Case Report

The UPAO Test in Preoperative Evaluation for Major Pulmonary Resection: An Operative Case with Markedly Improved Ventilatory Function after Radical Pulmonary Resection for Lung Cancer Associated with Pulmonary Emphysema

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A 65-year-old man was admitted to our hospital for treatment of a squamous cell carcinoma in his right lung. Respiratory function testing showed an extremely reduced forced expiratory volume in 1 second (FEV1) of 1.0 l (29.9% of predicted), and a reduced FEV1/FVC ratio of 24.1%. Arterial blood gases on room air showed a pH of 7.41, a $PaCO_2$ of 36.7 mmHg, and a PaO_2 of 79.3 mmHg. To assess the predictive postoperative cardiopulmonary function, unilateral pulmonary artery occlusion (UPAO) testing was performed. In the condition of right main PA occlusion, the mean pulmonary artery pressure (mPAP), cardiac index (CI) and total pulmonary vessel resistance index (TPVRI) was 18 mmHg, 3.2 l/min/m^2 and 443.37 dyne.sec.cm^{-5}/m^2, respectively. He underwent a middle lobectomy with combined partial resection of both the upper and lower lobes. He also underwent simultaneous resection of a giant bulla arising from the right upper lobe as lung volume reduction surgery. At 80 days after the operation, his FEV1 rose to 1.88 l, and the PaO_2 on room air was improved to 88.9 mmHg. UPAO testing was suggested to be more useful than routine pulmonary function test to determine the accurate predictive postoperative cardiopulmonary function and to decide indication for a radical operation. (Ann Thorac Cardiovasc Surg 2002; 8: 154–9)

Key words: lung cancer, pulmonary emphysema, lung volume reduction surgery, unilateral pulmonary artery occlusion test

Introduction

Pulmonary emphysema is frequently associated with lung cancer and, because of the impaired pulmonary function involved, it may contraindicate radical pulmonary resection. On the other hand, recently, improvement in pulmonary function has been reported after a combined operation in such cases.[1-3)]

Here we report a case of squamous cell carcinoma associated with severe pulmonary emphysema that achieved improved ventilatory function after radical pulmonary resection combined with lung volume reduction surgery.

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Case Report

A 65-year-old man was admitted to Kurume University Hospital for treatment of a tumor in his right lung in January 2000. He had been previously diagnosed as having pulmonary emphysema, and was treated using a bronchodilator. Routine chest radiographs had been taken at least once a year at the previous clinic, and a tumor-like lesion in the right lung was noted on a chest radiograph, in December 1999.

On physical examination, he was 164.4 cm tall and weighed 57 kg. His blood pressure was 112/58, with a pulse rate of 72 bpm, and a respiratory rate of 18/min. The Fletcher respiratory grade was grade 2. His smoking

