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Prediction of postoperative pulmonary reserve in lung resection patients

R. Krishnakumar¹, K. Vijayalakshmi¹, G. K. Rangarajan¹, M. C. Vinodkumar¹,
A. Krishnamurthy²

¹ Department of Nuclear Medicine, Cancer Institute (WIA) Adyar, Chennai, Tamil Nadu, India

² Department of Surgical Oncology, Cancer Institute (WIA) Adyar, Chennai, Tamil Nadu, India

Author's address: R. Krishnakumar, Department of Nuclear Medicine, Cancer Institute (WIA), Adyar Chennai – 600 020, India, e-mail: krishmanju12@yahoo.com

Summary

We performed Ventilation/Perfusion scans for patients planned for thoracotomy with resection of the primary or metastatic lung tumors. We predicted the post-operative FEV₁ (Forced Expiratory Volume in first second) using Differential Lung Analysis software. Methods: 34 patients were evaluated with Ventilation/Perfusion (V/Q) scans. Ventilation scan was performed with Tc-99m DTPA Aerosol and Perfusion Scan with Tc99m MAA, on 2 different days. The numbers of counts in anterior and posterior views of V/Q scans were calculated individually. Anterior and posterior arithmetical mean was calculated and post-operative FEV₁ was predicted with the use of Differential Lung Analysis software. In most of the patients, the counts in the ventilation scan were lower and they were related to preoperative FEV₁. Depending on the volume of lung resection, i.e. Upper, Middle and Lower zones or Total Pneumonectomy, FEV₁ was calculated. Whenever FEV₁ was >0.8 (L), the patient was taken up for resection (and if there were no other risk factors, such as cardiac complications, chronic obstructive pulmonary diseases, and any other pathological conditions involving the contralateral lung). Results: Most of the 34 patients were taken up for lung resection based on our FEV₁ predictions. In 7 patients, repeat spirometry (i.e. pulmonary function test) was done at varying intervals after surgical procedures and the variation between preoperative FEV₁ and postoperative FEV₁ was only ±15%, at the most. Conclusion: Postoperative FEV₁ based on V/Q scan and pulmonary function tests helped us to proceed with lung resection after assessment of the pulmonary reserve.

Key words: ventilation • Tc-99m MAA • perfusion • Tc-99m DTPA • FEV₁

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Background

Patients with bronchogenic carcinoma frequently have impaired pulmonary function, usually secondary to chronic airway obstruction¹. If these patients are referred for possible curative surgery, they are at increased risk of developing postoperative complications and some have such a poor respiratory reserve that pneumonectomy may result in an unacceptable quality of life. Numerous techniques have been used to evaluate the post-surgical risk. These include pulmonary function tests, exercise tests, and quantitative ventilation-perfusion scintigraphy [1].

The use of quantitative lung perfusion scanning to help determine a patient's ability to undergo resection of lung has been demonstrated to be of use to surgeons [2].

Preoperative evaluation of lung function is one of the essential procedures for surgical and postoperative risk assessment because postoperative pulmonary complications remain high, with an incidence exceeding 10%. Postoperative pulmonary complications are more common and serious in patients who require resection of a malignant lung mass, because these patients are most often smokers and have underlying chronic lung disease [3].

Preoperative assessment of pulmonary function has been the subject of extensive study. In the animal model, partial resection of the lung induces active compensatory growth of the remaining lung tissue and may restore the total lung volume [4]. In humans, lung volume increases significantly during long-term follow-up after lung resection. Such an increase in the volume of the remaining lung tissue is a compensatory process [5]. However, the degree of postoperative increase in lung function depends on the nature and extent of the lung disease. If the lung or the lobe to be resected contributes a large portion of the overall function, with a major share of ventilation and perfusion distribution, then the pulmonary function will be greatly reduced after resection.

