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Lung perfusion SPECT in predicting postoperative pulmonary function in lung cancer

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The aim of this prospective study is to evaluate the availability of preoperative perfusion SPECT in predicting postoperative pulmonary function following resection. Twenty-three patients with lung cancer who were candidates for lobectomy were investigated preoperatively with spirometry, x-ray computed tomography and ^{99m}Tc macroaggregated albumin SPECT. Their postoperative pulmonary functions were predicted with these examinations. The forced vital capacity and the forced expiratory volume in one second were selected as parameters for overall pulmonary function. The postoperative pulmonary function was predicted by the following formula: Predicted postoperative value=observed preoperative value × precent perfusion of the lung not to be resected. The patients were reinvestigated with spirometry at 3 months and 6 months after lobectomy, and the values obtained were statistically compared with the predicted values. Close relationships were found between predicted and observed forced vital capacity ($r=0.87$, $p<0.001$), and predicted and observed forced expiratory volume in one second ($r=0.90$, $p<0.001$). The accurate prediction of pulmonary function after lobectomy could be achieved by means of lung perfusion SPECT.

Key words: lung perfusion, SPECT, prediction, pulmonary function, lung cancer

INTRODUCTION

SURGICAL RESECTION is generally accepted as the most effective therapy for patients with lung cancer. Unfortunately, many patients with lung cancer often suffer from chronic obstructive pulmonary diseases. It is difficult to decide whether operation for such patients is indicated or not, because of the lack of a reserve of pulmonary function, which is a major factor in determining postoperative morbidity and mortality.[1]

Preoperative evaluation of pulmonary function is necessary to identify patients who are at risk due to postoperative pulmonary complications. Accurate prediction of pulmonary function after operation based on preoperative evaluation is clinically desirable. During the last two decades, studies of ventilation and/or perfusion lung scans with radionuclide have been used for preoperative evaluation of thoracic surgical patients.[1-8] Predictions of postoperative pulmonary function have been based on planar scintigraphy, which reflects only the radioactivity of a relatively superficial portion of the lung.

The present study was designed prospectively to evaluate the accuracy and usefulness of perfusion SPECT imaging with ^{99m}Tc macroaggregated albumin (MAA) for the prediction of postoperative pulmonary function.

MATERIALS AND METHODS

Twenty three patients (15 men and 8 women, mean age 67 years) with lung cancer who were candidates for lobectomy were studied prospectively. Age, sex, histological diagnosis and resected lobes of the patients are summarized in the Table 1.

Preoperative studies of pulmonary function by means of spirometry were performed with the patients

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in the standing position within two weeks prior to lobectomy, and forced vital capacity (FVC) and forced expiratory volume in one second ($FEV_{1.0}$) were selected as parameters for overall pulmonary function.[5-7]

The regional distribution of the lung perfusion was investigated preoperatively by ^{99m}Tc MAA SPECT imaging. All patients were placed in the supine position and intravenously administered ^{99m}Tc MAA 185 MBq. SPECT images were acquired with a dual-head rotating wide-angle scintillation camera (ZLC/75, Siemens) with a medium-energy collimator, linked to a computer (Scintipac 2400, Shimadzu). To obtain SPECT images, the detector was rotated in 5 degree steps over 360 degrees with the patient in the supine position and arms raised above the head. These data were acquired as 64×64 digital images for 10 seconds for each. Transverse sections, with a thickness of one pixel (0.6 cm) were first obtained by the filtered back projection technique. Butterworth and Wiener filters were used to provide adequate noise suppression.

The regions of the lung that were expected to remain after lobectomy were determined on the SPECT images by visual comparison with the thin-slice x-ray computed tomographic (CT) images. CT scans were performed on a TCT-900S scanner (Toshiba), with 0.6-cm-thick sections obtained at 0.6-cm intervals. The resection line was decided on consecutive CT images visually, and the lines were transferred to the corresponding SPECT images. On the SPECT images, the lung that was expected to remain after lobectomy was drawn as the region of interest (ROI) to obtain the activity of the radionuclide.

