Preoperative Risk Assessment for Marginal Patients Requiring Pulmonary Resection

J. Ryan Burke, MD, Ignacio G. Duarte, MD, Vinod H. Thourani, MD, and Joseph I. Miller, Jr, MD

Department of Surgery, Section of General Thoracic Surgery, Division of Cardiothoracic Surgery, and Emory University, School of Medicine, Atlanta, Georgia

Surgical resection remains the mainstay of treatment for pulmonary malignancy. The ability of patients to undergo resection is dependent on the anatomic characteristics of the tumor, and the respiratory and cardiovascular status of the patient. There have been recent advances in our understanding of respiratory function in the patient with marginal lung function that have allowed surgical therapy of lung cancer in patients previously deemed inoperable. This review will define the marginal patients who can safely undergo pulmonary resection.

© 2003 by The Society of Thoracic Surgeons

Surgical resection is the treatment of choice for non-small cell bronchogenic carcinoma, and it is the only method that provides prolonged arrest and the chance for a cure. A significant number of patients cannot undergo surgical resection because of associated comorbidities that increase operative mortality and postoperative morbidity. The major determinants of postoperative morbidity and mortality after thoracotomy and pulmonary resection are the physiologic and functional status of the pulmonary and cardiac systems.

Although there is general agreement regarding patients who are considered acceptable candidates for resection, there is far less information on patients who are marginal candidates. The current literature contains numerous methods to identify patients who are at risk for morbidity and increased mortality after pulmonary resection. However, there has been no summation to date regarding the patient who is a marginal candidate for pulmonary resection. This review will examine patients who are considered marginal candidates for pulmonary resection and provide a systematic approach to preoperative evaluation from a pulmonary and cardiac standpoint.

Pulmonary Evaluation

In 1972, Block and Olsen [1] reported a set of pulmonary function criteria for elective pneumonectomy that has remained the gold standard to the present day. Historically, Hodgkin and associates [2] listed seven factors predisposing a patient to high risk from cardiopulmonary complications. These included a maximal breathing capacity of less than 50% of that predicted, an increased arterial carbon dioxide concentration (Paco₂) with a low arterial oxygen concentration, a forced expiratory volume in 1 sec (FEV₁) of less than 0.5 L, a forced expiratory volume of 25% to 75% of less than 0.6 L, a maximum expiratory flow rate of less than 100 L per minute, a vital capacity of less than 1 L, and an abnormal electrocardiogram. Miller and colleagues [3] modified these criteria in 1981 and determined that high-risk patients with a maximal breathing capacity of less than 40% predicted, an FEV₁ of less than 1 L, a forced expiratory volume of 25% to 75% of less than 0.6 L, and a vital capacity of less than 1 L could undergo limited resection of lung cancer. In 1992, Miller [4] published a set of pulmonary function criteria for various types of pulmonary resection based on personal operative experience in 2,340 patients (Table 1). In this study, an attempt was made to define specific indicators to determine the amount of lung that could be resected without significant morbidity and mortality. These original criteria were derived by setting the lower limits for the basic studies using the experience of the author and a review of the literature. In the entire series, less than 1% of all patients evaluated were denied surgery. Subsequently the results have been used by many centers. With the reemergence of the lung volume reduction era in 1994, it was realized that criteria for pulmonary function test values that were once held absolute could no longer be applied to patients with marginal pulmonary function. It was clear that patients could undergo various types of pulmonary resection despite having severe pulmonary function impairment.

Peters and colleagues [5] stated that “the morbidity and mortality of patients who have undergone pulmonary resection for lung cancer can be viewed in terms of the continuity of clinical management, beginning with preoperative clinical evaluation, extending to intraoperative management and encompassing postoperative care.” According to Mountain and colleagues [6], “the final selection of the specific operative procedure must take place at the time of exploration, but the probable extent of the resection is carefully planned preopera-
Table 1. Standard Pulmonary Function Values for Resection

<table>
<thead>
<tr>
<th>Pulmonary Function Test</th>
<th>Maximum Voluntary Ventilation (% Predicted)</th>
<th>Forced Expiratory Volume in One Minute (L)</th>
<th>Forced Expiratory Volume 25%–75% (L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>75</td>
<td>&gt; 2</td>
<td>&gt; 2</td>
</tr>
<tr>
<td>Pneumonectomy</td>
<td>&gt; 55</td>
<td>&gt; 2</td>
<td>&gt; 1.6</td>
</tr>
<tr>
<td>Lobectomy</td>
<td>&gt; 40</td>
<td>&gt; 1</td>
<td>&gt; 0.6</td>
</tr>
<tr>
<td>Wedge</td>
<td>&gt; 35</td>
<td>&gt; 0.6</td>
<td>&gt; 0.6</td>
</tr>
<tr>
<td>Inoperable</td>
<td>&lt; 35</td>
<td>&lt; 0.6</td>
<td>&lt; 0.6</td>
</tr>
</tbody>
</table>

