The Value of Regional Ventilation Measurements in the Prediction of Postoperative Pulmonary Function Following Lobectomy

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Eleven patients, mean age 62, considered for lobectomy for lung carcinoma underwent regional quantitative ventilation/perfusion scintigraphy. Preoperative selection criteria included an FEV_1 (forced expiratory volume) of 55% predicted or less, and/or an FEV_1/FVC% (forced vital capacity) of <70%. All patients underwent a complete set of pulmonary function tests including flow rates, lung volumes, diffusing capacity and blood gases. A predicted postoperative FEV_1 was calculated by multiplying the percent ventilation estimated to be remaining postoperatively by the preoperative FEV_1. Results were compared with the actual postoperative FEV_1 using a paired t-test. The statistical correlation between the predicted postoperative FEV_1 and actual yielded an "r" value of of 0.67 with a "p" value of 0.56. There was good correlation between the predicted postoperative FEV_1 utilizing scintigraphy and the actual, but in several cases the predicted postoperative FEV_1 was underestimated. Although the degree of underestimation is insignificant, patients may be excluded from lobectomy when their values are marginal.

Radionuclide ventilation and perfusion lung scans have been used in several ways to evaluate patients with lung cancer. They have been used to quantitate relative lung function (*1–3*), to predict pulmonary function following pneumonectomy and lobectomy (*4–6*) and to predict patient's ability to survive postoperatively (*7–8*). The perfusion scan has also been used to predict resectability of the cancer prior to thoracotomy (*9–12*) and to evaluate the response of lung cancer to radiotherapy (*13–17*). Although conventional spirometry provides information about global pulmonary function, its measurements are not regionally specific. Differential bronchospirometry with temporary catheterization of the pulmonary arteries was initially used to predict postoperative lung function in patients undergoing pneumonectomy, but it was expensive, had low patient compliance and could not provide detailed regional information (*18*). The good correlation between differential bronchospirometry and xenon radiospirometry (*1,2*) led to the use of xenon in prediction of postoperative FEV_1 and forced vital capacity (FVC) in patients undergoing pneumonectomy (*4*). Subsequently the quantitative differential perfusion scan was found to be as accurate in predicting postoperative lung function (*19*) presumably due to a close relationship between unilateral ventilation and perfusion in patients with lung cancer. The "split-field" perfusion scan rapidly became the procedure of choice as it was simple to perform and widely available.

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TABLE 1. Ventilation-Perfusion Normals*

Global Fuction

Perfusion	Right Lung	Left Lung
Anterior	55.1 ± 2.5	44.9 ± 2.5
Posterior	51.8 ± 2.7	48.2 ± 2.6
Total	53.5 ± 1.9	46.5 ± 1.9
Ventilation		
Anterior	55.5 ± 2.8	44.5 ± 2.8
Posterior	51.8 ± 2.8	48.2 ± 2.9
Total	53.7 ± 1.7	46.3 ± 1.7

Regional Function

Right Lung	Upper	Middle	Lower
Perfusion			
Anterior	15.7 ± 1.91	23.9 ± 2.3	16.0 ± 1.5
Posterior	13.3 ± 1.7	21.2 ± 2.1	16.9 ± 1.5
Total	14.5	22.5	16.5
Ventilation			
Anterior	15.9 ± 3.1	22.7 ± 3.4	15.7 ± 2.6
Posterior	13.6 ± 2.8	21.5 ± 3.3	15.8 ± 3.3
Total	14.7	22.1	15.8
Left Lung			
Perfusion			
Anterior	14.2 ± 1.8	19.7 ± 2.1	10.7 ± 1.4
Posterior	13.3 ± 3.4	19.9 ± 1.4	14.8 ± 1.7
Total	13.8	19.8	12.8
Ventilation			
Anterior	15.8 ± 3.2	19.8 ± 2.9	10.3 ± 2.2
Posterior	14.2 ± 2.6	20.2 ± 3.4	14.9 ± 3.3
Total	15.0	20.0	12.6

Studies performed in sitting position.

* Laboratory-determined normals.

TABLE 2. Postoperative FEV_1 Results*

	Pre-op*	Post-op*
FEV_1/FVC	64.09 ± 4.04	64.64 ± 5.34
FEV_1%	65.27 ± 6.63	55.09 ± 7.63
FEV_1 Actual	1.60 ± 0.24	1.24 ± 0.17
Predicted FEV_1	—	1.153 ± 0.07

* Results (n = 11) (mean ± s.e.m.).

MATERIAL AND METHODS

Eleven patients, mean age 62, considered for lobectomy for lung carcinoma underwent regional quantitative ventilation/perfusion scintigraphy. Imaging was performed utilizing a multicrystal first-pass camera. Initially, the patient underwent a conventional xenon ventilation study. The patient was then positioned in the anterior projection in front of a multi-crystal camera and injected with 500 μCi of technetium-99m (^{99m}Tc) microspheres. An anterior static perfusion image was obtained. Background was then determined in the xenon window. A xenon dynamic study was performed during the inhalation of 5.0 mCi of xenon-133 (^{133}Xe) utilizing conventional techniques. The patient was then positioned in the posterior projection and a static perfusion image was obtained. Subsequently, the patient inhaled 5.0 mCi of ^{133}Xe, and posterior dynamic and static imaging were performed. Lung regions were divided into anterior, posterior and total; these were subdivided into upper, middle and lower regions (Table 1). Subdivision of the left lung into three regions was performed in order to assess the possibility of lobe overlap. Split-function quantitation studies were carried out by summing the activity of each lung in the anterior and posterior views. All phases of the ventilatory study were utilized for quantitation. The postoperative FEV_1 was predicted by multiplying the pre-operative value by the ratio of the counts of the remaining lung to the total lung activity.

