. *Functional Advantage of Parenchymal-Sparing Surgery for Early Hilar Lung Cancer.* Tohoku J. Exp. Med., 1991, **163** (2), 135-148 —— In a group of 27 patients with early hilar lung cancer, standard sleeve lobectomy was performed in 14 cases, standard lobectomy in 9 cases, and another 4 patients underwent parenchymal-sparing operations (2 had sleeve segmentectomy, 1 had sleeve middle lobectomy, and 1 had left second carinal resection). The changes of conventional pulmonary function tests and regional pulmonary function were compared between patients undergoing sleeve lobectomy and those undergoing parenchymal-sparing surgery. The parameters used for the conventional lung function tests were FVC, %FVC, $FEV_{1.0}$, and $\%FEV_{1.0}$. For the evaluation of regional pulmonary function, perfusion scans using ^{99m}Tc-MAA and ventilation scans using ^{133}Xe were performed. The decrease of FVC in the sleeve lobectomy group ($n=5$) was 724 ± 182.7 ml, whereas that in the parenchymal- sparing surgery group ($n=4$) was 367.5 ± 52.1 ml, a significant difference. Both the $FEV_{1.0}$ and $\%FEV_{1.0}$ showed no marked changes in both groups between the preoperative and postoperative values. Perfusion and ventilation scans in the parenchymal-sparing group showed a superior result in comparison with sleeve lobectomy group. All the patients undergoing parenchymal-sparing operations survived over the long term. It was thus concluded that parenchymal-sparing surgery can be applied to carefully selected patients with tiny localized cancers. ———— early hilar lung cancer ; parenchymal-sparing surgery ; sleeve segmentectomy ; conventional pulmonary function tests ; pulmonary scan

Standard lobectomy and pneumonectomy were accepted as the procedures of choice for the operative management of localized lung cancer before the clinical application of bronchoplastic surgery. At that time, cancers involving the main stem bronchi were resected by pneumonectomy, even if the lesion was a tiny localized one. Sleeve lobectomy, in which a portion of the main stem bronchus

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is removed in continuity with the involved lobe, was subsequently introduced as a parenchymal-sparing operation. In carefully selected patients with centrally located neoplasms, sleeve lobectomy appears to offer an alternative to pneumonectomy.

Early hilar lung cancer is defined as localized cancer situated proximal to the segmental bronchus without nodal involvement or distant metastases. Patients with early hilar lung cancer are the most suitable candidates for bronchoplastic operations (i.e., sleeve lobectomy), because they have the potential for a long period of disease-free survival. In patients undergoing sleeve lobectomy, it has been our policy to attempt parenchymal-sparing operations (such as sleeve middle lobectomy, sleeve segmentectomy, or second carinal resection) to preserve as much as possible of the functioning lung tissue, if the lesion is of limited extent and can be completely removed by such a procedure.

By definition, all patients with early hilar lung cancer have no nodal involvement or distant metastases, and so have stage 0 or I disease. Thus, the extent of the lesions in all these patients is almost the same and the main difference is the location of the lesion, according to which the operative procedure is varied as necessary. Furthermore, since all the lesions are too small to occlude the airway and cause obstructive pneumonia, impairment of the preoperative pulmonary function is the least. Thus, the changes in pulmonary function could be appropriately compared between the preoperative and postoperative states in this group of patients.

The present study compared the effects on pulmonary function of various operative procedures for early hilar lung cancer and the results emphasized the functional advantages of parenchymal-sparing operations.

Materials and Methods

The subjects were 27 patients who fulfilled the definition of the early hilar lung cancer proposed by the Japanese Lung Cancer Society (JLCS). The JLCS defines early hilar cancer as lesions that fulfill the following three microscopic criteria: 1) the lesion is localized proximal to the segmental bronchi, 2) tumor invasion is confined to within the bronchial wall, and 3) no lymph node metastases or distant metastases. The patients included 1 female and 26 males. Their ages ranged between 49 and 77 years, being 63.0 years on average. Excluding one case of mucoepidermoid carcinoma, all the lesions were squamous cell carcinoma. The operative procedures applied were standard sleeve lobectomy in 14 patients, standard lobectomy in 9 patients, sleeve segmentectomy in 2 patients, and sleeve middle lobectomy and left second carinal resection in 1 patient each. There was no operative morbidity or mortality among these 27 patients.

Conventional pulmonary function tests and regional pulmonary function studies were performed before and at various times (4 to 60 months) after the operations. Functional preservation of the lungs was compared between the patients undergoing sleeve lobectomy and those undergoing parenchymal-sparing procedures.

The conventional pulmonary function tests included forced vital capacity (FVC), the percentage of the predicted FVC (%FVC), the forced expiratory volume in one second ($FEV_{1.0}$), and the $\%FEV_{1.0}$ ($FEV_{1.0}/FVC$).

Regional pulmonary function in the reimplanted lung was evaluated by both blood flow and ventilatory function studies. Regional blood flow was evaluated by perfusion scanning using 4 mCi (148 MBq) technetium 99 m-labeled macroaggregated human albumin (^{99m}Tc-MAA), which was administered intravenously. Regional ventilatory function was evaluated by the inhalation of 10 mCi (370 MBq) xenon 133 (^{133}Xe) gas. Ventilatory gas distribution and air trapping were evaluated at the inspiratory phase, the equilibrium phase, and the washout phase.

Statistical significance was evaluated by the t-test and $p < 0.05$ was adopted as the level of significance.