The predicted postoperative FVC and $FEV_{1.0}$ were calculated by the following formula:

Predicted postoperative value = observed preoperative value $\times$ activity of the lung that is expected to remain after lobectomy/activity of the whole lung.

For example, if the observed preoperative FVC (or $FEV_{1.0}$) is 2.0L and the activity of the lung that is expected to remain after lobectomy is 80% of the activity of the whole lung, the predicted postoperative FVC (or $FEV_{1.0}$) is 1.6L ($2.0 \times 0.8 = 1.6$L).

The patients were reinvestigated with spirometry at 3 months and 6 months after lobectomy, and the values obtained were statistically compared with the predicted values.

All data are expressed as the mean $\pm$ the standard deviation. The level of significance among individual data was calculated by unpaired Student's t-test. Correlation coefficients were calculated by linear regression analysis. A value of $p<0.05$ was considered to be significant.

Table 1 Clinical characteristic of the patients

No.	Age	Sex	Histology	TNM*	Stage	Lobectomy
1	58	M	SCC	$T_1N_0M_0$	I	rt-L
2	70	M	SCC	$T_1N_0M_0$	I	lt-U
3	64	F	Adeno	$T_1N_0M_0$	I	lt-U
4	47	M	SCC	$T_1N_0M_0$	I	rt-L
5	56	M	SmCC	$T_2N_0M_0$	I	lt-L
6	63	M	LCC	$T_1N_0M_0$	I	rt-U
7	63	M	Adeno	$T_1N_0M_0$	I	rt-ML
8	65	M	Adeno	$T_2N_0M_0$	I	rt-L
9	65	M	SCC	$T_3N_0M_0$	IIIA	rt-M
10	67	M	Adeno	$T_1N_2M_0$	IIIA	rt-U
11	51	M	Adeno	$T_2N_2M_0$	IIIA	lt-UL
12	59	F	Met			lt-L
13	54	F	Adeno	$T_1N_0M_0$	I	rt-M
14	71	F	Adeno-SCC	$T_2N_0M_0$	I	rt-U
15	54	F	SmCC	$TisN_0M_0$	0	rt-U
16	57	F	Adeno	$T_1N_0M_0$	I	rt-M
17	64	M	SCC	$T_3N_0M_0$	IIIA	rt-L
18	74	M	SCC	$T_3N_0M_0$	IIIA	rt-L
19	69	M	SCC	$T_1N_0M_0$	I	rt-U
20	61	F	Adeno	$T_1N_0M_0$	I	lt-U
21	68	F	Adeno	$T_1N_0M_0$	I	lt-U
22	50	M	Adeno	$T_1N_2M_0$	IIIA	lt-U
23	68	M	Adeno	$T_1N_0M_0$	I	rt-ML

M=male, F=female, SCC=squamous cell carcinoma, Adeno=adenocarcinoma, SmCC=small cell carcinoma, LCC=large cell carcinoma, Met=metastatic carcinoma, rt=right, lt=left, U=upper lobectomy, M=middle lobectomy, L=lower lobectomy. *UICC Classification 1987

RESULTS

The predicted and observed postoperative pulmonary functions were well correlated. The correlation coefficients between the predicted and the observed postoperative FVC were 0.83 ($p<0.001$) and 0.87 ($p<0.001$) at 3 and 6 months after lobectomy, respectively (Fig. 1). The correlation coefficients between the predicted and the observed postoperative $FEV_{1.0}$ were 0.90 ($p<0.001$) and 0.91 ($p<0.001$) at 3 and 6 months after lobectomy, respectively (Fig. 2).