It is generally agreed that if a patient has an FEV₁ of greater than 2 L or a maximal breathing capacity greater than 50% of that predicted, one can proceed to any type of elective pulmonary resection without further pulmonary evaluation. When a patient possesses values less than these, a more detailed analysis of lung function must be carried out. Our goal is to define a set of pulmonary criteria that can be used in an analysis of a large number of patients and to define specific indicators for pulmonary resection in the marginal patient without denying operation, except to a small group of patients. These indicators will be defined in a step level technique of examination. The question by Gass and Olsen [7] of “What is an unacceptable surgical mortality in a disease with a 100% mortality unless treated surgically?” has yet to be answered.

The marginal patient is defined in terms of impairment of pulmonary function as listed in Table 2. The marginal patient has an FEV₁ of less than 1.2 L per minute; a maximum voluntary ventilation (MVV) of 35 to 40% predicted; a forced expiratory volume of 25% to 75% of 0.6 to 1 L per minute; a diffusion capacity for carbon monoxide (DLCO) of 30% to 40% predicted; and a PaCO₂ greater than 45 mm Hg. Generally, the truly marginal patient will fulfill at least three of these five criteria. These criteria were derived from personal experience of the authors, review of the literature, and more than 8,000 patients undergoing cardiopulmonary evaluation by the author (JIM). The specific tests will now be evaluated and applied in a decision-making analysis of patient management. These tests can be viewed at four different levels of screening (Table 3).

Level I

Before 1955, preoperative evaluation of the candidate for pulmonary resection was predicted on the results of the “match” or the “2-flight stair test”. In a landmark article presented in 1954, Gaensler and colleagues [8] reported his results in 460 patients undergoing surgical procedures for pulmonary tuberculosis between 1947 and 1953. This data included maximum breathing capacity, vital capacity as a percent of predicted, an air velocity index, exercise ventilation, and walking dyspnea index. The authors found a direct correlation between a low preoperative percent of predicted maximal breathing capacity of less than 50% and a percent predicted vital capacity less than 70% with early and late surgical deaths, as well as an increase in postoperative dyspnea. As such they were the first to demonstrate a correlation between preoperative pulmonary function testing and outcomes of pulmonary resection.

In subsequent years, arterial blood gases became a defining element in the evaluation of level I pulmonary criteria. Patients considered acceptable for almost any type of pulmonary resection had a low arterial oxygen concentration of greater than 90, a PaO₂ of less than 42, and an oxygen saturation greater than 92%. Patients with a low arterial oxygen concentration of 60 to 80 mm Hg or a PaCO₂ ranging from 42 to 45 or an oxygen saturation of 90 to 92% were considered borderline. Patients with a low arterial oxygen concentration less than 60 or a PaCO₂ greater than 45 or an oxygen saturation of less than 90% were considered at high-risk for pulmonary resection [9].

All patients should have a measurement of the pulmonary diffusion capacity. In 1988, Ferguson and colleagues [10] was the first to evaluate diffusion capacity of the lung as an indicator of underlying pulmonary function. In a retrospective study of 237 patients undergoing lobectomy, bilobectomy, or pneumonectomy, he used logistical regression analysis to identify that a DLCO greater than 60% of that predicted was associated with a significant decline in the incidence of overall mortality. There was an additional decrease in pulmonary complications from 33% to 13% when the DLCO was above 80% predicted. Wang and colleagues [11] points out in a retrospective review of 410 patients that the long-term mortality is not affected by predicted postoperative DLCO percentage when stratified by cancer stage. However, this limit of resectability with respect to DLCO has been challenged. Bousamra and colleagues [12] retrospectively evaluated 363 patients for lung resection. A group of 61 marginal patients with a DLCO of less than 60 who underwent pneumonectomy or lobectomy were compared with 262 patients with a DLCO greater than 60% of that predicted. The mortality rate was equal between the groups with a slightly higher rate of pulmonary complications in the high-risk group. The increased morbidity may have been confounded by the fact that the lower DLCO group had a more advanced stage and more frequently underwent extended resection and radiation.

