Lung cancer continues to be the leading cause of cancer deaths in the United States and the world. The estimated number of lung cancer cases in the United States for 1999 was 171,600, with 158,900 deaths. Among persons newly diagnosed with lung cancer between 1989 and 1995, the 5-year survival rate was 12.7% for white men, 9.9% for black men, 16.4% for white women, and 14% for black women.

Surgical resection is the treatment of choice for non-small cell cancer. However, only 20 to 25% of patients have resectable disease. About 30,000 lung resections are performed annually in the United States, per statistics reported by the Centers for Disease Control and Prevention. Commonly performed surgeries for lung cancer include pneumonectomy, lobectomy, wedge resection, and segmentectomy. The mortality rate from lung resection surgery is reported to range from 7 to 11%. The 5-year survival rate after resection ranges from 55% (stage I disease) to 26% (stage II disease). Incidences of complications vary, depending on the extent of resection, the pulmonary reserve of the patient, and the presence of comorbid factors.

The high risk of morbidity and mortality makes it mandatory to assess as accurately as possible which patients with anatomically resectable disease are suitable candidates for surgery. The literature relating to this topic is vast but is mostly confined to studies performed in the 1970s and 1980s. This review discusses the existing modalities and practices for preoperative evaluation prior to lung resection surgery.
in evaluating a patient for lung resection surgery. The objective of this review is to attempt to encompass all aspects of preoperative evaluation prior to lung resection surgery, because no recent comprehensive review exists on this subject.

PREOPERATIVE EVALUATION OF PATIENTS WITH OPERABLE LUNG CANCER

After determining the anatomic resectability of the disease, it needs to be decided whether the patient can withstand the planned procedure and can survive the loss of the resected lung. For this purpose, general and pulmonary-specific evaluations are necessary. Who should be evaluated? The general answer is as follows: all patients undergoing lung resection surgery, irrespective of age or extent of the lesion.

INITIAL EVALUATION

Prior to taking the patient to surgery, a detailed medical history, including that of any coexisting disease should be sought to ensure the optimal treatment and control of that disease. History should include the patient’s functional capacity and the degree of limitation of activity. Since patients with lung cancer are usually smokers, a history of smoking and of symptoms suggestive of COPD should be elicited. This history may lead to preoperative therapeutic interventions such as therapy with bronchodilators and/or steroids, which may result in some degree of reversal of airway obstruction and easier weaning from the ventilator postoperatively.

The physical examination should include an evaluation for signs of metastatic spread (eg, lymph node enlargement, hepatomegaly, or focal neurologic deficits) and the presence of cardiac failure and pulmonary hypertension. All of these may change the treatment mode and determine that the patient may not be a surgical candidate.

PULMONARY-SPECIFIC EVALUATION

The pulmonary-specific evaluation (Fig 1) aims at assessing the patient’s physiologic pulmonary function. It helps to decide whether the patient is a candidate for surgery and the extent of resection that can be tolerated. Although a number of physiologic tests exist for this purpose, there is no single measure that is a “gold standard” in accurately predicting complications. However, certain criteria, when applied, have been shown to be predictive of outcome.

STAGES OF PULMONARY-SPECIFIC EVALUATION

The pulmonary-specific evaluation can be divided into three stages of tests that are performed in a

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Routine PFTS → FEV1 > 60%, DLCO > 60%

FEV1 < 60%, DLCO < 60%

Quantitative Lung Scan → PPO-FEV1 > 40%
PPO-DLCO >40%

PPO-FEV1 < 40% / PPO-DLCO < 40%

EXERCISE TESTING → VO2 max > 15ml/kg/min

VO2 max < 15ml/kg/min → Other Options prior to attempting Surgery

**Figure 1.** A schematic representation of a stepwise approach to preoperative evaluation prior to lung resection surgery.
graded manner to meet the cited goals and help risk-stratify the patients prior to the anticipated surgery.

**Stage I Assessment**

The first stage of assessment consists of the following tests.

**Spirometry**

Spirometry is a simple, inexpensive, standardized, and readily available test. Spirometric indexes that are commonly tested and have been extensively studied include FEV\(_1\), FVC, forced expiratory flow, midexpiratory phase (FEF\(_{25-75}\)%), and maximum voluntary ventilation (MVV). FVC reflects lung volume, while FEV\(_1\) and FEF\(_{25-75}\) reflect airflow. MVV represents respiratory muscle strength and correlates with postoperative morbidity. However, it is very dependent on patient effort. Of all these indexes, FEV\(_1\) is regarded as being the best for predicting complications of lung resection in the initial assessment, and it is the one most commonly used for decision making.