TABLE 1. *Changes of pulmonary function after sleeve lobectomy and parenchymal-sparing surgery*

Case	Age (years)	Sex	Operative procedure	Resected lung region	Interval between tests (months)	FVC (ml)	%FVC (%)	$FEV_{1.0}$ (ml)	% $FEV_{1.0}$ (%)
1[a]	56	M	Sleeve lobectomy	Right upper	64	3,290	90.1	2,320	70.5
						2,660	76.1	1,930	72.6
						(−630)	(−14.0)	(−390)	(+2.1)
2[a]	62	M	Sleeve lobectomy	Left lower	22	2,660	76.1	1,930	72.6
						1,810	52.2	1,730	95.6
						(−850)	(−23.9)	(−200)	(+23.0)
3	72	M	Sleeve lobectomy	Right upper	72	3,960	124.1	2,470	62.4
						3,020	97.4	2,340	77.5
						(−940)	(−26.7)	(−130)	(+15.1)
4	65	M	Sleeve lobectomy	Left upper	28	3,070	90.3	1,700	55.4
						2,650	79.8	1,950	73.6
						(−420)	(−10.5)	(+250)	(+18.2)
5	67	M	Sleeve lobectomy	Left upper	50	2,920	90.0	1,990	68.2
						2,140	69.9	1,330	62.1
						(−780)	(−20.1)	(−660)	(−6.1)
6	55	F	Sleeve lobectomy	Right middle	66	2,960	114.2	2,230	75.3
						2,550	100.0	1,920	75.3
						(−410)	(−14.2)	(−310)	(−0)
7	63	M	Sleeve segmentectomy	Right S6	50	3,190	99.7	2,060	64.6
						2,900	88.2	2,050	70.7
						(−290)	(−11.5)	(− 10)	(+6.1)
8	76	M	Sleeve segmentectomy	Left lingula	14	2,990	93.1	1,950	65.2
						2,570	80.5	1,630	63.4
						(−420)	(−12.6)	(−280)	(−1.8)
9	62	M	2nd carinal resection	None	27	3,440	110.3	2,460	71.5
						3,090	98.7	2,450	79.3
						(−350)	(−11.6)	(− 10)	(+7.8)

Age, age at the first operation ; S6, superior segment of the right lower lobe ; FVC, forced vital capacity ; %FVC, percentage of the predicted FVC value ; $FEV_{1.0}$, forced expiratory volume in one second ; $\%FEV_{1.0}$, percentage of $FEV_{1.0}$/FVC.

Upper row, preoperative value ; middle row, postoperative value ; lower row in parentheses, amount of reduction.

[a]the same patient, who underwent bilateral sleeve lobectomy for metachronous early hilar cancer.

Results

Table 1 shows the conventional pulmonary function parameters for patients who underwent standard sleeve lobectomy (cases 1, 2, 3, 4 and 5), sleeve middle lobectomy (case 6), sleeve segmentectomy (cases 7 and 8), and second carinal resection (case 9).

Fig. 1 illustrates the operative procedures used for these 8 patients (cases 1 and 2 are the same patient).

Pulmonary function after standard sleeve lobectomy

Fig. 2 compares the preoperative and postoperative (3 years after surgery)

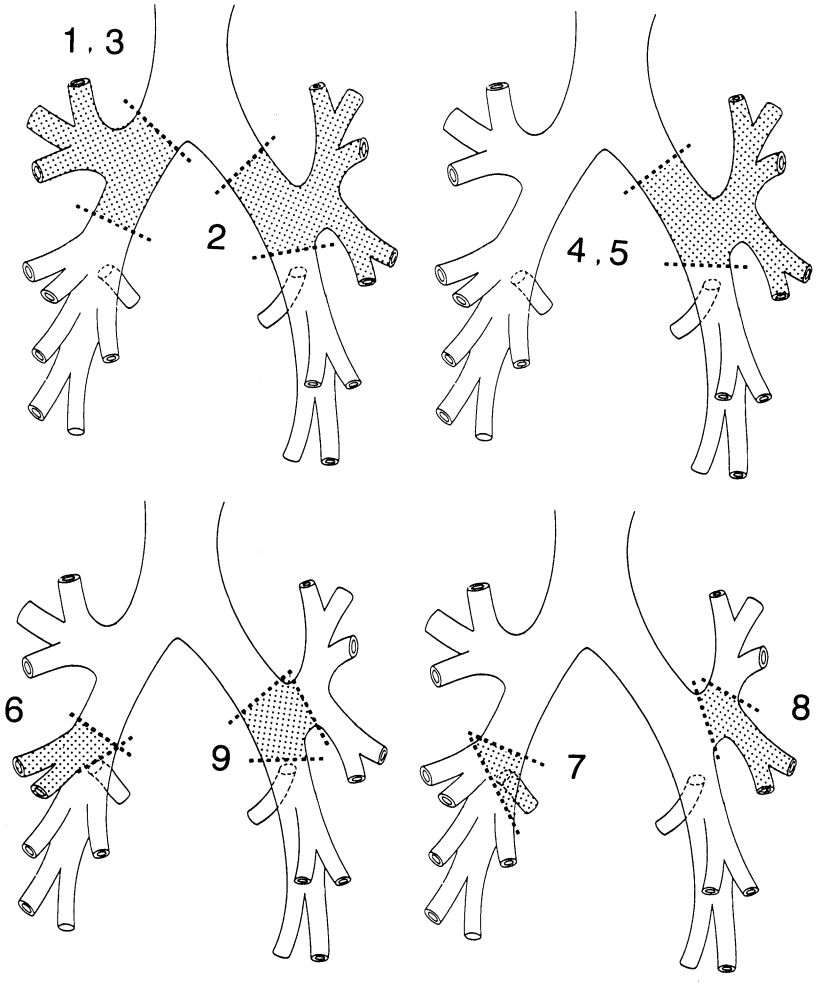

Fig. 1. Operative procedures applied for 8 patients. The numbers in the figure correspond to the case numbers in Table 1.