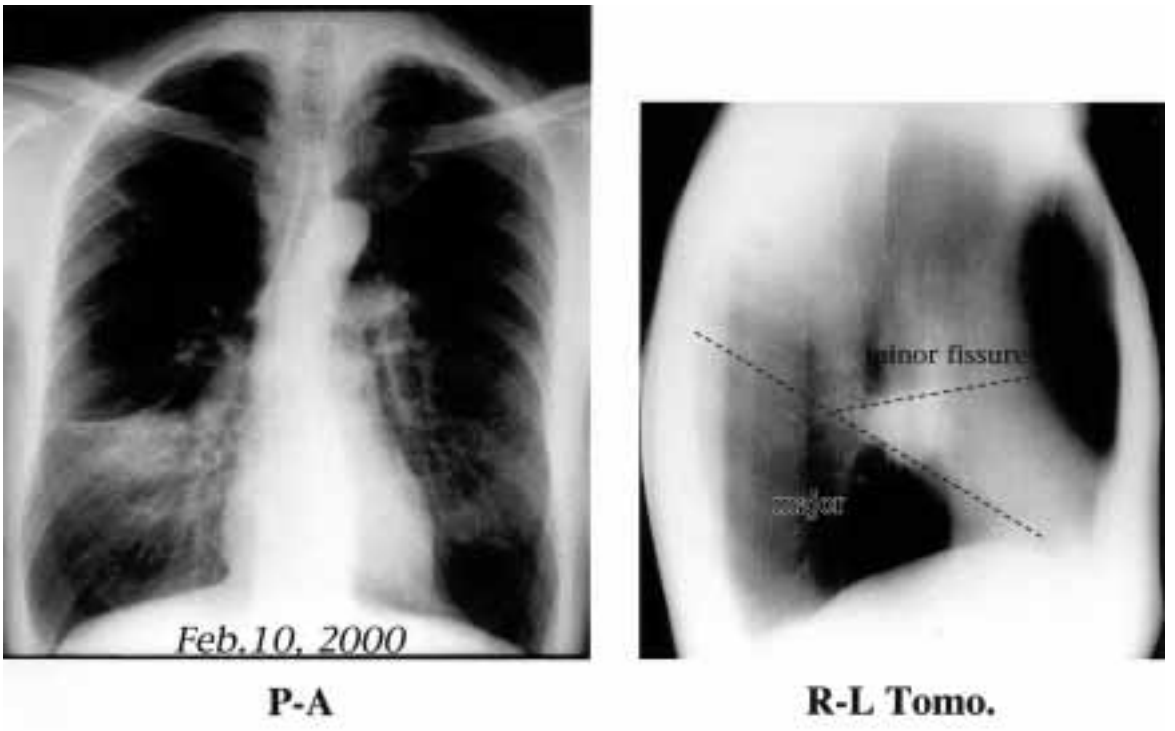

Fig. 1. Left: Preoperative plain chest X-ray showed a mass lesion in the middle-lower area of the right lung and bilateral over-inflated lungs. Right: Conventional lateral tomogram showed that the tumor located in the middle of the right lung invaded to both the upper and the lower lobes.

history was 45 packs per year.

On admission, a chest examination revealed marked reduction in breathing sounds in the right upper chest and fine crackles in the bilateral lower chest. The cardiac examinations were normal. Hematological examination and blood chemistry including tumor markers (CEA, SCC, CYFRA, NSE) were almost within normal limits.

Respiratory function testing showed an extremely reduced forced expiratory volume in 1 second (FEV1) of 1.0 l (29.9% of predicted), a reduced FEV1/FVC ratio of 24.1%, a vital capacity (VC) of 4.36 l (130% of predicted), diffusing capacity (DLCO) of 99% of predicted. Arterial blood gases on room air showed a pH of 7.41, a PCO_2 of 36.7 mmHg, and a PO_2 of 79.3 mmHg. The chest radiograph on admission showed over-inflation in the bilateral lungs with absence of the dome formation of the diaphragm, and especially revealed hyper-translucency in the right upper lobe with marked reduction in lung markings (Fig. 1). Also the chest radiograph revealed a lesion, 5.0×4.0 cm in size, located in the middle-lower area of the right lung. A chest computed tomographic (CT) scan revealed bilateral heterogeneous centrilobular type pulmonary emphysema with a giant bulla in the right upper lobe (Fig. 2). The tumor was located in the right middle lobe adjacent to the upper and lower lobes. This finding suggested direct tumor invasion beyond the inter-lobar pleura to both the upper and lower lobes. Other pulmonary nodules, infiltrates, pleural effusion and lymph node enlargement were all absent. Preoperative perfusion scintigrams revealed a distinct defect of the right upper lobe (Fig. 3). Trans-flexible bronchofiberscopic tumor biopsy confirmed a squamous cell carcinoma. There was no evidence of distant metastasis, and this case was diagnosed as clinical-T3N0M0, stage IIB.

To assess the predictive postoperative cardiopulmonary function, unilateral (right-sided) pulmonary artery occlusion (UPAO) testing using a thermodilution catheter with a balloon (Model 93A-841, 7.5 Fr, Baxter Healthcare. Irvine, CA) was performed. The results of UPAO testing are shown in Table 1. In the condition of right main PA occlusion, the mean pulmonary artery pressure (mPAP), cardiac index (CI) and total pulmonary vessel resistance index (TPVRI) was 18 mmHg, 3.2 l/min/m^2, and 443.37 dyne.sec.cm^{-5}/m^2, respectively. From these data, and from evaluation of the radiological findings, we decided to perform radical pulmonary resection in this case.