Table 2. Pulmonary Function Values in the Marginal Patient

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Marginal Patient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forced expiratory volume in one minute</td>
<td>&lt; 1.2 L</td>
</tr>
<tr>
<td>Maximum voluntary ventilation</td>
<td>35–40% Predicted</td>
</tr>
<tr>
<td>Forced expiratory volume 25%–75%</td>
<td>0.6–1.0 L</td>
</tr>
<tr>
<td>Diffusion capacity for carbon monoxide</td>
<td>35%–40% Predicted</td>
</tr>
<tr>
<td>Increased arterial carbon dioxide concentration</td>
<td>&gt; 45 mm Hg</td>
</tr>
</tbody>
</table>
However, Bousamra and colleagues’ [12] data show that, although quality of life remained suboptimal for the low DLCO group, the dyspnea scale actually improved postoperatively in this group, whereas it remained the same for the high DLCO group. Markos and colleagues [13] prospectively evaluated 55 patients for lobectomy or pneumonectomy. In this study, a DLCO of less than 40% of that predicted was associated with a mortality of 42%, whereas there were no deaths above 40% of that predicted.

Level II
Split perfusion lung scanning with lobar counts is used in selected patients at the level II of preoperative evaluation. This test is used as an adjunct to the basic profile in patients with an FEV1 less than 2 L per minute who require pneumonectomy or in specific cases when the FEV1 is less than 1.2 L per minute in patients who require a lobectomy. Specifically, split perfusion lung scanning enables the calculation of postoperative FEV1 (ppoFEV1). In 1975, Olsen and colleagues [14] established a ppoFEV1 of 0.8 L as the minimum for operability. This was subsequently modified to adjust for age, height, and sex, and the ppoFEV1 is now described as a percentage of that predicted. Gass and Olsen [15] determined that a ppoFEV1 of less than 35% of that predicted deemed a patient inoperable. The suggested lower limit for ppoFEV1 was confirmed by Markos and colleagues [13] in a prospective study of 55 patients who showed there were no associated postoperative deaths with pneumonectomy or lobectomy in patients with a predicted ppoFEV1 greater than 40% of that predicted [13].

Level III
Patients who are felt to be at increased risk or to be marginal on the basis of level I or II screening should be considered for exercise assessment. These level III tests include the 6-minute walk test, exercise oximetry, and the maximum voluntary oxygen consumption. The 6-minute walk test evaluates total distance walked on a flat surface over 6 minutes to provide an objective measurement of exercise performance. This test evolved from studies of exercise testing in normal subjects by Cooper [16] in 1968. McGavin and colleagues [17] were the first to apply Cooper’s correlation of walk distance in maximal oxygen consumption in a chronic bronchitis population. The original time of 12 minutes used by Cooper was found to correlate with a 6-minute timeframe that was more easily tolerated in patients with lung disease. Van Stel and colleagues [18] were able to use multivariate analysis in 53 patients who had chronic obstructive pulmonary disease to determine four independent variables, which include heart rate pattern, walk distance, oxygen desaturation, and dyspnea. In patients with obstructive lung disease, there was a strong correlation with cardiopulmonary reserve and the ability to predict peak oxygen uptake. In one study by Holden and colleagues [19], there were no postoperative deaths in patients who walked more than 1,000 feet.

In the lung volume reduction era, the 6-minute walk test became a standardized modality in the evaluation of patients undergoing consideration for surgery. It was generally accepted that any patient that could not walk more than 500 feet after pulmonary rehabilitation was not an acceptable candidate for lung volume reduction surgery. Application of standard preoperative selection criteria for lung volume reduction surgery has shown that the majority of patients could walk between 700 to 900 feet after undergoing pulmonary rehabilitation. Therefore, patients who are unable to initially demonstrate a 6-minute walk of more than 500 feet probably should not be considered as a candidate for pulmonary resection.

In addition to the 6-minute walk test, exercise oximetry has provided a significant predictor of morbidity and potential mortality in patients undergoing pulmonary resection. Patients who have an oxygen saturation less than 90% or greater than 90% but who desaturate by more than 5 points during a 6-minute walk test on room air have a significantly increased rate of developing
postoperative pulmonary complications and death [20]. In general, if the patient can maintain an oxygen saturation greater than 90% on 2 L of nasal cannula oxygen while participating in a 6-minute walk with a value greater than 700 feet, they have a reasonable chance of coming through the postoperative period after pulmonary resection without an excessive risk of morbidity or mortality.

