Patients with impaired pulmonary function are at increased risk for the development of postoperative complications. Recently exercise testing and predicted postoperative (ppo) function have gained increasing importance in the evaluation of lung resection candidates. We prospectively evaluated an algorithm for the preoperative functional evaluation that was developed at our institution. This algorithm incorporated the cardiac history including an electrocardiogram (ECG), and the three parameters FEV₁, diffusing capacity of the lungs for carbon monoxide (DLCO), and maximal oxygen uptake (V̇O₂max), as well as their respective ppo values (FEV₁-ppo, DLCO-ppo, and V̇O₂max-ppo) calculated based on radionuclide perfusion scans. A consecutive group of 137 patients (mean age 62 yr; range 23 to 81; 102 males, 35 females) with clinically resectable lesions underwent assessment according to our algorithm. Five patients were deemed functionally inoperable, 132 passed the algorithm and underwent pulmonary resections with standard thoracotomy: 9 segmental or wedge resections, 85 lobectomies (inclusive 3 bilobectomies), and 38 pneumonectomies. All patients were extubated within 24 h. The mean stay in the ICU was 1.4 (± 1.8) d, and the mean hospital stay was 14.6 (± 5) d. Postoperative complications (within 30 d) occurred in 15 patients (11%), of whom two died (overall mortality rate 1.5%). In comparison to our previous series this meant a 50% reduction in complications whereas the percentage of inoperable patients remained unchanged (4% now, 5% before). We conclude that adherence to our algorithm resulted in a very low complication rate (morbidity and mortality), and excluded more rigorous patient selection as a bias for the improved results. Wyser C, Stulz P, Solèr M, Tamm M, Müller-Brand J, Habicht J, Perruchoud AP, Bolliger CT. Prospective evaluation of an algorithm for the functional assessment of lung resection candidates.

AM J RESPIR CRIT CARE MED 1999;159:1450-1456.

Despite increasing enthusiasm for exercise testing and split function studies, one has to remember that many patients undergoing lung resections up to pneumonectomy do not need extensive tests for the assessment of their cardiorespiratory reserves. We therefore developed an algorithm for the preoperative functional evaluation (Figure 1) incorporating the cardiac history including an electrocardiogram (ECG), and the three parameters FEV₁, DLCO, and V̇CO₂max with their ppo values. The choice of these parameters of cardiorespiratory function and their respective cutoff values for operability were based on our previous investigations as described in METHODS (3, 4), and on the recent literature (1, 5-7).

The goal of the current study was to prospectively assess the impact of this algorithm on postoperative morbidity and mortality in a consecutive series of lung resection candidates scheduled for standard thoracotomy. The validation of the algorithm was done by comparing the postoperative complication rates with the ones obtained in our previous series (4) and with other reports in the literature.

METHODS

Study Population

A II patients enrolled in this study were referred to the Respiratory Division of our hospital for investigation and treatment of suspected or
If both \( FEV_1 \cdotppo \) and \( DLCO \cdotppo \) were < 40% of predicted the patient was deemed inoperable (1, 2); if either one or both was > 40% of predicted, \( V_O2\max \cdotppo \) became the decisive factor. Patients with a \( V_O2\max \cdotppo \) of < 10 ml/kg/min as well as < 40% of predicted were deemed inoperable (3); if it was either > 40% of predicted or > 10 ml/kg/min, the patient was deemed operable up to the calculated extent of resection.

Pulmonary Function Tests

Pulmonary function tests (PFT) were performed while the patient was at rest in a seated upright position. These tests consisted of spirometry and body plethysmography using the Masterlab (Äger, Würzburg, Germany). The measurement of the flow–volume loops was recorded according to the American Thoracic Society (ATS) criteria (9). Of all recorded parameters the following two were used for the assessment of operability: the best expiratory volume in the first second (\( FEV_1 \)) and \( DLCO \). In patients with obstructive airflow limitation, the PFT were repeated after 1 to 2 wk of intensive bronchodilator therapy including a steroid trial, and the best performance of each patient was used.

The term "percent predicted" used throughout the article refers to the relationship of the value obtained to the normal value for the patient’s sex, age, and height. The term “postoperative predicted” refers to the value predicted for the patient after operation and can be expressed in absolute or in percentage of predicted values.