**Diffusion Capacity**

Diffusing capacity of the lung for carbon monoxide (DLCO) reflects alveolar membrane integrity and pulmonary capillary blood flow in the patient’s lungs. In a retrospective study of 247 patients by Ferguson et al.\(^6\) the DLCO was the most important predictor of mortality and was the sole predictor of postoperative pulmonary complications. However, others\(^7,8\) have not found it to be a significant predictor of postoperative complications.

**Arterial Blood Gas Levels**

Arterial blood gas level has not been extensively studied as predictor of postoperative complications. Hypercapnia (ie, P\(_{CO_2}\) > 45 mm Hg) in arterial blood has been a relative contraindication to lung resection as it indicates chronic respiratory failure. However, in a study by Morice et al.\(^9\) it has been reported that patients with a P\(_{CO_2}\) of > 45 mm Hg did well postoperatively. A few other studies\(^7,10\) did not find that a P\(_{CO_2}\) of > 45 mm Hg was predictive of postoperative complications.

Most of the literature on pulmonary function tests (PFTs) as predictors of outcome following lung resection surgery date to the 1970s and 1980s. Different authors have had varying results when studying traditionally cited pulmonary function variables as predictors of postoperative pulmonary complications. Gaensler et al.\(^11\) were the first to show in 1955 that patients undergoing lung resection surgery who had MVV < 50% and FVC < 70% had a 40% postoperative mortality. Subsequent studies\(^12,13\) reported a higher postoperative mortality ranging from 9 to 27% with FEV\(_1\) < 2 L and MVV < 50%. However, Keagy et al.\(^14\) in 1983 found no significant correlation between spirometric indexes and postoperative complications.

Miller et al.\(^15\) studied complications in 500 patients undergoing lung resection and correlated them with preoperative spirometric indexes and type of surgery performed. Based on the results of their study, the recommended requirements for a pneumonectomy are as follows: FEV\(_1\), > 2 L; MVV, > 55% of predicted; and FEF\(_{25-75}\)%, > 1.6 L/min. The recommended requirements for a lobectomy are as follows: MVV, > 40% of predicted; FEV\(_1\), > 1 L; and FEF\(_{25-75}\)%, > 0.6 L/s. The requirement for a segmentectomy or wedge resection was as follows: MVV, > 40% of predicted; FEV\(_1\), > 0.6 L; and FEF\(_{25-75}\)%, 0.6 L/s.

Three relatively recent studies reassessed the relationship between spirometric indexes and postoperative complications. A prospective study of 331 patients by Kearney et al.\(^10\) in 1994 reported that an FEV\(_1\) of < 1 L was not predictive of complications. In this study, complications were seen in 3 of 17 patients (18%) with FEV\(_1\) < 1 L and in 51 of 307 patients (17%) with FEV\(_1\) > 1 L (p > 0.05). Complications were seen in 39% of patients undergoing pneumonectomy, 19% of patients undergoing lobectomy, and 6% of patients undergoing wedge resection. The type of surgery that the patients with FEV\(_1\) < 1 L underwent, in which the FEV\(_1\) was not predictive of complications, is not mentioned in the study. However, the power to detect a significant difference in this study was limited by the small number of patients having FEV\(_1\) values of < 1 L. A prospective study of 12 patients by Pate et al.\(^16\) in 1996 concluded that patients with FEV\(_1\) values of > 1.6 L or > 40% of predicted could safely undergo lobectomy. A retrospective study of 236 patients by Stephan et al.\(^7\) in 2000 found that the incidence of postoperative pulmonary complications in patients with FEV\(_1\) values of < 2 L was 40% vs 19% for those with FEV\(_1\) > 2 L.

To summarize, studies on pulmonary function testing in the preoperative evaluation for lung resection surgery indicate that the following criteria are predictive of increased postoperative complications and mortality: for pneumonectomy: FEV\(_1\), < 2 L or < 60% of predicted; MVV, < 55% of predicted; DLCO, < 50% of predicted; and FEF\(_{25-75}\)%, < 1.6 L/s. For lobectomy, the criteria are: FEV\(_1\), < 1 L; MVV, < 40% of predicted; FEF\(_{25-75}\)%, < 0.6 L/s; and DLCO, < 50% of predicted. The criteria for
wedge resection/segmentectomy are: FEV1, < 0.6 L; and DLCO, < 50% of predicted.