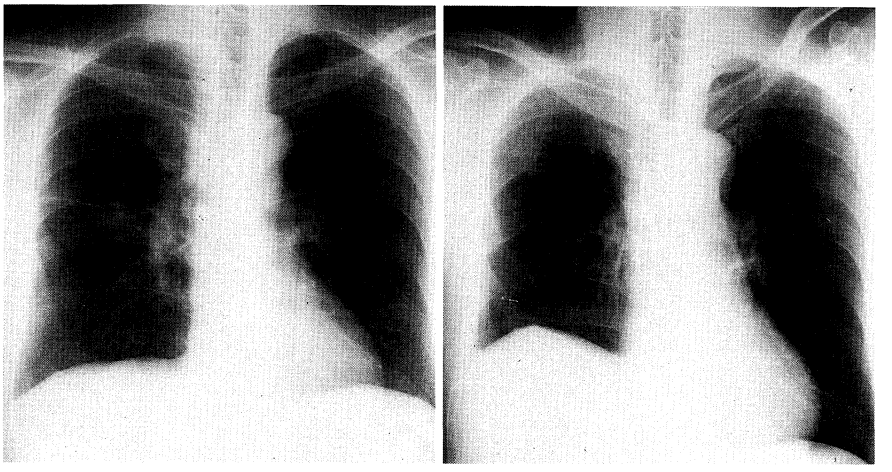

Fig. 2. Preoperative and postoperative (3 years after sleeve right upper lobectomy) chest x-ray films of a 56-year-old man.

chest films in a 56-year-old man who underwent sleeve right upper lobectomy. Loss of lung volume on the right side and elevation of the diaphragm are apparent in the chest film taken after lobectomy. Table 1 shows the preoperative and postoperative pulmonary function tests for this patient (case 1). The FVC was reduced by 630 ml (14% of the preoperative value) by the right upper lobectomy, but the $\%FEV_{1.0}$ did not show any marked change. Six years later, he developed a second early hilar cancer in the opposite lung, which was again successfully resected by a second sleeve lobectomy (Watanabe et al. 1986). Following the second operation (case 2), his FVC was reduced by 850 ml, but his $\%FEV_{1.0}$ did not fall (in fact, there was an inverse increase due to the decrease of vital capacity). A perfusion scan taken 5 years after the first operation showed volume loss in the right lung due to lobectomy, but the ventilation scan showed good preservation of lung function. He remains alive and well 6 years after the second sleeve lobectomy.

Fig. 3 shows postoperative pulmonary scans in a 61-year-old man who underwent sleeve right upper lobectomy. Pulmonary scanning in the 27th postoperative month showed volume loss in the right lung due to lobectomy, but neither perfusion nor ventilation defects were observed in the residual lung. Furthermore, washout was excellent without any sign of air trapping at the reconstructed airway site, and the washout curves for both lung fields were normal. He remains alive and well 39 months after the surgery without any complaints.

The reduction of vital capacity (mean $\pm$ S.D.) in the 5 patients who underwent standard sleeve lobectomy (cases 1 to 5) was 724 ± 182.7 ml.