Exercise Testing

If either \( FEV_1 \) or \( DLCO \) was < 80% of predicted, symptom-limited cycle ergometry was performed according to our algorithm (cycle: ER 900 L, Äger; cardiopulmonary stress testing unit; EOS Sprint, Äger). Baseline measurements were recorded after a minimal resting period of 3 min on the bicycle. The patients then started exercising at constant speed (60 rpm). After a 2 min warm-up period at 20 watts a ramp protocol with a 20 watt per minute workload increase was started. The exercise test was stopped when the patients were exhausted, a plateau in \( V_O2 \) uptake appeared or at any signs (ECG) or symptoms of myocardial ischemia, including a fall in blood pressure. All parameters were recorded until the end of a 6-min recovery period. Continuous measurements of ventilation (\( V_e \)), oxygen consumption (\( V_O2 \)), carbon dioxide production (\( V_CO2 \)), and pulse rate were averaged every 15 sec. Blood pressure was measured manually (Riva-Rocci) every minute. A precordial ECG (equivalent leads \( V_II \), and \( V_3 \)) was monitored continuously (Cardiotest EK 53 R; Hellige, Freiburg, Germany) and hard copies were written at rest, at peak exercise, and at the end of the recovery period, and additionally when arrhythmias or changes in the ST-T segments occurred. A trerital blood samples were drawn from the radial or brachial artery at rest and at peak exercise and analyzed immediately. Maximal oxygen consumption was recorded in L/min, ml/kg/min, and as a percentage of predicted normal values according to Jones and colleagues (10).

Split Function Studies

Split function studies of regional pulmonary function were performed while the patient was in a seated upright position and breathing normally at rest. All patients with \( V_O2\max \) values between 10 to 20 ml/kg/min and 40 to 75% of predicted underwent additional radioisotope ventilation-perfusion studies to estimate the postoperative \( FEV_1 \) (\( FEV_1 \cdotppo \)) according to the method described by Marks and coworkers (1). Using the perfusion lung scans (technetium-99m-labeled macroaggregates), we calculated the fractional contribution of the lung tissue to be resected to overall lung function. Thereby the following formulas were used: pneumoectomy: postoperative \( FEV_1 \) (\( FEV_1 \cdotppo \) = preoperative \( FEV_1 \) \times (1 – fractional contribution of the affected lung); lobarectomy: postoperative \( FEV_1 \) (\( FEV_1 \cdotppo \) = preoperative \( FEV_1 \) \times (1 – lobar fractional contribution). The same technique was used to predict the postoperative diffusion capacity (\( DLCO \cdotppo \)) (1) and the postoperative exercise capacity (\( V_O2\max \cdotppo \) (3). Calculations were made both for absolute and for percentage of predicted values of \( FEV_1 \cdotppo \), \( DLCO \cdotppo \), and \( V_O2\max \cdotppo \). For \( FEV_1 \cdotppo \) and \( DLCO \cdotppo \) only the percentage of predicted values were used in the algorithm.

Algorithm

The following algorithm was used in the preoperative functional evaluation (Figure 1): A new patient with active or suspected cardiac disease had to undergo a thorough cardiac workup and if necessary even cardiac bypass surgery in case of ischemic heart disease. Only patients whose cardiac condition was amenable to treatment could undergo further investigation for pulmonary resection. Patients who had a negative cardiac history (including a normal ECG) and whose \( FEV_1 \) and \( DLCO \) were both > 80% of predicted normal could undergo lung resection up to a pneumonectomy without any further tests. The cutoff values of 80% of predicted were chosen because the respective postoperative values are usually > 40% of predicted—identified as safe (1, 2)—even after pneumonectomy as the diseased lung generally contributes < 50% of the total lung function (8). If either \( FEV_1 \) or \( DLCO \) was < 80% of predicted, exercise testing with the measurement of \( V_O2\max \) was performed. If \( V_O2\max \) was > 75% of predicted (4) or > 20 ml/kg/min (5, 6), patients again qualified for resection up to pneumonectomy. A \( V_O2\max \) < 10 ml/kg/min (3, 6) or < 40% of predicted (4) was generally considered prohibitive for any resection. All patients with \( V_O2\max \) values in between, that is 40 to 75% of predicted as well as 10 to 20 ml/kg/min, underwent split function studies to determine the ppo values for \( FEV_1 \), \( DLCO \), and \( V_O2\max \). For the calculation of the remaining pulmonary function for each of these three parameters, the fractional contribution of the lung tissue to be resected with curative intent was deducted from overall preoperative lung function. This calculation was based on lung perfusion scans (see also Split Function Studies).
Surgical Procedures, Postoperative Care, and Complications