We calculated the ratios of the predicted postoperative values to the observed postoperative values to evaluate whether there were any differences in the period after lobectomy. These ratios are shown in Figures 3 and 4. Here a ratio of 1.0 showed that the predicted postoperative values were exactly equal to the observed postoperative values. Mean ratios

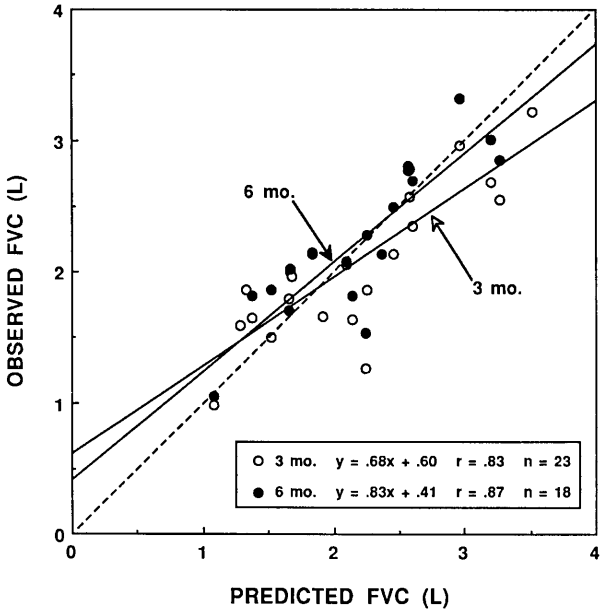

Fig. 1 Correlation between predicted forced vital capacity (FVC) and observed FVC. Broken line=line of identity.

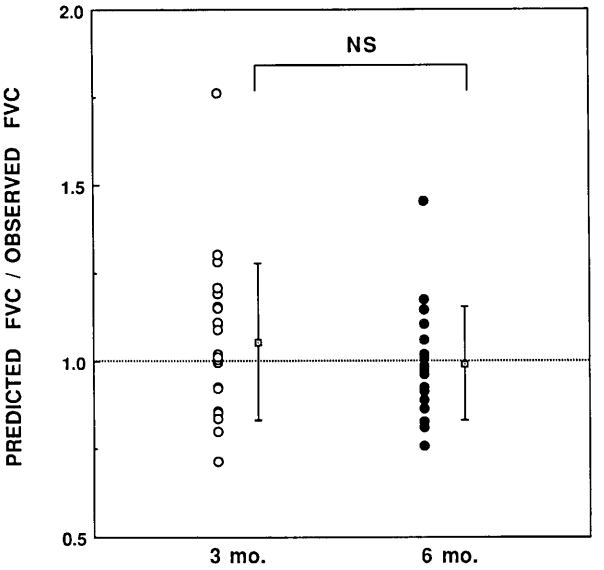

Fig. 3 Comparison of the mean ratios of predicted FVC/observed FVC, for at 3 and 6 months after lobectomy. NS=not significant.

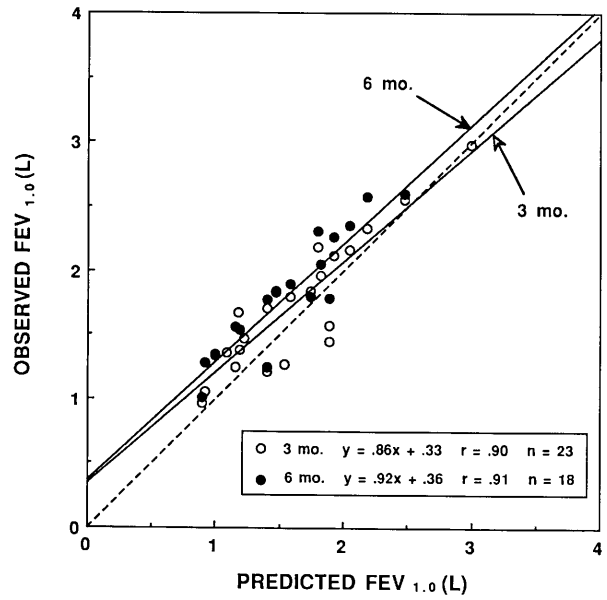

Fig. 2 Correlation between predicted forced expiratory volume in one second ($FEV_{1.0}$) and observed $FEV_{1.0}$. Broken line=line of identity.