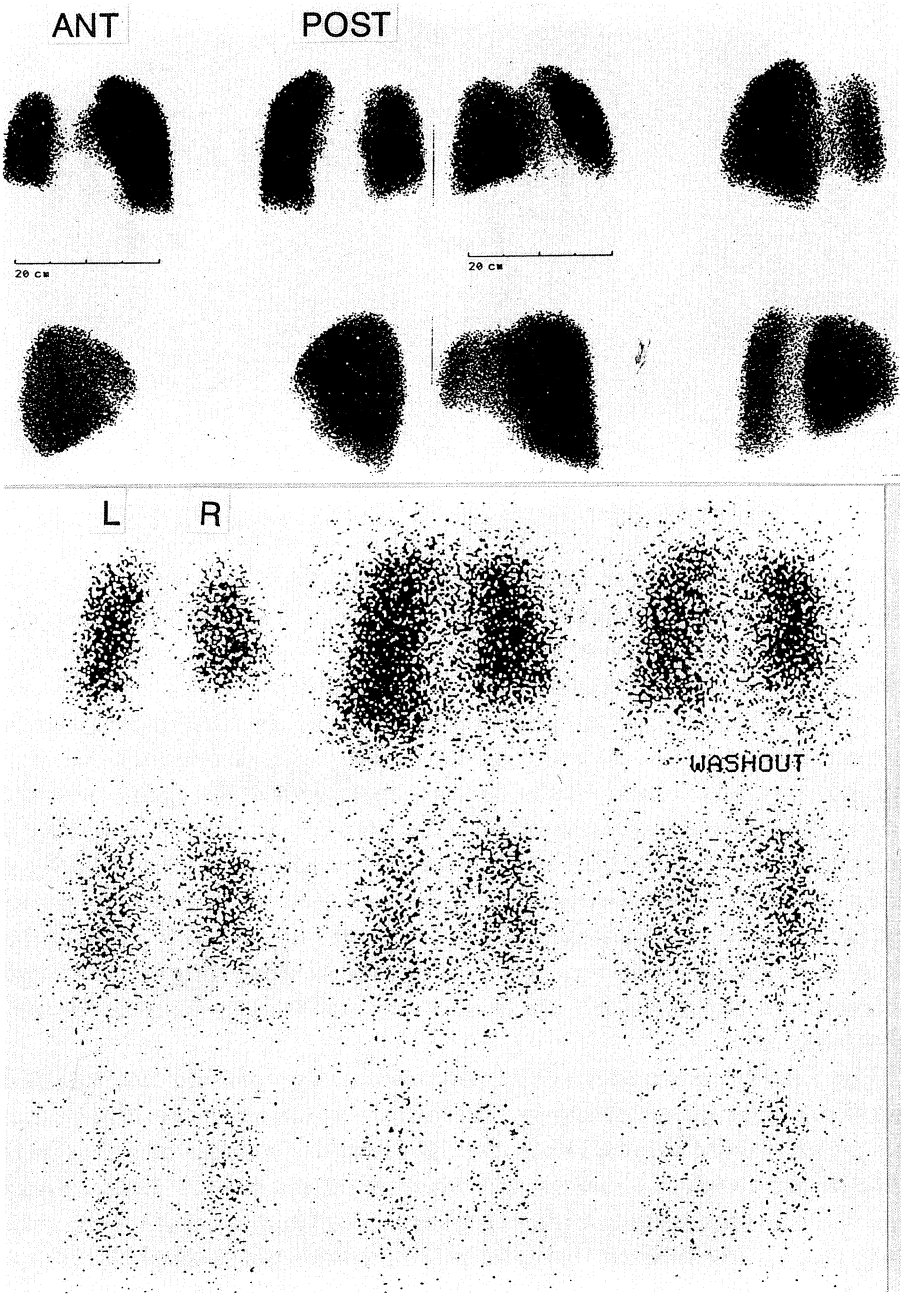

Fig. 3. Postoperative perfusion (upper) and ventilation (lower) scans (27 months after surgery) from a 61-year-old man who underwent sleeve right upper lobectomy.

Pulmonary function after parenchymal-sparing operation

Sleeve middle lobectomy

Fig. 4 shows postoperative scans in a 55-year-old man (case 6) who underwent sleeve right middle lobectomy. Pulmonary function testing before and after the operation showed a 410 ml reduction of vital capacity. Although pulmonary scans performed 17 months after the operation show a segmental perfusion defect in the right middle lung field that was possibly caused by resection of the right middle lobe, there was no abnormality in the ventilation scan. He remains alive

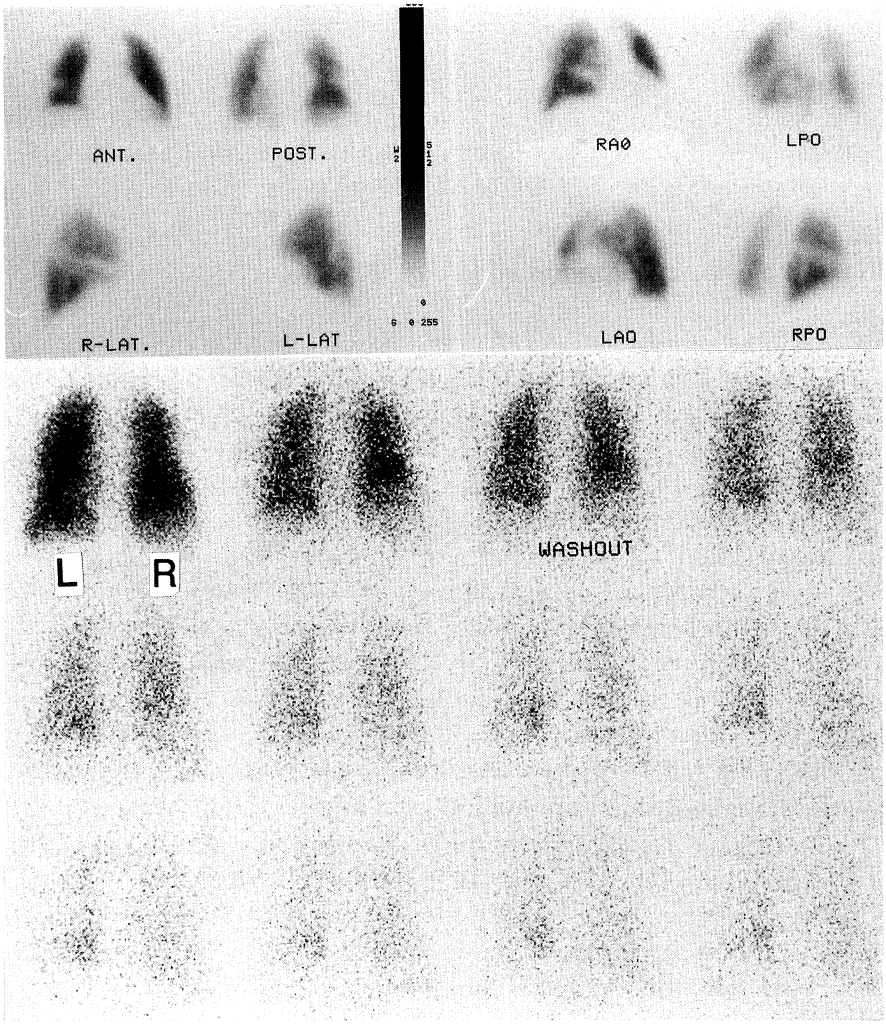

Fig. 4. Postoperative perfusion (upper) and ventilation (lower) scans (17 months after surgery) from a 61-year-old man who underwent sleeve right middle lobectomy.