If spirometry, lung volume, and DLCO values are within accepted limits, no further evaluation is needed. If FEV1 values of > 2 L or > 60% of predicted, MVV values of > 55% of predicted, and DLCO values of > 60% of predicted are obtained, the patient is at low risk for complications and can undergo pulmonary resection, including pneumonectomy, without further testing.

If the above requirements are not met, the patient needs further evaluation.

**Stage II Assessment**

The next stage of assessment consists of tests that measure individual lung function. These include the following.

**Quantitative Ventilation-Perfusion Scan or Differential Lung Scan**

133Xe is inhaled or 99mTc-labeled macroaggregates are injected IV. The uptake of radioactive ions by the lung by inhalation of the 133Xe or perfusion of the 99mTc macroaggregates is measured by a gamma camera and computer.17 The percentage of radioactivity contributed by each lung correlates with the contribution to the function of that lung. Normally, the right lung contributes 55% of lung function, while the left lung contributes 45% of lung function. Based on the measured radioactive uptake of the lung that will not be operated on, the predicted FEV1 of the residual lung following surgery was calculated by Kristersson et al18 using the following formula:

\[
\text{postoperative FEV}_1 = \text{preoperative FEV}_1 \times \% \text{ of radioactivity contributed by nonoperated lung}
\]

Using 133Xe ventilation scanning, Kristersson et al18 reported that a predicted postoperative (ppo) FEV1 of < 1 L was indicative of physiologic inoperability. Using 99mTc macroaggregate perfusion scanning, Olsen19 reported a good correlation between ppo FEV1 and the FEV1 measured 3 months postoperatively, after pneumonectomy in 13 patients. Olsen19 also estimated that a ppo FEV1 of < 0.8 L indicated surgical inoperability. The criteria of ppo FEV1 of < 0.5 L was based on an earlier study by Segal and Butterworth,20 which reported that patients with COPD with an FEV1 of < 0.8 L had CO2 retention. However, the data in these studies were not corrected for age, height, or sex.

Wernly et al21 developed and tested the following formula for predicting postlobectomy pulmonary function using ventilation-perfusion scanning:

\[
\text{expected loss of function} = \text{preoperative FEV}_1 \times \% \text{ of function of affected lung} \times \frac{\text{No. of segments in lobe to be resected}}{\text{total No. of segments in the whole lung}}
\]

No prospective study has established a cutoff limit of FEV1 that precludes a safe resection. Markos et al22 found that a higher mortality rate was associated with ppo FEV1 < 40% and recommended a ppo FEV1 of ≥ 40% as a safe preoperative criterion for operability. Gass and Olsen23 suggested a ppo FEV1 of < 35% of normal as a lower limit for all patients. However, this recommendation has not been critically tested. Ladurie and Ranson-Bitker24 found significant differences between predicted and estimated postoperative FEV1 values in 75% of patients following pneumonectomy. Despite these limitations, ventilation-perfusion lung scanning is still considered by most as a useful tool in the preoperative evaluation of high-risk patients for lung resection surgery. It is noninvasive and readily available.

Markos et al22 used lung ventilation scanning to measure ppo FEV1 as well as ppo DLCO, and they reported that a low ppo DLCO value was associated with higher mortality and morbidity. An increased mortality was associated with a ppo DLCO < 40%. They found it to be the best predictor of postoperative respiratory failure.

The ppo FEV1 also can be calculated without performing a split lung function test such as a lung perfusion scanning, by using the formula published by Juhl and Frost.25 According to them, ppo FEV1 = preoperative FEV1 × (1 - [S × 5.26]/100), where S is the number of bronchopulmonary segments involved. Two studies7,10 have found the calculated ppo FEV1 to be significantly predictive of postoperative complications.

To summarize, patients who undergo a differential lung scan, in the course of their preoperative evaluation for lung resection, may be allowed to undergo surgery (including pneumonectomy) if their ppo FEV1 is > 40% of predicted and their ppo DLCO is > 40% of predicted. Patients who have ppo FEV1 values of < 40% and ppo DLCO values of < 40% need to undergo further evaluation before surgery can be undertaken.

**Other Tests of Differential Lung Function**

Other tests assessing differential lung function include bronchopulmonary segment perfusion imaging,26 lateral position testing,27 and total unilateral pulmonary artery occlusion.28 All are invasive, and all require specialized equipment and a high level of technical expertise for their performance. For these reasons, and for the
advantages of ventilation-perfusion scanning, these tests are no longer performed in the preoperative evaluation of patients who are awaiting lung resection.