On February 16, 2000, he underwent the operation. Right thoracotomy was performed through the 4th inter-

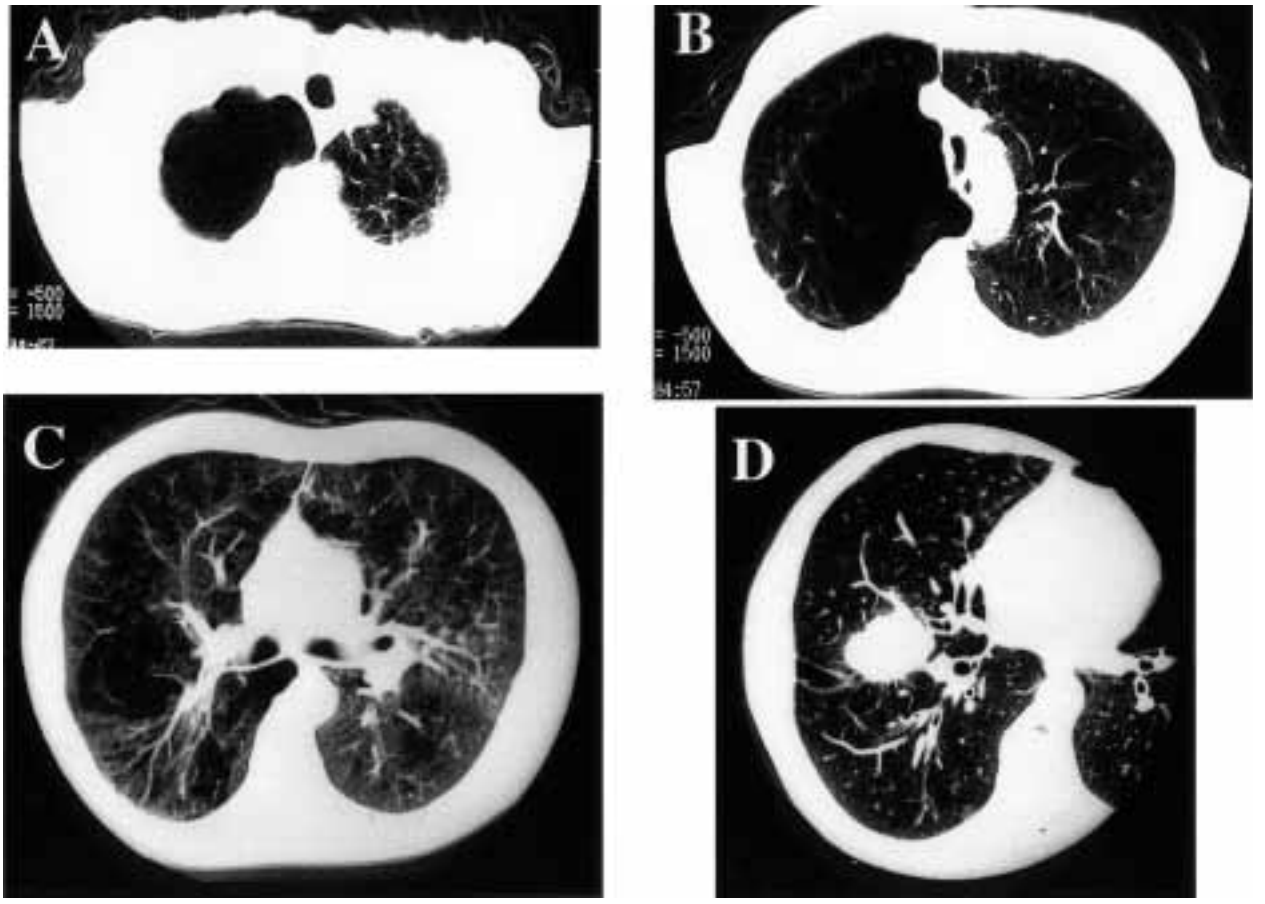

Fig. 2. Preoperative chest CT (A, B, C) showed bilateral heterogeneous severe pulmonary emphysema with a giant bulla in the right upper lobe and revealed a tumor lesion in the right middle lobe (D).

Table 1. Results of preoperative UPAO test

	BP (mmHg)	HR (/min)	PaO_2 (Torr)	PAP (mmHg) (mean)	CO (l/min) (CI) (CO/m^2)	TPVRI
At rest	118/62	78	79.3	15/8 (10)	4.84 (3.1)	262.3
During occlusion	104/60	77	65.7	29/15 (18)	5.16 (3.2)	443.4

Hemodynamic findings at rest (non PA occlusion) and during right pulmonary artery occlusion
BP: blood pressure, HR: heart rate, PAP: pulmonary artery pressure, CO: cardiac output, CI: cardiac output index,
TPVRI: total pulmonary vessel pressure
At rest: in the condition of before right PA occlusion
During occlusion: in the condition at 15 min after right PA occlusion

costal space, S2 and S3 of the right upper lobe were found to be compressed by a bulky emphysematous bulla arising from S1. First, lung volume reduction surgery was carried out to resect the giant bulla using a linear cutter and stapler, reinforcing the staple line with Goretex® sleeves (Gore Inc., AZ). Subsequently, a middle lobectomy with combined partial resection of both the upper and lower lobes using a linear cutter and stapler were performed in the same way to remove the invading tumor. Hilar and mediastinal lymph node dissection were performed. A sealing test revealed no air leak from pulmonary parenchyma on the staple line.