If the region to be resected has a similar distribution of ventilation and perfusion as does the rest of the lung, the postoperative reduction in lung function will be proportional to the volume of the resection. Pulmonary function will not be affected by the resection if the region to be removed has no significant function with regard to ventilation-perfusion distribution. Postoperative pulmonary function will be increased when the region to be resected contains a major impediment to the distribution of ventilation and perfusion.

The minimum pulmonary function that is sufficient for a patient to carry on a functional life is not well documented. Olsen et al. reported an FEV₁ of 0.8 liters as the minimum postoperative ventilation volume that can accommodate cardiac output without producing arterial hypoxemia or pulmonary hypertension. A postoperative FEV₁ volume of 0.8 liters has become a widely accepted parameter [4].

Predictive Measurements of Postoperative Lung Function

Clinical spirometry and arterial blood gas analysis were used until the 1960s for the preoperative assessment of pulmonary risk factors [6,7]. Regional lung function cannot be assessed, however, with spirometry or blood gas analysis. Therefore, differential bronchspirometry and temporary balloon occlusion of unilateral pulmonary artery were used to differentiate each lung capacity for ventilation or perfusion [7,8]. When radioactive tracers and convenient imaging instruments became available, those tests that were invasive or incapable of assessing regional function were replaced by simple and effective radioactive tracer techniques. The use of an image-processing computer and radioactive gas – xenon-133 or aerosol Tc-99m diethylene-triaminepentaacetic acid (DTPA) and the perfusion imaging agent Technetium 99m (99^mTc) albumin particles – allows accurate analysis of the regional distribution of ventilation and perfusion.

The regional pulmonary perfusion was measured by obtaining an intravenous injection of ¹³³Xe that was dissolved in saline solution. Regional ventilation was measured by obtaining regional activity counts after a single inhalation and holding the breath or a tidal breath wash-in of 133-xenon air mixture or by Tc-99m DTPA aerosol inhalation study. Xenon-133 is not available in our country and therefore we used DTPA (Board of Radio Isotope Technology, BRIT, India).

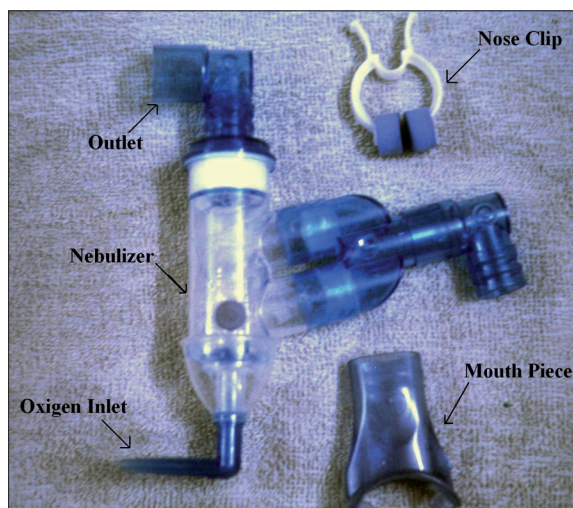


Figure 1. Aerosol Generator Kit.

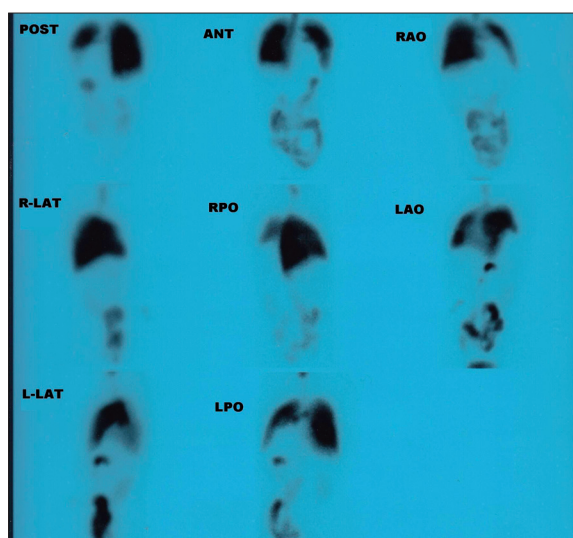


Figure 2. Tc-99m DTPA aerosol lung ventilation study – various views.