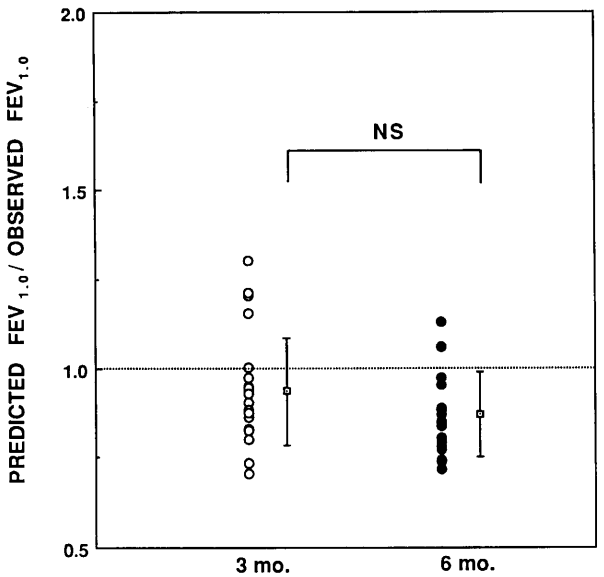

Fig. 4 Comparison of the mean ratios of predicted $FEV_{1.0}$/observed $FEV_{1.0}$, for at 3 and 6 months after lobectomy. NS=not significant.

at 6 months after lobectomy were smaller than at 3 months, and standard deviations were also smaller, but there was no statistical significance between the figures for 3 and 6 months after lobectomy.

DISCUSSION

This preliminary study showed that preoperative lung perfusion SPECT could accurately predict postoperative pulmonary function in patients with lung cancer undergoing lobectomy. The simple quantitative perfusion scan seems to be an acceptable method for predicting postoperative function.[4]

In previous studies, the predictions of postoperative pulmonary function were performed by planar scintigraphy, and some reports introduced the number of anatomical segments to be resected[4–6] because the relative functional performance of the lobe to be resected is difficult to isolate by external counting techniques.[5] There are two problems in the procedure. First, planar scintigraphy reflects only the radioactivity of a relatively superficial portion of the lung. Second, the number of segments is not proportional to the volume of the regions that must be resected, because there might be some changes in lung size resulting from atelectasis and compensatory hyperinflation and so on.[5] Therefore, a combination of planar scintigraphy and the number of anatomical segments to be resected is not suitable for the accurate prediction of postoperative pulmonary function.

The recent development of SPECT has enabled us to predict postoperative pulmonary function accurately and reliably. SPECT images express exactly not only the superficial part, but also the state of perfusion in the deep part, and can depict the defect more clearly than the planar images.[9] On the assumption that pulmonary function loss is directly proportional to perfusion loss, we proposed the formula. Better prediction could be achieved than in previous studies in terms of correlation coefficients.[2–4,8]

The postoperative pulmonary function observed was more improved at 6 months than at 3 months after lobectomy. Soon after lobectomy, pulmonary function was impaired by some factors such as muscle weakness, scar pain, decrease in compliance, atelectasis or pleural effusion. We had expected better correlation between the predicted and the observed postoperative values at 6 months than at 3 months after lobectomy. Although standard deviations were smaller at 6 months than at 3 months after lobectomy, no statistical significance was seen. Prediction might be possible 3 months following resection.

CONCLUSION

It is concluded that pulmonary function after lobectomy can be accurately predicted with ^{99m}Tc MAA SPECT, and that prediction might be possible 3 months after lobectomy. This technique is advantageous in that it is readily available in most hospitals and is simple and noninvasive, and does not require specialized personnel.[7]

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