All pulmonary resections from wedge resection to pneumonectomy were performed with an open thoracotomy; the same team of four thoracic surgeons performed all operations. All patients received standardized anticoagulant therapy with low-molecular-weight heparin (3,000 IU subcutaneously/day) perioperatively. A total of ten procedures were performed on all patients admitted to the intensive care unit (ICU) for the first postoperative night. They were extubated either in the theater at the end of the operation or in the ICU within 2 to 4 h. If no complications occurred the patients were transferred to a normal thoracic surgery ward not later than 24 h postoperatively. The duration of hospital stay was calculated as 1 d prior to surgery until discharge. The decision to transfer a patient from the ICU to the normal ward and from there to discharge him or her from hospital was taken by the anesthetists and the thoracic surgeons respectively according to their clinical assessment. The postoperative period (30 d) was recorded for complications as defined in Table 1. Only moderate and severe complications expected to occur as a result of poor cardiopulmonary reserve were included in the list. For comparison's sake it contained the same criteria that were used in our previous reports (3, 4) and in some important earlier studies (1, 5, 6).

Statistical Analysis

The comparison of all variables between the current and our previous study results was made with the use of the chi-square test for categorical variables, and Student's t test for continuous variables. A significance level of p < 0.05 was chosen.

Functional Assessment in Our Previous Series

The equipment and test analyses for PFT, exercise testing, and split function studies were identical in our previous (4) and in the current study. The number of investigations per patient, however, differed between the two studies. In the previous series all patients underwent PFT and exercise testing; further, all patients with either an FEV1 < 2 L or a DLCO < 50% underwent additional radioisotope ventilation–perfusion studies to estimate the postoperative FEV1 and DLCO. All patients who were able to perform all investigations then underwent pulmonary resection irrespective of the functional test results. This was essential to analyze each test parameter for its predictive value of postoperative complications, and for the elaboration of cutoff values for safe resection.

RESULTS

Functional Evaluation

Six (4%) of the 137 patients (Figure 1) underwent first thoracic surgery workup because of known or suspected cardiac disease; four of them were deemed operable from a cardiac point of view after radionuclide heart studies had ruled out active disease and confirmed a normal left ventricular ejection fraction (LVEF). Two were considered inoperable as their cardiac condition was not controllable by medical or surgical treatment. Sixty-seven patients (49%) who had a negative cardiac history (including a normal ECG) and whose FEV1 and DLCO were both > 80% were deemed operable for resections up to a pneumonectomy without any further testing.

The remaining 68 patients underwent a symptom-limited cycle ergometry; thereafter 51 patients (37% of the initial 137, 75% of the 68) qualified for resection up to a pneumonectomy. Two patients with sufficient PFT reserves (italic numbers in Figure 1) showed marked ischemic ECG changes occurring during maximal exercise. One of them had known coronary artery disease and previous aortic valve replacement. A subsequent radionuclide ventriculography showed a stunned area but normal LVEF; he was therefore deemed operable but died of pneumonia and consecutive multiple organ failure 9 d after a left upper pneumectomy. The second patient underwent coronary angiography, which revealed serious three-vessel disease; he underwent coronary artery bypass surgery, and subsequently a lobectomy with an uncomplicated postoperative course.

Seventeen patients (12%) with VO2max values between 10–20 ml/kg/min underwent split function studies to determine their ppo function according to our algorithm. In eight patients postoperative predicted lung function parameters were good enough for pneumonectomy; six patients could undergo resection up to a lobectomy only. In three patients the VO2max-ppo was < 10 ml/kg/min as well as < 40%, therefore they were deemed inoperable (Patients 1, 2, and 5 of Table 2).

Thus, of the consecutive group of 137 lung resection candidates, who were functionally assessed with our algorithm, five patients (4%)—all with lung cancer—were deemed inoperable because of inadequate cardiopulmonary functional reserve (Table 2). Two of these five patients would have been scheduled for pneumonectomy, three for lobectomy. The parameters for which they were excluded from surgery are indicated in italic in Table 2. Two patients (Patients 1 and 2) had sufficient pulmonary function results, but very poor cardiopulmonary reserves reflecting a marginal cardiac output (low VO2max, and low LVEF on echocardiography). Three were excluded because of poor pulmonary function results (Patients 3–5); two of these three patients were unable to perform the exercise test, one of them would also have been excluded because of a low VO2max (Patient 5). The 1-yr follow-up of the spontaneous course of four of these five patients was complicated by recurring episodes of either acute respiratory failure or of congestive heart failure which necessitated hospitalization in each case; the respiratory failures were not directly tumor-related, but resulted from an exacerbation of the patient's chronic obstructive pulmonary disease (COPD). One patient had an uneventful course up to 1 yr after radiotherapy.