In the aerosol study with Tc-99m DTPA, the patient was instructed to breath in and breath out aerosol through mouthpiece, with oxygen being supplied at the rate of 5–6 liters per minute. The nebulizer produced particles of 0.5 micron diameter, which were then inhaled. Almost 40–50 mCi of Tc-99m DTPA was kept in the compartment of aerosol generator kit of the nebulizer (Figure 1). Moreover, the exhaled aerosol was let into fumehood so that there was no contamination in the room. Then, the patient was given a cup of water to drink so that any pharyngeal activity would be washed into the stomach. Next, the patient was instructed to lie in supine position on a special SPECT couch (being a part of gamma camera), with both hands away from the chest. Anterior and posterior planar images were acquired in 256×256 matrix for 800 kilo counts. The same procedure was repeated for right anterior oblique (RAO), right lateral (RL), right posterior oblique (RPO), left posterior oblique (LPO), left lateral (LL) and left anterior oblique (LAO) views (800 kilo counts each).

Tc-99m labeled macro-aggregated albumin (MAA) (Mallinckrodt, Netherlands) was used for perfusion

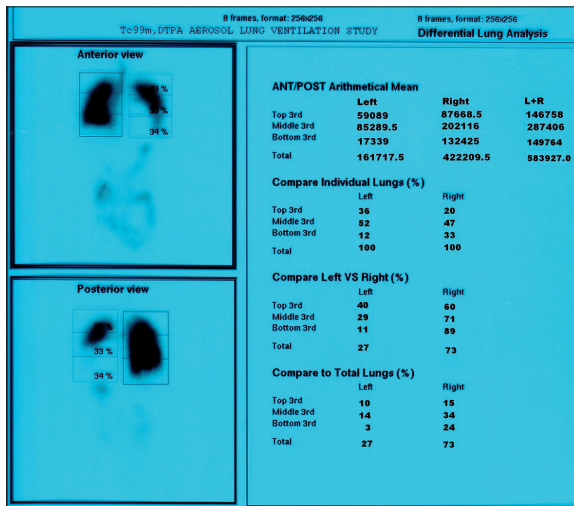


Figure 3. Tc-99m DTPA aerosol lung ventilation study – differential lung analysis.

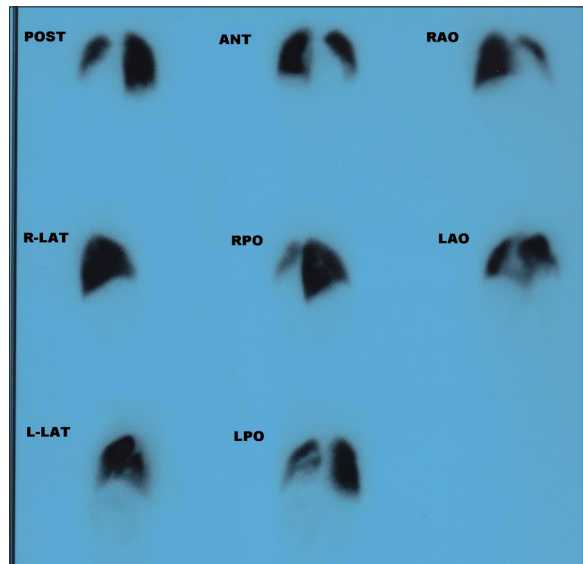


Figure 5. Tc-99m MAA lung perfusion study – differential analysis.



Figure 4. Tc-99m MAA lung perfusion study – various views.

scanning. Approximately 3 mCi of Tc-99m MAA were injected intravenously with the patient in a reclining position. The posterior image of lung perfusion was obtained by reaching 800 kilo counts using a large field-of-view gamma camera (Hitachi RC 1500 I) and an on-line computer. Eight views were acquired (256 x 256 matrix) as in the ventilation study – RAO, RL, RPO, LPO, LL, LAO views.

