Prospective Evaluation for Pneumonectomy Using Perfusion Scanning*

Follow-Up beyond One Year

P. G. Boysen, M.D., F.C.C.P.; J. O. Harris, M.D., F.C.C.P.; A. J. Block, M.D., F.C.C.P.; and G. N. Olsen, M.D., F.C.C.P.

Thirty-eight high-risk patients (forced expiratory volume in one second [FEV₁] less than 2.0L or maximum voluntary ventilation [MVV] less than 50 percent of predicted) were observed for a minimum of one year after pneumonectomy for carcinoma of the lung. Operability was assessed by calculating a predicted postoperative FEV₁ (based on the right-left fractional perfusion estimated by a perfusion lung scan) and requiring this predicted postoperative value to exceed 800 ml. No other invasive physiologic studies were performed before surgery. At one year, 23 of 38 patients were still alive, and 13 of 38 patients survived to the end of the second year. At five years, two of 15 patients were alive with no evidence of metastatic disease. This simple physiologic approach involves widely available techniques and, in patients with lung cancer who have compromised pulmonary function, appears to result in acceptable survival over a longer period.

A major task of pulmonary function laboratories continues to be the preoperative physiologic evaluation of patients with carcinoma of the lung. Except in those with oat cell carcinoma, surgical resection remains the best hope for survival. Because many patients with lung cancer have a long history of exposure to cigarettes, coexisting chronic obstructive pulmonary disease is common and may be severe enough to prohibit pneumonectomy. Even less extensive surgery may be hazardous if the remaining pulmonary tissue has inadequate pulmonary reserve.

To define ventilatory criteria of operative risk, investigators have sought to use routine studies of pulmonary function. Obviously, these procedures comprehensively measure pulmonary function. Attempts have also been made to determine the amount of function that will remain after resection. Techniques for "split" pulmonary function were developed to try to determine the percentage of pulmonary function contributed by the noncancerous lung.

We collectively evaluated various methods for split function and then prospectively evaluated the split-function perfusion lung scan in conjunction with routine tests of pulmonary function to predict postoperative pulmonary function. Because we found that for a given lung the percentages of perfusion measured by radioactive technetium and of ventilation measured by radioactive xenon were nearly the same, we were able to combine these techniques and derive a predictive postoperative formula. We then prospectively tested these results and subsequently reported that death from any cause occurred in 15 percent of a group of patients with a mean age of 63 years.

The question then arose as to the fate of these patients over a longer period. We therefore prospectively evaluated, in the same fashion, a group of patients who underwent pneumonectomy and survived the perioperative period. We sought to determine not only survival during the first postoperative year but also the causes of death in the nonsurvivors. We were specifically interested in the number of cancer-related deaths vs deaths from respiratory failure.

MATERIALS AND METHODS

During the evaluation before surgery, all patients underwent routine testing of pulmonary function. Spirometric evaluation was performed with the patients seated and was repeated several times to obtain a maximal effort. Best effort was used to determine the forced vital capacity (FVC) and the forced expiratory volume at one second (FEV₁). Spirometric testing was then repeated after a nebulized bronchodilator drug was administered. The func-
tional residual capacity was determined by the closedcircuit helium-dilution technique or the nitrogen-washout technique. The carbon monoxide diffusing capacity was determined by either the steady-state or the single-breath technique.

A patient whose FEV₁ (best effort) exceeded 2 L in any of the attempts before or after administration of the bronchodilator agent was approved for surgery, up to and including pneumonectomy, with no further testing. If the FEV₁ was less than 2 L or the maximum voluntary ventilation (MVV) was less than 50 percent of predicted, the patient underwent a quantitative perfusion lung scan to assess split pulmonary function. Estimation of a postoperative FEV₁ was obtained by the following equation: predicted postoperative FEV₁ = preoperative FEV₁ × the percentage of contralateral perfusion. If the predicted postoperative FEV₁ was less than 800 ml, surgery was not recommended without further hemodynamic evaluation. If the predicted postoperative FEV₁ exceeded 800 ml, the patient was approved for surgery, up to and including pneumonectomy, without further physiologic testing.

After the first year a patient was presumed dead if he did not return for follow-up visits and could not be contacted through family, referring physicians, or the Florida Bureau of Vital Statistics.

RESULTS

This group of patients included 38 who underwent pneumonectomy. Their mean age was 61 years, and there were 33 men and five women. Twenty-two patients underwent left pneumonectomy, and 16 underwent right pneumonectomy. The mean preoperative FEV₁ was 1.68 L (range, 1.23 to 1.96 L), and the mean predicted postoperative FEV₁ was 1.09 L (range, 0.86 to 1.69 L). Two patients were lost to follow-up, one during the third and one during the fourth postoperative year.

Of the original group, 23 (61 percent) of 38 patients were still alive at one year. At the end of the second year, 13 (34 percent) of the 38 patients were still alive. Of the 15 patients who had surgery more than five years ago, two lived five years. Twelve of the 38 patients had a calculated postoperative FEV₁ between 800 and 1,000 ml, eight (67 percent) of the 12 were alive at one year, and their clinical course was indistinguishable from the remainder of the group.

There were 15 deaths during the first year. Only one was attributed to respiratory insufficiency; in eight, there was clinical, biopsy, or postmortem documentation of metastatic disease; and the remainder died of other causes. In nine of the 23 patients still alive, metastases were documented by the end of the first year. In fact, these patients with metastases accounted for most of the deaths during the second postoperative year.