On the 3rd postoperative day, he suffered from pneumonia with atelectasis in the residual right lower lobe. He was administered antibiotics and treated with endobronchial suction secretion with bronchial toiletting using a fiberoptic bronchoscope, and he recovered by the 7th postoperative day.

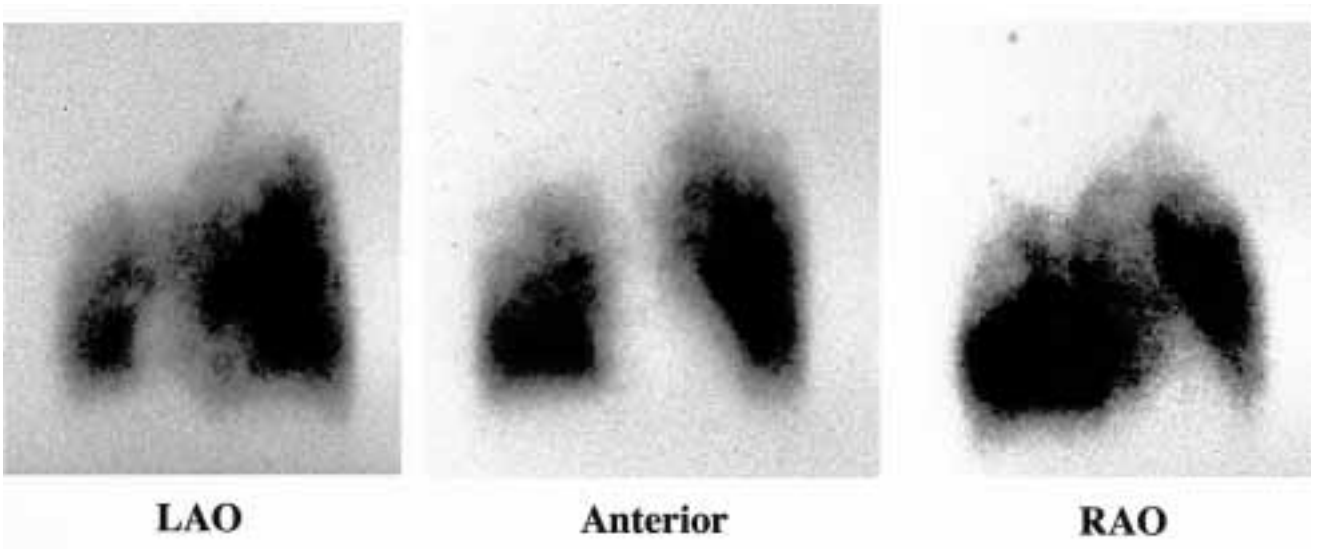

Fig. 3. Preoperative perfusion scintigrams showed a distinct defect of the right upper lobe. Right: RAO, middle: anterior, left: LAO.

Table 2. Changes in respiratory function and BGA

		Postoperative day				
Parameter	Preoperative	20th	30th	80th	200th	300th
VC (l)	4.36	2.72	2.76	3.29	3.52	3.63
FEV1 (l)	1.0	1.46	1.64	1.88	1.74	1.75
PaO_2* (Torr)	82	–	84.2	88.9	–	89.7
$PaCO_2$* (Torr)	37	–	35.6	39.1	–	34.4

Comparison of respiratory function and arterial blood gas analysis between preoperative data and postoperative data
*Arterial blood gas analysis on room air breathing

On the 30th postoperative day, FEV1 was improved to 1.46 l. On the 80th postoperative day, the FEV1 was 1.88 l (88% improvement), and the PaO_2 of arterial blood gases on room air was 88.9 mmHg (Table 2).

Postoperative radiological findings revealed volume reduction of the right lung with dome formation of the right diaphragm and bilateral bullous lung (Fig. 4).

At 10 months postoperatively, he presented with a good general condition with no shortness of breath, and no evidence of tumor recurrence.