Analysis of Regional Lung Function

The anterior and posterior images of lung ventilation and perfusion were displayed on a computer monitor. Using the region-of-interest selection mode, the entire lung was divided into three regions of equal vertical height (Figures 2–5).

Another region-of-interest was drawn outside the lung field to obtain background activity. The regional distribution of ventilation or perfusion was calculated depending on the total count in ventilation or perfusion scans. The lower counts of ventilation or perfusion scan were taken into account, i.e. arithmetical mean of anterior and posterior image counts of ventilation and perfusion scans was

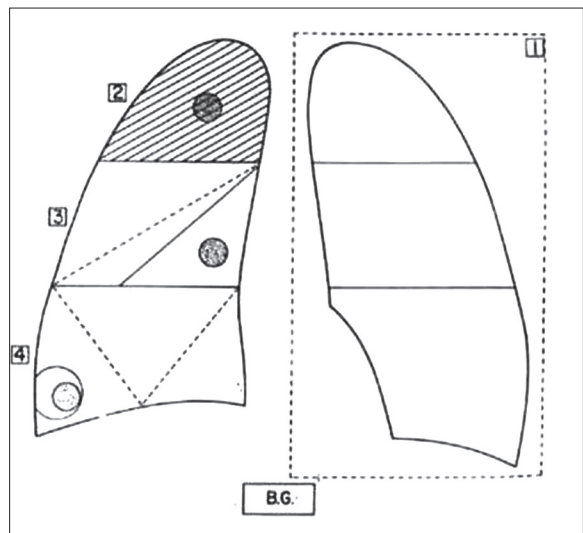


Figure 6. Prediction of postsurgical loss of lung function on the basis of extent of lung resection: 1) Pneumonectomy 2) Lobectomy 3) Segmentectomy or 4) Nodulectomy. Lobectomy is computed as the loss of one region, and segmentectomy is computed as the loss of a half of one region.

found by a dedicated software. The same was related to the pulmonary function test.

Spirometric lung functions, FEV₁ and forced vital capacity were measured prior to the quantitative regional lung function study. The prediction of postsurgical reduction in lung function was made by computing FEV₁ in liters, and the fraction of the distribution of ventilation or perfusion in the region to be resected. Pneumonectomy is a loss of one lung, lobectomy – of upper 1/3, middle 1/3 or lower 1/3 of the lung. Segmental resection or resection of a nodule may be regarded as the loss of a half or 1/3 of the region (Figure 6).

Surgical procedures do not always go as planned; therefore, the prediction of postsurgical reduction in lung function

Table 1. Age groups of patients.

Decades	3 rd	4 th	5 th	6 th	7 th	8 th
Patients	6	5	2	4	14	3
Total	34 patients					

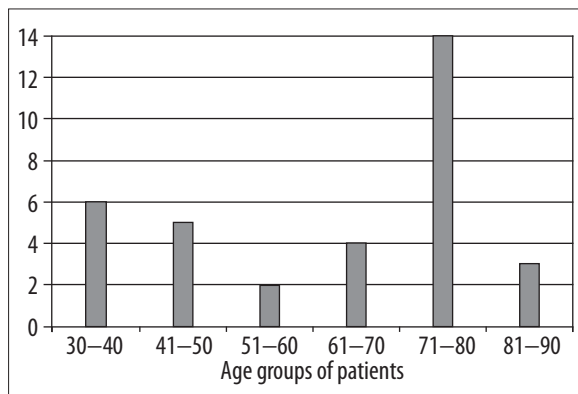


Figure 7. Bar diagram of Table 1.

Table 2. FEV₁.

1-2	>2	>3
24 patients	9 patients	1 patient
In total: 34 patients		

In 7 patients, repeat spirometry (i.e. pulmonary function test) was performed at varying intervals after surgical procedures. It was found that in all seven patients, the variation between preoperative FEV₁ and postoperative FEV₁ was only ±15%, at the most. Various procedures are listed below.