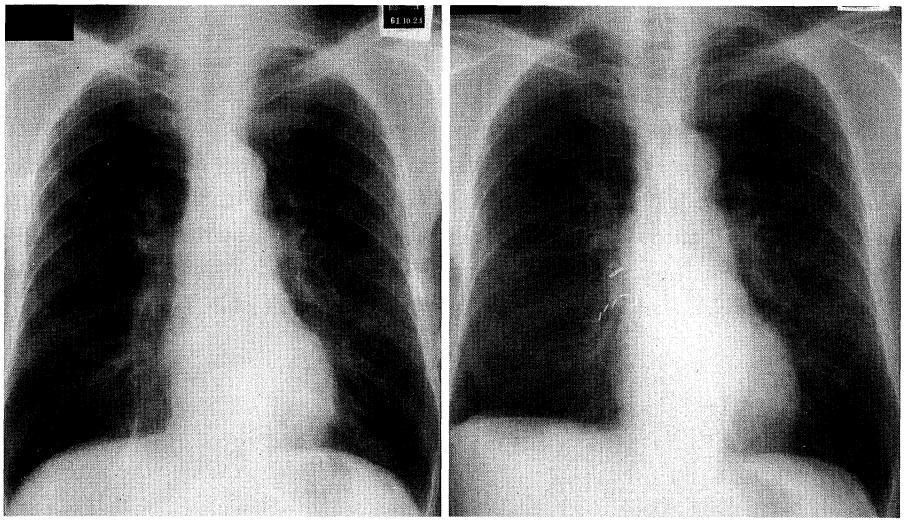

Fig. 5. Preoperative and postoperative (50 months after sleeve right S6 segmentectomy) chest x-ray films of a 63-year-old man.

and well 41 months after the operation.

Sleeve segmentectomy

Fig. 5 shows chest x-ray films from a 63-year old man (case 7) who underwent sleeve segmentectomy of the superior segment of the right lower lobe (S6). Following a parenchymal-sparing operation, the chest film taken before and 50 months after the operation show no marked changes. Pulmonary function was affected to a lesser degree in this patient in comparison with the patients who underwent standard sleeve lobectomy. His preoperative FVC was 3,190 ml (99.7% of of the predicted value) and a recent test showed a value of 2,900 ml (88.2% of the predicted value). Thus, there was no significant change. The preoperative and postoperative $FEV_{1.0}$ values were 2,060 ml and 2,050 ml, respectively, also showing no significant change. Fig. 6 shows his pulmonary scans taken 21 months after the operation ; perfusion scan shows small perfusion defects in the right lung and ventilation scan shows slightly decreased washout in the right lung. He remains alive and well 49 months after the surgery.

Fig. 7 compares preoperative and postoperative chest films (taken 12 months after the operation) from a 76-year-old man (case 8) who underwent sleeve left lingual segmentectomy. The loss of volume in the left lung was minimal owing to the use of a parenchymal-sparing procedure. Pulmonary function tests showed a 420 ml reduction in FVC, which corresponded well with that noted following right middle sleeve lobectomy in case 6. $FEV_{1.0}$ value showed no marked changes. Fig. 8 shows pulmonary scans obtained 4 months after the operation. Although the perfusion scans show slightly decreased pulmonary blood flow at the