Discussion

Cigarette smoking is the major cause of lung cancer and of pulmonary emphysema. Also pulmonary emphysema is commonly associated with primary lung cancer in an elderly smoker.

Radical surgical resection by lobectomy or pneumonectomy with lymph node dissection has been widely recognized as the optimal therapy for patients with relatively early-staged non small cell lung cancer. However, radical lung resection is contraindicated for some lung cancer patients with severe pulmonary emphysema at risk of postoperative pulmonary insufficiency from a consequent compromised respiratory function.

In lung cancer cases, the extent of resection is determined preoperatively using both radiological (including chest CT scan) assessment and bronchofiberscopic findings. Furthermore, tolerability to radical lung resection is evaluated using the standard pulmonary function test.

Lung volume reduction surgery (LVRS) for patients with diffuse pulmonary emphysema was first reported by Brantigan et al. in 1957.[4] Recently, LVRS has been employed in the treatment of diffuse heterogeneous type emphysema with good results.[5]

Assessment of LVRS indication for emphysema patients is very complex. Standard preoperative studies which include an electrocardiogram, routine blood examination, routine chest radiography, chest CT scan and standard pulmonary function test are performed. More-

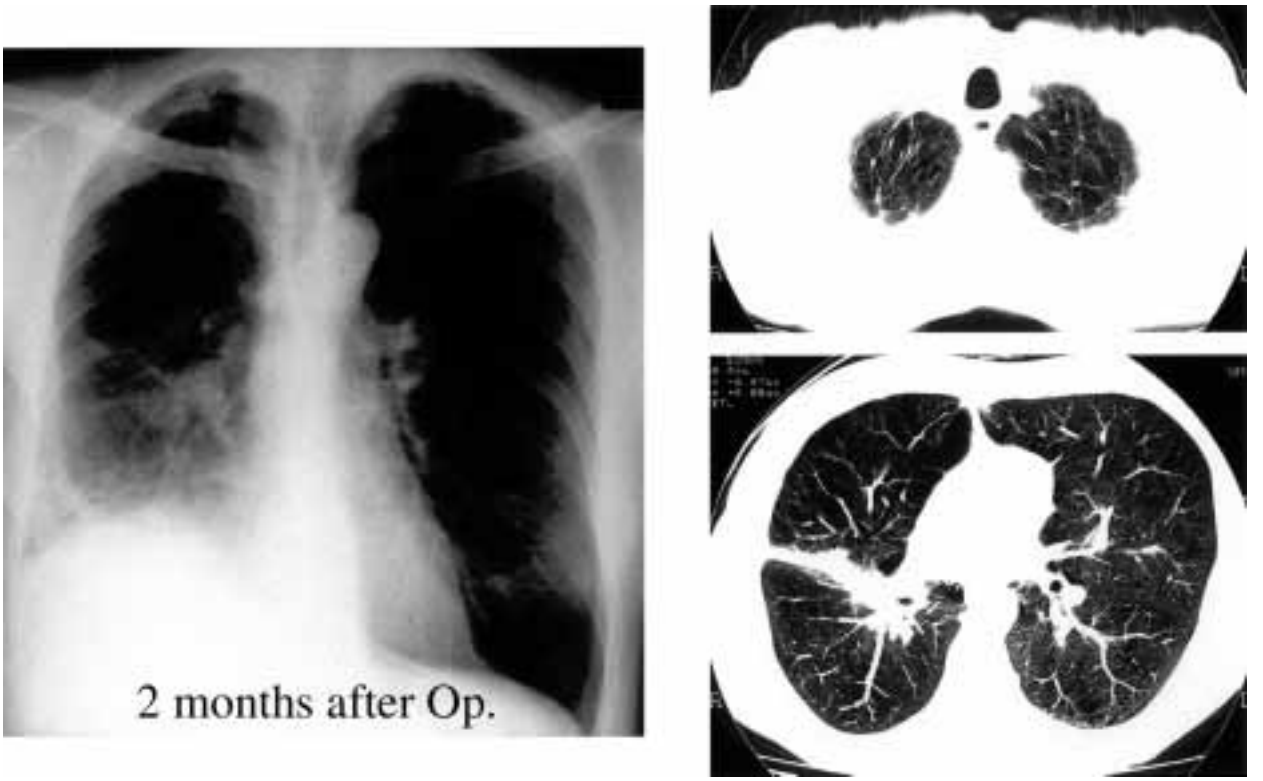

Fig. 4. Left: Postoperative plain chest X-ray showed volume reduction of the right lung with dome formation of the right diaphragm. Right: Chest CT showed removal of the right middle lobe with a tumor and a giant bulla of the right upper lobe.

over cardiopulmonary function studies including echocardiogram, exercise cardiopulmonary test and ventilation/perfusion scintigram are evaluated. And finally, the extent of the area of lung volume reduction is usually determined by means of findings from both chest CT scan and ventilation/perfusion scanning.