Of the initial 38 patients, information on the cause of death is available on 29. Of the remaining nine patients, five are still alive, and two were lost to follow-up; for the two others, no clear cause of death could be elicited. In 20 (69 percent) of the 29 patients, recurrence or metastasis of the cancer was implicated in their eventual death. Five (17 percent) of the 29 died of respiratory failure. One of these deaths occurred during the first year and the remainder during subsequent years. Other causes of death (e.g., cerebrovascular accident) were noted in four (14 percent) of the 29 patients.

DISCUSSION

For most patients with suspected or proven carcinoma of the lung, surgery remains the best hope for cure. If contiguous spread of the disease or distant metastases are not evident, the patient's ability to withstand pneumonectomy should be evaluated. One always hopes that less extensive resectional surgery may suffice, but often this is not known before the operation. Obviously, the preoperative assessment of cardiopulmonary function is of primary importance in trying to predict postoperative status.

Many studies have described criteria for pulmonary function that might identify the patients who are at high operative risk. Gaensler et al reported high postoperative mortality caused by cardiopulmonary failure with MVV less than 50 percent of predicted and vital capacity less than 70 percent of predicted.

Mittman confirmed the usefulness of the MVV and found that a combination of tests had a better predictive value than any single test. Boushy et al reported that the FEV₁ was a reliable indicator of a patient's ability to tolerate surgery. If the absolute value of the FEV₁ was less than 2.0 L in a patient older than 60 years, this was found to be a sign of poor prognosis. In our experience the absolute value of the FEV₁ (>2.0 L) and an MVV that exceeds 50 percent of the predicted value have been the most useful indicators of the patient's ability to tolerate surgery and be left with adequate postoperative pulmonary function.

The obvious importance of the amount of pulmonary function that will remain after resectional surgery is the reason split-function techniques were developed to study each lung separately. Bronchospinometric, bronchoradiospirometric, and temporary unilateral balloon-occlusion studies were developed in an attempt to predict postoperative pulmonary function. Our earlier reports suggested that one could use the data from a routine perfusion lung scan to quantify right vs left function. We found that for any given lung the percentage of perfusion vs the percentage of ventilation were
nearly identical, despite the localized ventilation-perfusion imbalances in patients with chronic obstruction of the airways.

We combined the information from a split-function perfusion scan with the results of routine tests of pulmonary function to predict postoperative function. We then tested this method prospectively, found it to be reliable, and reported a perioperative mortality of 15 percent in the first 30 days after surgery.10

This technique is advantageous in that it is readily available in most hospitals and is simple and noninvasive and does not require specialized personnel other than those usually available. Similar physiologic assessment may be obtained by the lateral position test,12,13 which has also been prospectively tested with promising results,14 although its reproducibility has been questioned.15

Although these high-risk patients may survive the perioperative period, there has been concern that they may still be respiratory cripples. We therefore observed patients in this study for at least one year after surgery and 15 patients for at least five years. We found a low incidence of deaths due to respiratory failure. In the majority of these patients, there were no signs or symptoms of cor pulmonale, and although exercise tolerance is frequently limited, their subjective complaint of shortness of breath is infrequent; however, a significant amount of metastatic disease recurred despite surgical resection. Metastatic disease accounted for most of the early deaths and for those during the second year. Resection of functional pulmonary tissue in patients with chronic obstruction of the airways would certainly shorten life expectancy if cancer were not involved. The effects of pneumonectomy cannot be fully assessed because of the high frequency of recurrence of disease and death from cancer. When compared with other data of survival after pneumonectomy, there appears to be a similar pattern. Belcher and Rehahn16 reported survival of 56 percent at one year in 473 patients, which compares to the 61 percent we found.

Similarly, at five years, 104 (22 percent) of 473 of their patients were still alive. Ashor et al17 reported that at five years, 241 (19 percent) of their patients undergoing pneumonectomy had survived, compared to the 14 percent we found.

Because we arbitrarily chose the predictive postoperative FEV1 of 800 ml, we were interested in the fate of those patients with a predicted value between 800 and 1,000 ml. Twelve of the 38 patients were in this group. They did not differ from the others in either their perioperative mortality or their subsequent postoperative course. In fact, the longest living survivor had a predicted postoperative FEV1 of 0.879 L and has lived more than six years.

Similarly, eight of these 38 patients were at least 70 years of age. Their perioperative mortality did not differ from that of the rest of the group, and their subsequent course paralleled that of the other patients. We and others18 therefore believe that age in itself does not contraindicate surgery in those patients who are physiologically well preserved, as evidenced by criteria of pulmonary function.

In summary, we have previously shown8-10 that these simple physiologic and noninvasive principles are useful for predicting pulmonary function after pneumonectomy. The present data indicate that deaths from respiratory failure are infrequent perioperatively and subsequently during the first two postoperative years. Comparison at one year with studies of patients undergoing pneumonectomy who were not selected on the basis of tests of pulmonary function reveals a similar length of survival. If these principles are used, surgery can be offered to patients with carcinoma of the lung and marginal pulmonary function with acceptable cardiorespiratory morbidity and mortality after pneumonectomy.

REFERENCES
8 Olsen GN, Block AJ, Tobias JA. Prediction of postpneumonectomy pulmonary function using quantitative...