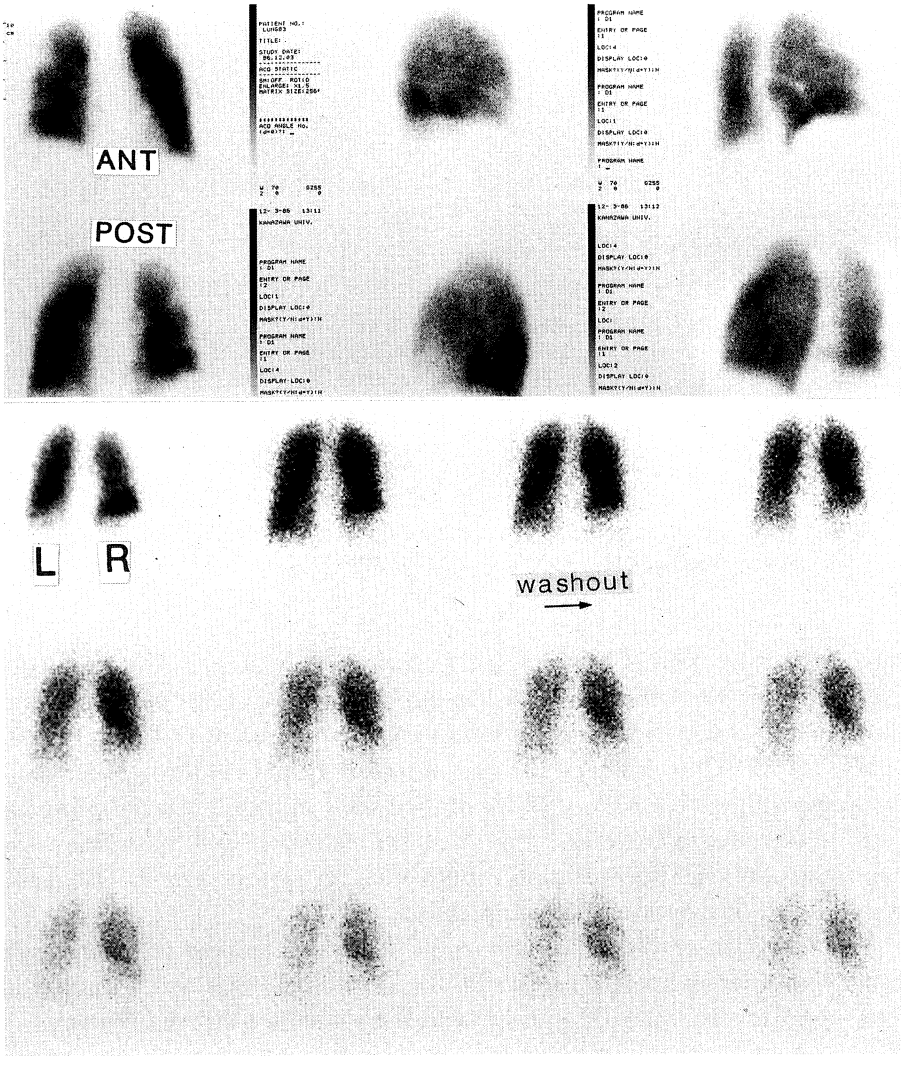

Fig. 6. Postoperative perfusion (upper) and ventilation (lower) scans (21 months after surgery) for the same patient as shown in Fig. 5.

left lung due to lingulectomy, ventilation scans show almost normal appearance at the left lung. He remains alive and well 13 months after the operation.

Second carinal resection without lung resection

Fig. 9 compares preoperative and postoperative (50 months after surgery) chest films from a 61-year-old man (case 9) who underwent left second carinal resection without lung resection. A lesion of about 5 mm in diameter that occupied the spur at the junction of the left upper and lower bronchi was successufully removed by second carinal resection without any resection of lung

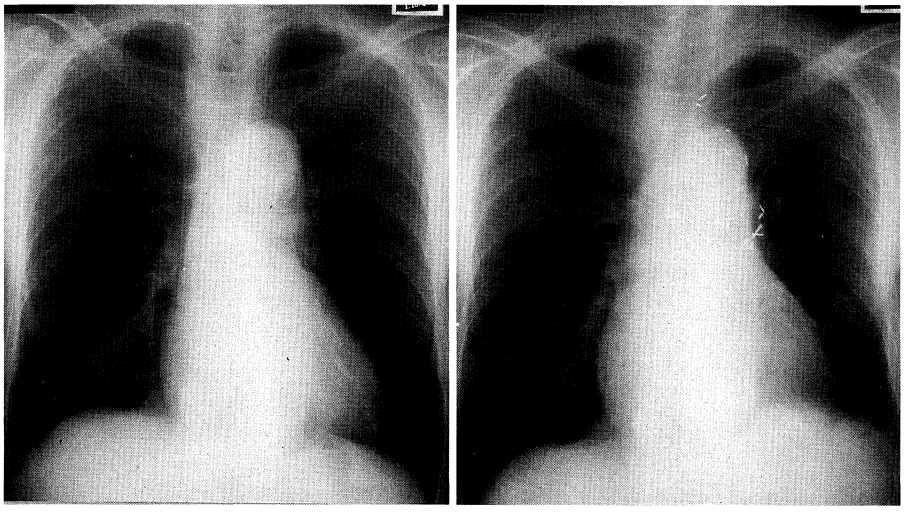

Fig. 7. Preoperative and postoperative (12 months after sleeve segmentectomy of the left lingula) chest x-ray films of a 74-year-old man.

tissue. Reconstruction of the airway was performed by a double-barrelled anastomosis between the left main bronchus and the stumps of the upper and lower lobe bronchi. Pulmonary function tests showed reduction of FVC from 3,340 ml (110.3% of %FVC) to 3,090 ml (98.7%), a loss of 330 ml (11.6%). His preoperative and postoperative $FEV_{1.0}$ values did not show apparent change, being 2,460 ml and 2,450 ml, respectively. Fig. 10 shows perfusion and ventilation scans taken 26 months after the operation. Both scans are almost normal. He remains alive and well 55 months after the operation.

The reduction of vital capacity in the 4 patients (cases 6 to 9) undergoing parenchymal-sparing operations was 353.3 ± 53.1 ml, and this was a significantly smaller decrease than at in the group treated by standard sleeve lobectomy.

Discussion

As an alternative to pneumonectomy, sleeve lobectomy is increasingly being used with safety (Watanabe et al. 1990). As early hilar lung cancer is a potentially curable disease and can be definitively diagnosed by preoperative bronchoscopic examination, pulmonary parenchymal-sparing surgery using bronchoplastic procedures is the operation of choice if it is feasible. All early hilar lung cancers are resectable by standard lobectomy or by sleeve lobectomy. In fact, we treated all of the patients in the earlier half of the present series by sleeve lobectomy or standard lobectomy, and all of these patients survived for more than five years. However, in the recent half of this series, we encountered some cases of early hilar cancer that were tiny and very localized. In such patients, we thought that more lung tissue could be saved without impairing the operative radicality. Although