Exercise performance can be further evaluated by measuring maximum oxygen consumption during exercise. Patients who have cardiopulmonary abnormalities that develop during exercise are believed to have limited metabolic reserve tolerating the circulatory changes associated with major lung resection. Several studies have shown a correlation between maximum oxygen consumption and postoperative complications. In Smith and colleagues’ [21] prospective study of 22 patients undergoing thoracotomy, all 6 patients with a maximal oxygen consumption of less than 15 mL·kg\(^{-1}\)·min\(^{-1}\) suffered a significant cardiopulmonary complication. In patients with a maximal oxygen consumption greater than 20 mL·kg\(^{-1}\)·min\(^{-1}\), there was only one complication. Bechard and Wetstein [22] selected 50 consecutive patients and stratified them by FEV\(_1\). Patients with an FEV\(_1\) greater than 1.7 L underwent pneumonectomy, whereas those with an FEV\(_1\) greater than 1.2 L underwent lobectomy and an FEV\(_1\) greater than 0.9 L underwent wedge resection. Their results were similar to Smith and colleagues [21] in that there was no associated morbidity or mortality in patients with a maximal oxygen consumption greater than 20 mL·kg\(^{-1}\)·min\(^{-1}\). When patients are stratified by predicted postFEV\(_1\) or DLCO, as Ribas and colleagues’ [23] demonstrated, the maximal oxygen consumption lost the ability to predict complications but not overall mortality. In their study, 65 patients were selected based on FEV\(_1\) of less than 40% predicted or a DLCO less than 40%, placing them in a high-risk category. There were 31 complications and only 4 deaths. There was no statistical difference in the peak oxygen uptake. Table 4 outlines several studies that have been done by quantitating the risk of pulmonary resection by measuring the maximal oxygen consumption [21, 22, 24].

**Level IV**

In an effort to further define cardiopulmonary reserve, clinicians have incorporated graded work in preoperative testing. The most basic method has been stair climbing. One may be critical of using stair climbing as a level IV rather than a level I examination. Historically, before 1954, stair climbing was the only method of preoperative evaluation. However, the current standards of care dictate that patients undergo a thorough evaluation using the level I through level III studies. These studies are quite capable of identifying the majority of acceptable and unacceptable candidates. Therefore, level IV testing should be used in the extremely marginal patient to provide additional objective evidence of physiologic status.

Most studies have been retrospective but have demonstrated a significant risk of postoperative complications in patients who are unable to climb two flights of stairs. Pollock and colleagues [25] have been able to directly correlate the number of flights of stairs climbed to oxygen consumption. In a recent prospective study, Girish and colleagues [26] demonstrated a positive predictive value for postoperative complications of 80% for patients who failed to climb two flights of stairs and 63% for those climbing less than three flights. Of interest is the inability of stair climbing to predict mortality in this prospective study. Two of three deaths occurred in patients climbing more than three flights of stairs. Table 5 lists several studies that sought to evaluate the ability of stair climbing to predict postoperative morbidity and mortality. These studies agree that the risk of postoperative complications and death decline with an increase in exercise tolerance.

One additional advance that has enabled compromised patients to undergo pulmonary resection is the incorporation of pulmonary rehabilitation in the preoperative preparation. In those patients who have marginal or unacceptable pulmonary reserve, completion of a comprehensive pulmonary rehabilitation program can improve endurance and potentially lower the risk of postoperative complications. Traditionally, rehabilitation has combined education, behavioral and psychosocial training, along with lower and some upper extremity exercise training over a 6- to 8-week period of time. The goal of preoperative pulmonary rehabilitation therapy includes ultimately being able to exercise 30 consecutive minutes on a bicycle at a speed of 1.2 mph or on a treadmill at a similar calibration. In Cooper and colleagues’ [31] original article on lung volume reduction surgery, all patients were enrolled in a preoperative rehabilitation program. This resulted in an increase in the 6-minute walk distance from 958 to 1,220 feet. O’Donnell and colleagues [32] demonstrated in 60 patients with a mean FEV\(_1\) of 0.96 L that the 6-minute walk distance increased 18% with multimodality training. In addition, inclusion of upper extremity training has improved task specific performance. The results of rehabilitation are intriguing in that they suggest, as O’Donnell