**Stage III Assessment**

Patients with a low ppo FEV$_1$ (ie, < 0.8 to 1 L or < 35 to 40% of predicted values) are considered to be at high risk for postoperative complications following lung resection surgery and need further workup. This can be done fairly accurately by means of exercise testing.

Exercise testing stresses the entire cardiopulmonary and oxygen delivery system, and provides a good estimate of cardiopulmonary reserve. Currently, exercise testing consists of having the patient perform an incremental amount of exercise by bicycle ergometer or treadmill for a duration that is limited by time or symptoms, with monitoring of heart rate, BP, ECG, and oxygen saturation. The measurement of exhaled gases can determine the following parameters$^{39}$: oxygen uptake (VO$_2$); maximal VO$_2$ (VO$_{2\text{max}}$); carbon dioxide output; and minute ventilation.

**Principles of Exercise Testing**

VO$_2$ in the lungs is representative of VO$_2$ at the cellular level. With an increase in the cellular respiration from exercise, there is a predictable increase in VO$_2$. VO$_2$ is related to age, sex, weight, and type of work performed. A formula for estimating VO$_2$ reported by Wasserman and Whipp$^{30}$ is as follows:

\[
predicted \, VO_2 = 5.8 \times \text{weight in kg} + 151 + 10.1 \, (W \, \text{of workload})
\]

The rate of VO$_2$ increases with exercise until a point at which a plateau is reached and a further increase in work does not result in a continued rise in VO$_2$. This is the VO$_{2\text{max}}$. In patients with COPD, dyspnea or fatigue often interrupts exercise before this plateau. The VO$_2$ at this stage is called peak VO$_2$. VO$_{2\text{max}}$ or peak VO$_2$ indicates whether the patient has the reserve to counter the multiple physiologic stresses that accompany surgery.

Reichel$^{31}$ first reported the value of exercise testing in the preoperative evaluation of patients prior to lung resection surgery in 1972. In their retrospective study of 75 patients, significant postoperative complications developed in 57% of those who did not complete all six stages on a treadmill-walking test, while those who successfully completed all six stages of the protocol had no complications.

**Types of Exercise Testing**

Two major types of exercise tests have been used in the preoperative evaluation of high-risk patients being considered for lung resection surgery.$^{32}$ These are: (1) fixed exercise challenge, in which a sustained level of work is performed, and (2) incremental exercise testing, in which the work rate is sequentially increased to a desired end point. These two types are further divided into maximal or submaximal, based on their end points. The *maximal end point* can be defined as an exercise, usually incremental, that is performed to a plateau (ie, VO$_{2\text{max}}$) at which further work will not produce an increase in VO$_2$. The *submaximal end point* can be defined as exercise performed short of achieving the plateau (ie, VO$_{2\text{max}}$).

The following is a brief review of studies that have been done with exercise testing preoperatively in evaluating patients prior to lung resection surgery.

**Fixed Challenge Exercise Testing**

Fixed challenge exercise testing involves assessing performance status by doing a fixed amount of work such as climbing a certain number of stairs or walking a fixed distance. Before the availability of PFTs and sophisticated exercise testing, surgeons used the ability to climb stairs as an informal measurement of exercise capacity. Van Nostrand et al$^{33}$ first used stair climbing as a test for endurance in the preoperative evaluation for lung resection surgery in a series of 119 patients. He reported a postoperative mortality rate of 50% in patients who were unable to climb one flight of stairs with minimal dyspnea vs a mortality rate of 11% in those who were able to climb two flights of stairs with minimal dyspnea.

Olsen et al$^{34}$ reported that patients who were able to climb three flights of stairs (ie, 75 steps) had a reduced number of postoperative complications. Holden et al$^{35}$ in 1992 did a prospective study of 16 patients who underwent stair climbing as part of the evaluation prior to surgery. Five of the 16 patients who died in the perioperative period had a significantly shorter 6-min walk distance and a lower stair climb than the group of patients with minor or no complications. In this study, a 6-min walk distance of > 1,000 feet and a stair climb of > 44 stairs were predictive of successful surgical outcome. Thus, stair climbing appears to be a simple method of preoperative evaluation of exercise ability and pulmonary reserve.