RESULTS

Preoperative selection criteria included FEV_1 of 55% predicted or less, and/or an FEV_1/FVC% of <70%. All patients underwent a complete set of pulmonary function tests including flow rates, lung volumes, diffusing capacity and blood gases. A predicted postoperative FEV_1 was calculated by multiplying the percent of ventilation estimated to be remaining postoperative by the preoperative FEV_1. Results were compared with the actual postoperative FEV_1 using a paired t-test. Results are presented in Table 2.

The statistical correlation between the predicted postoperative FEV_1 and actual, yielded an "r" of 0.67 with a "p" value of 0.56 (t = 0.60, and n = 10) where "r" = simple correlation, "p" = measure of statistical significance, and "n" = degrees of freedom. There was good correlation between the predicted postoperative FEV_1 utilizing scintigraphy and the actual, but in several cases the predicted postoperative FEV_1 was underestimated (Table 3). Although the degree of underestimation is insignificant, patients may be excluded from lobectomy when their values are marginal.

DISCUSSION

Numerous studies have validated the use of quantitative pulmonary scintigraphy prior to pneumonectomy in the prediction of post-pneumonectomy lung function. An equation useful in the prediction of pulmonary function after resection of a lung is:

$$\text{post-pneumonectomy } FEV_1 \text{ (in liters)} = \text{pre-op } FEV_1 \text{(in liters)} \times (\text{\% of total function of remaining lung}).$$

Simply, postoperative lung function is predicted by multiplying the FEV_1 by the percentage of ventilation or perfusion in the lung remaining after pneumonectomy (*20,21*).

The predicted postlobectomy FEV_1 is determined by multiplying the preoperative FEV_1 by the lobar percentages of the ventilation or perfusion of the remaining lung (*8*). Ali and co-workers (*22*) demonstrated that pulmonary perfusion lung scan when performed quantitatively is the best predictor of pulmonary function after lung resection. This test is easy to perform and extremely valuable when residual postoperative pulmonary function is in question. Surgery is usually not performed if a predicted postoperative FEV_1 is <0.8 liters (*23*).

TABLE 3. Predicted Postoperative FEV_1

Patient	Age	Pre-op FEV_1/FVC ratio	Pre-op FEV¹%	Pre-op FEV_1 actual (L)	Post-op FEV_1/FVC ratio	Post-op FEV_1%	Post-op FEV_1 (actual L)	Predicted post-op FEV_1 (L)
A.E.	55	71	60	2.75	77	34	1.54	1.40
D.C.	33	87	77	2.08	93	60	1.60	1.04
J.L.	68	68	112	3.18	63	83	2.36	2.67
P.L.	63	41	32	0.94	41	30	0.85	0.75
C.D.	67	65	72	1.42	62	48	0.96	1.10
C.R.	69	61	61	1.03	55	42	0.70	0.85
E.R.	51	51	89	0.98	59	40	0.97	0.89
J.K.	63	78	62	1.92	77	90	0.92	1.59
F.M.	66	65	51	1.05	87	102	1.98	0.88
E.Z.	73	70	59	1.24	61	46	0.98	0.84
W.B.	73	48	43	0.96	36	31	0.73	0.67

The following clinical strategy has been suggested in preoperatively evaluating a patient for lung resection:

1. Every pneumonectomy patient should have total pulmonary function measured.
2. Physiologically the patient will tolerate removal of a whole lung if preoperative studies meet the following criteria: (a) FEV_1 is >50% of FVC and is >2 liters; (b) the maximum voluntary ventilation is >50% of predicted; and (c) the ratio of residual volume to total lung capacity is <50%.

If these criteria are not satisfied, radionuclide split-function studies are appropriate. Surgery is usually not performed with predicted postoperative FEV_1 <0.8 liters. Where pneumonectomy is avoidable, segmental resection or lobectomy has become the surgical procedure of choice. The operative mortality of lobectomy is approximately the same as for pneumonectomy but the five-year survival rate is higher after lobectomy, presumably due to a lower incidence of respiratory disability. Studies have validated the use of scintigraphic techniques prior to pneumonectomy although efforts are now being directed towards the prediction of postlobectomy lung function. For example, where resections involve more than three segments, Ali et al. (*22*) found that predicted FEV_1 and FVC correlate well with postoperative values. Segmental and lobar analyses present problems not encountered in pneumonectomy studies related to the overlap of lobes as well as changes associated with regional hyperinflation. Regional quantitation may be best performed using the lateral and oblique images given that the lobar separation is more readily defined in these views. The interlobar planes are not as well defined in the posterior oblique views, however, they are less affected by counts from the opposite lung. Although the optimal method for extracting lobar data is not established, an average of the lobar counts obtained from the lateral oblique views may be a reasonable compromise between the conflicting goals of optimal lobar separation and avoidance of contralateral activity (*23,24*). Considerable disability may result from hypercapnea and chronic ventilatory insufficiency if the patient's postoperative FEV_1 is <0.8 liters. There was good correlation between the predicted postoperative FEV_1 utilizing scintigraphy and the actual, but in several cases the predicted postoperative FEV_1 was underestimated. Although the degree of underestimation is insignificant, patients may be excluded from lobectomy when their values are marginal. It is this particular group of patients, i.e., those with marginal predicted FEV_1 who should undergo further scrutiny before surgical resection is denied.

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