<table>
<thead>
<tr>
<th>Author</th>
<th>No. of Patients</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Olesen and colleagues [27]</td>
<td>54</td>
<td>&gt; 3 Flights: acceptable risk</td>
</tr>
<tr>
<td>Holden and colleagues [19]</td>
<td>16 (High risk)</td>
<td>&gt; 44 Steps: acceptable risk</td>
</tr>
<tr>
<td>Van Nostrand and colleagues [28]</td>
<td></td>
<td>&gt; 2 Flights: acceptable risk</td>
</tr>
<tr>
<td>Ginsberg [29]</td>
<td></td>
<td>2 Flights = pneumonectomy</td>
</tr>
<tr>
<td>Pate and colleagues [30]</td>
<td>12 (High risk)</td>
<td>&gt; 3 Flights = lobectomy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 1 Flight = segmentectomy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 5 Flights = pneumonectomy</td>
</tr>
</tbody>
</table>

1 Flight = 12 steps.

---

**Table 5. Stair Climbing as a Predictor of Postoperative Risk**
showed, that patients who do not initially meet resection criteria may possess enough reserve to compensate for the loss of significant amount of lung tissue after completion of a successful pulmonary rehabilitation program. To date, the addition of pulmonary rehabilitation has been the greatest advance in moving a patient from the physiologically unresectable category to the resectable category.

Beginning in 1995, at which time the newest era of lung volume reduction surgery was introduced by Cooper and colleagues [31], and to the present day the definition of physiologically unresectable lung cancer is less defined. Data analyzed by numerous groups have identified the patient at high risk for lung volume reduction surgery to include a PaCO2 greater than 50, an FEV1 of less than 0.5 L/min, an FEV1 of less than 20% of that predicted, or a DLCO of less than 20% of that predicted, as well as age greater than 70 years [33–35]. McKenna and colleagues [36] reported on a series of 11 patients who underwent wedge or lobectomy for stage I nonsmall cell lung cancer during lung volume reduction surgery. The mean preoperative FEV1 was 0.654 L or 21% of that predicted, and they used wedge resection in those patients whose cancer was not within the target area of reduction. There was no associated morbidity or mortality, and these patients enjoyed an increase in mean FEV1 by more than 20% of that predicted. Derose and colleagues [37] were able to perform combined lung volume reduction with wedge or lobectomy patients with an FEV1 of 680 mL. There was a death with 1 patient who had previous thoracic surgery and who had a bronchopleural fistula develop thereafter. In addition, there was a significant improvement of FEV1 and dyspnea index. With the increased rate of recurrence from limited resection, it may be desirable to provide a potentially curative resection for patients with severe emphysema. Demeester and colleagues [38] combined lobectomy and volume reduction in 5 patients with lesions confined to the emphysematous segments of the lung. All 5 patients sustained an average increase in FEV1 of 43%. There was no cancer recurrence at the 19-month follow-up. It has been emphasized by all major groups performing lung volume reduction surgery that the basic criteria to undergo resection for lung cancer requires that these patients have an FEV1 of 20% to 30% of that predicted, a diffusion capacity greater than 30% of that predicted, an age of less than 70 years of age, and a PaCO2 of less than 50. Figure 1 shows our basic algorithm for the pulmonary evaluation of surgical candidates.

Preoperative Cardiac Evaluation

The greatest cardiac risk in the patient undergoing thoracotomy with pulmonary resection is the presence of coronary disease. Selected data from three large series has shown the risk of perioperative myocardial infarction to be 0.15% in patients without prior clinical evidence of heart disease [39–42]. However, in patients who have a prior history of myocardial infarction, the incidence of reinfarction during a major noncardiac operation has ranged from 2.8% to 17.7%. The mean is approximately 6%. The mortality from perioperative myocardial infarction remains high, ranging from 32% to 69%, averaging approximately 50%, and is highest the first 6 months after infarction [39–42]. Overall, 1 million patients undergoing noncardiac surgery will have a perioperative cardiac complication with a resultant cost of over $20 billion [43].

The first significant attempt to identify patients at increased risk from surgery was presented by Dripps and colleagues [44] in 1961. The authors retrospectively evaluated 33,224 patients who underwent spinal or general anesthesia between 1947 and 1957. From their review, they developed the American Society of Anesthesiology classification as an index of physical status and severity of systemic illness still used today.