1. Lobectomy (one or two),

Table 3. Measurement of FEV₁ (post-operative).

FEV ₁ (preoperative)	Predicted FEV ₁ (preoperative)	Surgical procedure performed	Actual FEV ₁	Time Interval (post-operative)
1.57	1.36	Lt. Upper Lobectomy	1.32	5 months
1.8	1.44	Rt. Lower Lobectomy	1.37	2 months
1.8	1.40	B/L Metastectomy	1.54	30 months
1.92	1.56	Rt. Lower Lobe and Metastectomy	1.87	16 months
2.49	Lt-1.12; Rt-1.37	B/L Metastectomy	2.3	63 months
1.75	1.60	Rt. Upper and Middle Lobectomy	1.48	7 months
1.1	0.93	Lt. Upper Lobectomy	1.28	34 months

should also include possible complications, such as those indicating a need for expansion of lung resection. For example, a planned segmentectomy may end up as pneumonectomy, due to unexpected complications. As the quantitative ventilation and perfusion lung scans show the distribution of lung function in all eight regions, the surgeon can establish allowable contingency plans based on regional lung function data.

Material and Methods

We carried out the above defined ventilation and perfusion scanning in 34 patients. The age groups of patients were presented in Table 1 and Figure 7.

The preoperative FEV₁ (Forced expiratory volume) was established before scanning, and the range was given in Table 2.

In all 34 patients, the total number of counts in ventilation scans was lower than in perfusion scans (i.e. arithmetical mean of counts from anterior and posterior images).

2. B/L Metastectomy,
3. Pneumonectomy,
4. Wedge resection.

Discussion

Correlation between preoperative prediction and postoperative measurement of lung function.

We repeated FEV₁ in seven patients only. The rest of the patients will be evaluated when they report for further follow-up. Clinically, all these patients lead a normal life with no restriction of activity (Table 3).

Lung function becomes markedly restricted immediately after lung resection, and a minimal period of 1 month is required for recovery from surgery [10,11]. Many studies have shown that postoperative function performed by the remaining lung tissue increased significantly during long-term follow-up of 3 months or longer. This increase in function of the remaining lung is attributed to compensatory increase in volume [12-14].

A good correlation between the preoperatively predicted value and postoperative measurements has been observed with either quantitative ventilation scanning using ^{133}Xe or with perfusion scanning using $^{99\text{m}}\text{Tc}$ MAA [15,16].

In their recent study, Fogh et al. [17] reported a low yield of the preoperative ventilation perfusion scan in the prediction of postoperative pulmonary complications. There were considerable individual variations ranging from more than a 20% underestimation to a 20% overestimation of postsurgical loss in lung function.

The wide variation was mainly due to a difference in the underlying chronic lung disease and the extent of the lung cancer. A difference in the time of postsurgical spirometry, 1 to 3 months, also played a role in causing the variation. On the average, however, pre-operative predictive values were very near to postoperative measurements. Preoperative prediction made on the basis of ventilation and perfusion scan results correlated more closely with postoperative FEV₁ values than those of Forced Vital Capacity (FVC). We used FEV₁ values for postoperative prediction.

The difference between the ventilation and perfusion study in predicting postoperative loss of function was not significant [18], although the predicted values from the ventilation study tended to be slightly closer to the postoperative spirometric measurements.

Though ventilation scintigraphy has been recommended to predict the postoperative FEV₁, it has been found to underestimate the actual postoperative lung function. Thus, if this underestimation is not fully appreciated, some patients may be unnecessarily deprived of curative surgery [1].

Conclusions

The quantitative measurements of regional ventilation and perfusion distribution are simple and reliable when performed with routinely available radioactive tracers and perfusion lung scanning agents and a large field-of-view gamma camera with an on-line computer. Both the regional ventilation study and the perfusion study may be used for the prediction, but the analysis of regional ventilation distribution appears to be a better parameter than the analysis of perfusion distribution in the prediction of postoperative loss of FEV₁.

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