If the tumor is located within the same area of lung parenchyma that is targeted for LVRS, in a lung cancer case with emphysema, then simultaneous radical lung resection and LVRS might be indicated. However, if the tumor is not located in the same area of the lung parenchyma, then assessment of radical resectability for the lung cancer may be very complicated, and the optimal surgical treatment may be too difficult to determine.

DeMeester et al. reported five patients with lung cancer and severe emphysema who had undergone lobectomy and lung volume reduction surgery.[1] All those five patients did well postoperatively, and each patient demonstrated subjective and objective improvement in respiratory function. Maximal postoperative improvement in FEV1 averaged 43% in their five patients, with a range from 27 to 51%.

In the present case, the tumor was located in the middle lobe of the right lung with suspected direct tumor invasion of the adjacent upper and lower lobes. Chest CT scan revealed a bilateral heterogeneous centrilobular type pulmonary emphysema with a giant bulla in the right upper lobe. Therefore, LVRS alone was not indicated for emphysema in this case.

On the other hand, from preoperative evaluation of the resection volume for a curative lung cancer operation, the present case might be similar to a candidate for a right pneumonectomy, because it might be necessary for this patient to undergo middle lobectomy and further resection of the invaded lobes of the right lung.

Wahi et al. reported that the postpneumonectomy operative mortality rate was 7%, and patients having a right pneumonectomy had a higher operative mortality rate than patients having a left pneumonectomy.[6]

Postpneumonectomy pulmonary edema (PPE) is a rarely reported form of acute lung injury which occurs in up to 4% of all cases of pneumonectomy.[7] We have presumed that a restricted pulmonary capillary volume plays a critical role in the development of PPE. Furthermore, the presence of severe pulmonary hypertension may induce heart failure due to right ventricular overload.

Olsen et al. reported in 1975 that lung cancer with a predictive postoperative FEV1 (ppoFEV1) of less than

800 ml will not be resectable.[8] Subsequently, Wahi et al. and Miller have also suggested that the predictive postoperative FEV1 was an important predictor of operative risk.[6,9] They both reported that the morbidity and mortality rates were significantly higher when the ppoFEV1 was less than 40%.

On the other hand, Ferguson et al. and Bousamra et al. reported that the predictive postoperative diffusion capacity of lung (ppoDLCO) was the most valuable predictor of operative risk in the assessment for major lung resection.[10-12]

However, Cerfolio et al. reported that they were unable to identify any specific preoperative pulmonary function test as a predictor of postoperative morbidity.[13]

Therefore, we have routinely performed UPAO testing for a compromised pulmonary function patient (such as with severe emphysema), who may be a candidate for pneumonectomy, to evaluate the predictive postoperative cardiopulmonary function and to determine the resectability.

The UPAO test was first proposed by Carlens et al. in 1951, and also Sloan et al. reported UPAO as a useful preoperative assessment of pulmonary capacity before major lung resection.[14] Fee et al. advocated the value of pulmonary vascular resistance measurements in preoperative evaluation of candidates with borderline pulmonary reserve for pulmonary resection.[15]

Our criteria of the tolerance limit for lung resection have been TPVRI of less than 700 dyne.sec.cm^{-5}/m^2 with mPAP of less than 30 mmHg, using a UPAO testing measurement.

In the present case, the mPAP, CI, and TPVRI was 18 mmHg, 3.2 l/min/m^2, and 443.37 dyne.sec.cm^{-5}/m^2, respectively, in the condition of right main PA occlusion. This case suffered from pneumonia in the residual lower lobe of the right lung postoperatively. With respect to developing operative morbidity, preoperative UPAO testing is valuable for assessing the postoperative cardiopulmonary function and operative risk in such cases that have a compromised pulmonary function.

In summary, despite a significantly greater risk to operative mortality and morbidity, selected patients with a compromised pulmonary function can safely undergo major lung resection as a radical operation for lung cancer. There is no specific preoperative pulmonary function test as a predictor of resectability. The UPAO seemed to be the most valuable examination for assessing the accurate predictive postoperative cardiopulmonary function and for assessing operability.

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