Goldman and colleagues [45] were the first to present a multifactorial index for preoperative cardiac risk assessment. In their prospective evaluation of 1,001 patients older than 40 years of age undergoing noncardiac operations from 1975 to 1976, they were able to identify a series of preoperative factors associated with an increased risk of life-threatening and fatal cardiac complications. A point value for each variable was derived from a discriminate-function coefficient and accumulated points were used to categorize patients into four groups. As such, they felt that patients in class III warranted further preoperative cardiac evaluation, whereas the highest risk or class IV patients should only undergo potential lifesaving procedures.

In 1986, Detsky and colleagues [46] modified Goldman...
and colleagues’ [45] criteria based on 455 prospectively evaluated patients. In their validating study, the original criteria were expanded to include myocardial infarctions occurring more than 6 months preoperatively, a Canadian cardiovascular Society angina class III or IV, unstable angina within the previous 6 months, and pulmonary edema (current or remote). They concluded that the presence of S3 gallop or jugular venous distention and age greater than 70 years, as well as the type of noncardiac operation were not independent risk factors. Despite the strong predictive information provided by the Detsky scale, Detsky and colleagues [46] suggest that these indices should be used with caution and further evaluation of risk is often indicated, particularly for high-risk procedures, regardless of the patient’s risk index.

The use of preoperative risk assessment at our institution leads to a systematic screening of patients undergoing an intrathoracic procedure. Our basic approach is outlined in Figure 2. This is based on the senior author’s evaluation of more than 8,000 patients undergoing pulmonary resection with a mortality of less than 1%. Any asymptomatic patient from 45 to 60 years of age undergoes an exercise treadmill test. Any patient older than 60 years of age or with a history of a myocardial infarction, angina, or congestive heart failure, undergoes dobutamine stress echocardiography.

The ability to exercise is an important indication of how the patient will tolerate a major intrathoracic procedure. Exercise stress testing provides an excellent means of functional assessment before surgery, and this is especially important when the functional status is unclear. Routine exercise treadmill testing has the sensitivity of 90% in the detection of coronary artery disease. It is those patients with painless ischemia or occult coronary disease that we hope to identify with preoperative cardiac assessment in addition to defining the cardiac status of patients with known heart disease.

In addition, we have had extensive experience with the use of dobutamine stress echocardiography, and it has become the standard modality at our institution for testing patients who are at high risk for cardiopulmonary complications. A review of 85 noncardiac thoracic surgical patients undergoing lung volume reduction surgery at our institution revealed that dobutamine stress echocardiography had a specificity of 88% for detecting subclinical coronary artery disease. Patients who are found to have fixed cardiac defects on imaging have lower risk of perioperative cardiac complications than those with reversible defects or areas of ischemia. For most patients identified as high risk with ischemia by dobutamine stress echocardiography, preoperative evaluation should subsequently include coronary catheterization. There are currently no randomized trials that can be used to determine the efficacy of preoperative coronary revascularization. Two sets of guidelines exist from national societies that address the issue of interventions to reduce the incidence of perioperative cardiac complications. These guidelines conclude that coronary artery bypass or percutaneous transluminal coronary angioplasty should be limited to patients who have a clearly defined need for the procedure independent of the need for noncardiac surgery. This category includes patients with poorly controlled angina despite maximal medical therapy, patients with high-risk coronary characteristics, clinically significant stenosis more than 70% or left main stenosis more than 50%, easily inducible myocardial ischemia on preoperative testing, and left ventricular dysfunction at rest.

Fleisher and Eagle [43] have advocated perioperative treatment with beta blockers in all patients at risk for coronary events who are scheduled to undergo noncardiac surgery. High-risk patients are those with a history of one or more of the following: myocardial infarction, angina, heart failure, or diabetes.

Comment
The evaluation of patients for pulmonary resection should follow a logical progression through basic testing modalities. Once marginal patients have been identified by initial screening, there are numerous methods to further stratify risk. Adjunctive testing can minimize the number of patients denied potentially curative surgical therapy. In this brief review, we have attempted to point out that there are no absolute definable areas of unresectability, but values in a number of different types of studies that should be considered that point to increased morbidity and mortality. As Blalock pointed out, not all patients need to die in the operating room. However, as pointed out by Gass and Olsen [7], “What is an acceptable mortality in a disease with a 100% mortality unless treated surgically?” has yet to be defined. At the present time, thoracic surgeons should strive for mortality rates of less than 1% for limited resections, less than 2% for lobectomies, and less than 10% with pneumonectomies.
The well-trained thoracic surgeon must be keenly aware of pulmonary and cardiac indicators, and possess sound judgment and manual dexterity before assuming responsibility for performing pulmonary resections.

References