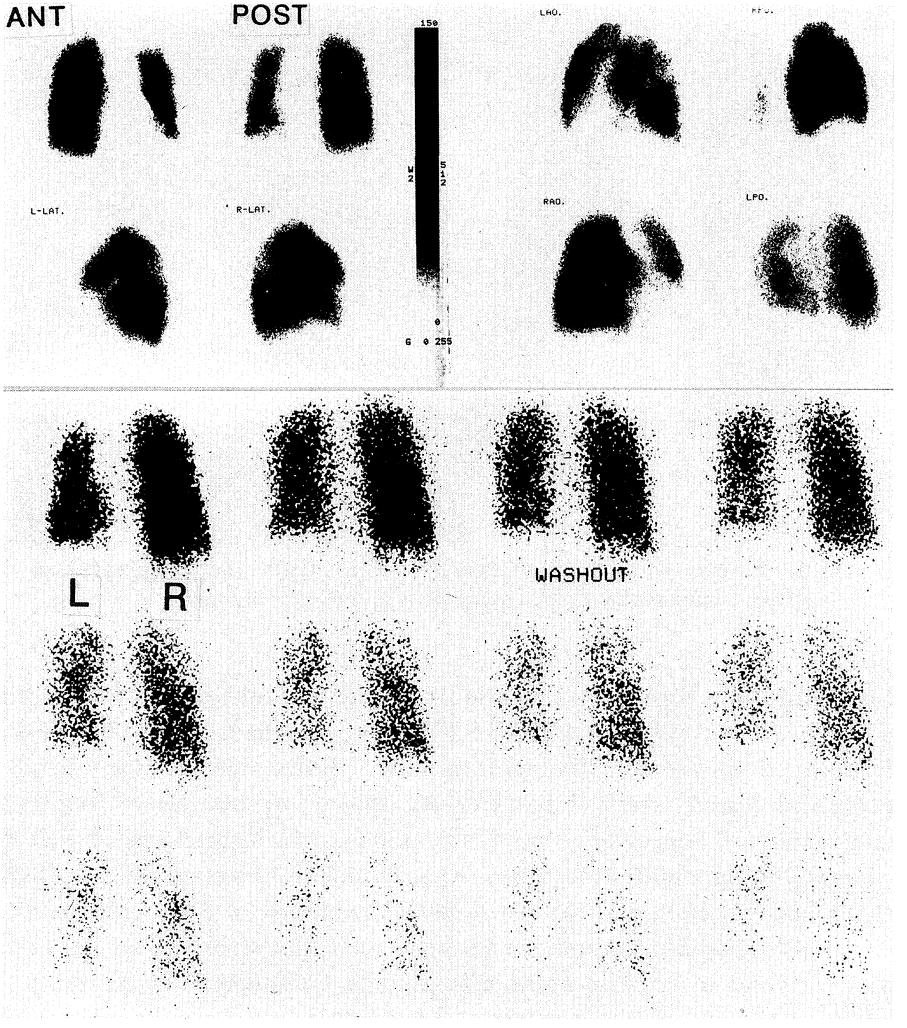

Fig. 8. Postoperative perfusion (upper) and ventilation (lower) scans (4 months after the operation) for the same patient as shown in Fig. 7.

such surgery is only applicable to a few patients, we attempted parenchymal-sparing operations for a selected group. The procedures which were applied in the present series were middle sleeve lobectomy, sleeve segmentectomy, and second carinal resection. Parenchymal-sparing surgery had a favorable effect on pulmonary function, as verified by both conventional pulmonary function tests and regional pulmonary function study.

If a lesion occupies the orifice of the middle lobe, as in case 6, the tumor can be completely removed by bilobectomy of the middle and lower lobes. However, a bilobectomy procedure will reduce the FVC by about 900 ml (the data was collected from our patients undergoing standard lobectomy for lung cancer with

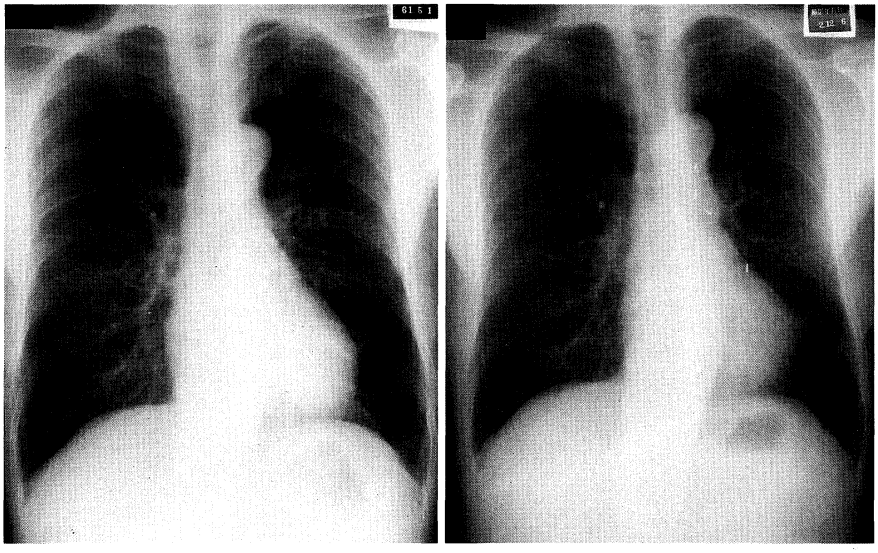

Fig. 9. Preoperative and postoperative (50 months after second carinal resection without lung resection) chest x-ray films of a 62-year-old man.

T1N0M0 disease). Since sleeve middle lobectomy was performed for case 6, there was a reduction of only 410 ml in the FVC, i.e., less than half of the presumed volume loss if bilobectomy were to be applied. Sleeve segmentectomy removing one segment (case 7) reduced the FVC by 290 ml, whereas sleeve lingual segmentectomy (two segments) reduced it by 420 ml, which corresponded well with the loss following middle lobectomy. Case 9 underwent second carinal resection without lung resection and showed a 420 ml reduction of FVC. Although his postoperative chest film and pulmonary scans were almost normal, the loss of vital capacity similar to the loss noted after middle lobectomy. There was no air trapping at the bronchial anastomosis and repeated bronchoscopic examinations found no strictures or obstruction of the bronchus in the residual lung. Accordingly, this reduction of FVC was thought to be caused by restrictive impairment of pulmonary function due to adhesion in the left thoracic cavity produced by the meticulous operative procedure used for reconstructing the airway.