A more recent study by Girish et al$^{36}$ prospectively evaluated symptom-limited stair climbing as a predictor of postoperative cardiopulmonary complications in 83 patients undergoing thoracic and upper abdominal surgery. They found that complications
occurred in 89% of patients who were unable to climb one flight of stairs. The inability to climb two flights of stairs had a positive predictive value of 80%, while the inability to climb five flights of stairs had a positive predictive value of 32%. No complications were seen in patients who could climb seven flights of stairs. The ability of patients to climb stairs was inversely related to the length of postoperative hospital stay.

Although stair climbing as a measure of exercise capacity can predict postoperative complications, more studies are needed to determine whether it can supplant more sophisticated exercise testing.

Incremental Exercise Testing

Eugene et al37 in 1982 were the first to use incremental exercise to the point of maximal exertion and to measure VO₂max in patients being evaluated for lung resection surgery. They found that no mortality occurred in patients with VO₂max values of >1 L/min, while the mortality rate was 100% in those with VO₂max values of <1 L/min. Smith et al38 in a 1984 study performed with 22 patients, demonstrated that the incidence of postoperative complications was 100% if VO₂max values were <15 mL/kg. 66% with VO₂max values of 15 to 20 mL/kg, and only 10% with VO₂max values of >20 mL/kg. This study demonstrated that VO₂max at peak exercise was a valuable noninvasive method of preoperative evaluation. Berggren et al39 in 1984 reported a postoperative mortality rate of 7.7% in 26 patients who completed 83 W of work for 6 min vs a postoperative mortality rate 22% in the remaining 18 patients who were unable to perform that amount of work.

Bechard and Wetstein40 in 1987 studied 50 patients who underwent exercise testing by cycle ergometry, with 1-min increments of 12.5 W to exhaustion or dyspnea, with the measurement of VO₂max and anaerobic threshold. The postoperative mortality rate was 4%, and it occurred in all patients with VO₂max levels of <10 mL/kg/min. Based on these results, the authors proposed that a patient with VO₂max values of <10 mL/kg should not undergo lung resection surgery. The study by Pate et al41 also revealed that patients with VO₂max values of >10 mL/kg/min could safely undergo lung resection surgery. However, the study by Markos et al42 reported that oxygen desaturation during a 12-min walk, ppo DLCO, and ppo FEV₁ were more reliable predictors of postoperative mortality than VO₂max.

Bolliger et al43 assessed exercise testing in evaluating lung resection candidates and reported that VO₂max, expressed as a percentage of the predicted values, was the single best predictor of postoperative complications. They found that, irrespective of extent of resection, patients with VO₂max values >75% of predicted had a 90% probability of an uneventful postoperative course, while those with VO₂max values <43% had a 90% probability of developing postoperative complications. Smith et al48 had earlier analyzed VO₂max as a percentage of predicted normal values and found it to be inferior to absolute values in predicting postoperative complications.

Using the formula for calculating postoperative FEV₁ based on radionuclide ventilation-perfusion scanning, Corris et al44 were able to predict postoperative VO₂max. Bolliger et al45 used this formula to estimate ppo VO₂max in a group of 25 patients, and found good correlation between estimated ppo VO₂max and the measured postoperative VO₂max values. The value of ppo VO₂max needs to be studied prospectively to establish its utility in the preoperative assessment of patients prior to lung resection surgery.

Submaximal Exercise Testing

Submaximal exercise testing is particularly useful in patients with COPD who are unable to exercise to achieve VO₂max secondary to dyspnea or fatigue. Although VO₂max is a proven predictor of postoperative outcome, some studies have evaluated the role of submaximal exercise in the preoperative assessment for lung surgery. Miyoshi et al46 studied 33 patients who underwent cycle ergometry to submaximal levels (reaching a heart rate of 140 beats/min or a respiratory quotient of >1) with arterial lactate levels measured during the last 3 s of each work rate period. They found that VO₂ per meter of body surface area, at a submaximal lactate level of 20 mg/dL, discriminated between survivors and nonsurvivors. This study suggested that in-house mortality could be predicted by submaximal exercise VO₂ when the work level achieved was corrected for a fixed level of lactate production.

Olsen et al45 in 1989 prospectively studied 52 patients with FEV₁ values of <2 L who underwent cycle ergometry at two submaximal workloads. The VO₂ values were significantly lower in 7 of the 29 patients who underwent lung resection and did not tolerate the procedure. These studies revealed that cardiopulmonary testing by submaximal levels of exercise also could predict mortality accurately.