Overall, the loss of FVC in the group undergoing parenchymal-sparing operations was significantly less in comparison with that in the standard sleeve lobectomy group. Chest x-ray films and regional pulmonary scans also showed a favorable result. There are few reports on the postoperative lung function after sleeve lobectomy (Deslauriers et al. 1986; Brusasco et al. 1988), and no previous studies have assessed the effect restricted resection for hilar lung cancer. It can be concluded from the present study that parenchymal-sparing operations have some advantages over sleeve lobectomy. Such operations may not be the standard procedure for most patients with lung cancer. However, as all of the 4

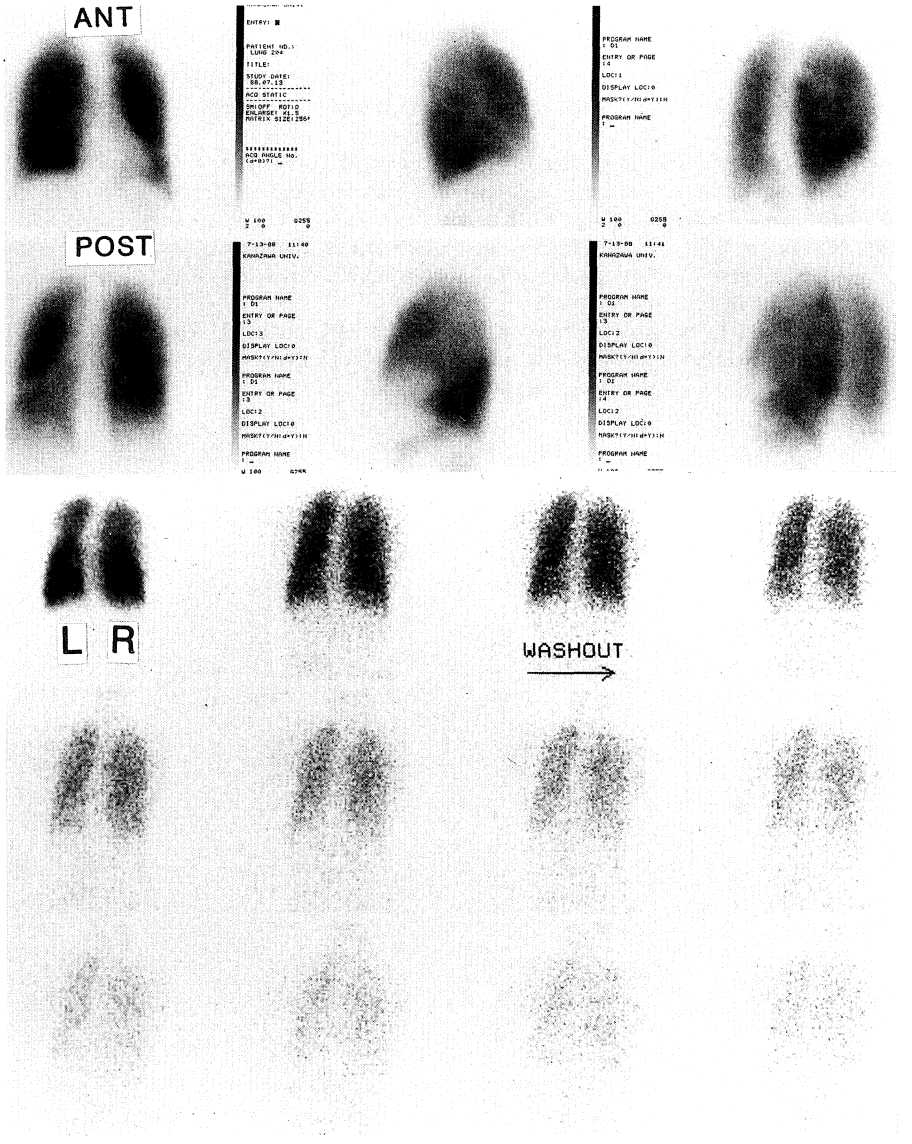

Fig. 10. Postoperative perfusion (upper) and ventilation (lower) scans (26 months after surgery) for the same patient as shown in Fig. 9.

patients in our series have survived long-term without any sign of recurrence, these bronchoplastic procedures appear to be applicable to some cases of very tiny and localized early hilar lung cancer.

References

1) Brusasco,V., Ratto, G.B., Crimi, P., Sacco, A. & Motta, G. (1988) Lung function following upper sleeve lobectomy for bronchogenic carcinoma. *Scand. J. Thorac. Cardiovasc. Surg.*, **22**, 73-78.
2) Deslauriers, J., Gaulin, P., Beaulieu, M., Piraux, M., Bernier, R. & Cormier, Y. (1986) Long-term clinical and functional results of sleeve lobectomy for primary lung cancer. *J. Thorac. Cardiovasc. Surg.*, **92**, 871-879.
3) Watanabe, Y., Kobayashi, H., Murakami, S., Sawa, S., Shinagawa, M. & Iwa, T. (1986) Bilateral sleeve lobectomy for metachronous multiple primary lung cancer. *Jpn. J. Surg.*, **16**, 56-61.
4) Watanabe, Y., Shimizu, J., Oda, M., Hayashi, Y., Watanabe, S., Yazaki, U. & Iwa, T. (1990) Results in 104 patients undergoing bronchoplastic procedures for bronchial lesions. *Ann. Thorac. Surg.*, **50**, 607-614.