To summarize, studies on exercise testing in the preoperative evaluation of patients for lung resection surgery indicate that VO₂max predicts postoperative complications and mortality fairly accurately. VO₂ values that are obtained at submaximal levels also can predict mortality. Most studies agree that pa-
Patients with \( \dot{V}O_{2\text{max}} \) values > 20 mL/kg/min will tolerate surgery with acceptable morbidity and mortality, while patients with \( \dot{V}O_{2\text{max}} \) values < 10 to 15 mL/kg/min appear to be at increased risk of complications and death.

**AN ALTERNATIVE APPROACH TO PREOPERATIVE EVALUATION PRIOR TO LUNG RESECTION SURGERY**

An important study was performed by Wyser et al.\(^{46} \) in 1999. This study evaluated prospectively an algorithm for the functional assessment of lung resection candidates that was different from the approach traditionally used. Unlike earlier approaches to preoperative evaluation for lung resection surgery, this algorithm used exercise testing to determine \( \dot{V}O_{2\text{max}} \) earlier in the assessment. Patients with either FEV\(_1\) or DLCO values < 80% of predicted underwent exercise testing to determine \( \dot{V}O_{2\text{max}} \). Patients with \( \dot{V}O_{2\text{max}} \) values > 20 mL/kg/min could undergo surgical resection, while those with \( \dot{V}O_{2\text{max}} \) values between 10 and 20 mL/kg/min underwent split lung function testing. If the ppo FEV\(_1\)/ppo DLCO ratio was < 40%, the patients were deemed to be inoperable. For those patients in whom the ppo FEV\(_1\)/ppo DLCO ratio was > 40%, the ppo \( \dot{V}O_{2\text{max}} \) was determined. If this was > 10 mL/kg/min, patients could undergo resection up to the calculated extent.

Using this algorithm, the postoperative mortality rate was 1.5%, with a postoperative complication rate of 11%. This represented a reduction in mortality of 50% compared to the authors’ previous series, in which postoperative complications occurred in 20% of patients (16 of 80 patients) and the postoperative mortality rate was 4% (3 of 80 patients). Although the use of an FEV\(_1\)/DLCO ratio of 80% as the initial cutoff parameter may represent too rigorous a patient selection, the improved outcome achieved due to the algorithm is impressive. The earlier use of exercise testing identified 86% of patients as being potentially operable for pneumonectomy, thus reducing the need for radionuclide studies to only 12% of patients, resulting in lower costs. This algorithm may well represent an alternative approach to evaluating patients for lung resection surgery.

**CONCLUSION**

Patients in whom anatomically resectable lung cancer is diagnosed should undergo evaluation for surgical resectability. This begins with routine pulmonary function testing. Patients whose PFT results show good lung function (ie, FEV\(_1\) > 2 L or > 60% of predicted; and DLCO > 60%) can be referred for surgery without undergoing other tests for further assessing their pulmonary status.

Patients with preoperative FEV\(_1\) values < 60% of predicted and/or DLCO values < 60% of predicted need further evaluation. They should undergo a quantitative ventilation-perfusion lung scan to estimate ppo FEV\(_1\) and ppo DLCO. If the ppo FEV\(_1\) and ppo DLCO are > 40% of predicted, surgical risk is acceptable, and surgery (including pneumonectomy) should be offered to these patients.

Patients with ppo FEV\(_1\) and ppo DLCO values of < 40% should undergo exercise testing to evaluate pulmonary reserve and to assess the adequacy of oxygen transport. Cycle ergometry with incremental workloads, which measures \( \dot{V}O_{2\text{max}} \), \( \dot{V}O_{2\text{max}} \), minute ventilation, and carbon dioxide output with concomitant monitoring of ECG, BP, oximetry, while the patient exercises to the maximal end point or to the symptom-limited maximum, is probably the best form of exercise testing. Patients with ppo FEV\(_1\)/DLCO ratios of < 40% of predicted, but with \( \dot{V}O_{2\text{max}} \) values on exercise testing of > 15 mL/kg/min, can undergo surgical resection, including pneumonectomy. The algorithm validated by Wyser et al.\(^{46} \) using a higher cutoff of 80% of predicted for FEV\(_1\) and DLCO, and incorporating exercise testing earlier in the evaluation, represents an alternative approach to evaluating patients for lung resection surgery.

**REFERENCES**

23 Gass GD, Olsen GN. Pre-operative pulmonary function testing to predict post-operative morbidity and mortality. Chest 1986; 89:127–135
24 Ladurie ML, Hanson-Bitker B. Uncertainties in the expected value for forced expiratory value in one second after surgery. Chest 1986; 90:222–226
28 Carlens E, Hanson HE, Nordenstrom B. Temporary unilater-