Procedures

Finally, 132 patients were considered operable and underwent lung resection by thoracotomy. The mean age was 62 yr (range 23 to 81). The baseline characteristics are summarized in Table 3; they were comparable to the ones obtained in our previous study group (4) (no differences on Student's t test). There were 99 (75%) men and 33 (25%) women. The majority of patients (n = 123) had clinically resectable malignancies whereas a few had benign disorders (n = 3) or carcinoid tumors (n = 6). The operations performed were 38 pneumonectomies, 3 bilobectomies, 82 lobectomies, and 9 segmental or wedge resections. There were no operative deaths. All patients were extubated within 24 h.

Postoperative Course

One hundred seventeen patients had an uneventful postoperative course. Postoperative complications (within 30 d) oc-

<table>
<thead>
<tr>
<th>TABLE 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEFINITION OF POSTOPERATIVE COMPLICATIONS (WITHIN 30 D OF SURGERY)*</td>
</tr>
<tr>
<td>Acute CO2 retention (partial pressure of arterial CO2 &gt; 45 mm Hg)</td>
</tr>
<tr>
<td>Prolonged mechanical ventilation (&gt; 48 h)</td>
</tr>
<tr>
<td>Symptomatic cardiac arrhythmias necessitating treatment</td>
</tr>
<tr>
<td>Myocardial infarction</td>
</tr>
<tr>
<td>Pneumonia (temperature &lt; 38°C, purulent sputum and infiltrate on chest roentgenogram)</td>
</tr>
<tr>
<td>Pulmonary embolism (high probability ventilation/perfusion scan or diagnostic pulmonary angiogram)</td>
</tr>
<tr>
<td>Lobar atelectasis (necesitating bronchoscopy)</td>
</tr>
<tr>
<td>Death</td>
</tr>
</tbody>
</table>

* According to our previous reports (3, 4).
curred in 15 patients (11%), of whom two died, which reflects an overall mortality rate of 1.5%. Of the 15 patients with complications, four had undergone a pneumonectomy, 10 patients a lobectomy, and one patient a segmental resection. No patient died after pneumonectomy, bilobectomy, or a resection of less than a lobe; the mortality of lobectomies was 2.5% (2 of 82). The two patients who died had a VO₂max-ppo of < 10 ml/kg/min (7.5 and 8.2 ml/kg/min respectively), but > 40% of predicted (41 and 46%). Both had undergone a lobectomy; one died of intractable respiratory failure and the other one of pneumonia and multiple organ failure. The complications are summarized in Table 4. In comparison with our previous study (4) the complication rate was reduced by 49% (from 20 to 68% of pre-

### TABLE 2

<table>
<thead>
<tr>
<th>Age (yr)</th>
<th>Planned Resection</th>
<th>FEV₁ (% pred)</th>
<th>FEV₁-ppo (% pred)</th>
<th>DLCO (% pred)</th>
<th>DLCO-ppo (% pred)</th>
<th>VO₂max (% pred)</th>
<th>VO₂max-ppo (% pred)</th>
<th>Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>M 69</td>
<td>P</td>
<td>60</td>
<td>42</td>
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<td>47</td>
<td>55</td>
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<tr>
<td>F 72</td>
<td>P</td>
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<td>Acute respiratory failure</td>
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<tr>
<td>M 74</td>
<td>L</td>
<td>34</td>
<td>25</td>
<td>38</td>
<td>28</td>
<td>—</td>
<td>—</td>
<td>Acute respiratory failure</td>
</tr>
<tr>
<td>M 70</td>
<td>P</td>
<td>44</td>
<td>18</td>
<td>80</td>
<td>33</td>
<td>79</td>
<td>32</td>
<td>Acute respiratory failure</td>
</tr>
</tbody>
</table>

* Values are expressed as mean ± SD.

**Definition of abbreviations:** L = lobectomy; P = pneumonectomy.

### DISCUSSION

We tested in a prospective study the feasibility of an algorithm established for the functional evaluation of lung resection candidates. The results showed that adherence to the cutoff points of the various parameters reduced the postoperative complications—morbidity and mortality—by half (49%) in comparison to our previous series (4). This improvement was statistically not significant because of the low number of complications, especially the low mortality rate. Clinically, however, we consider a decrease in mortality from 3.8% to 1.5% very relevant, as it is very hard to lower an already low figure further while extending the limits of operability at the same time. A nonoverall morbidity of 11% with a mortality of 1.5% compares favorably with most of the larger published series. Two large studies show even lower mortality than ours: Miller (11) had an overall mortality of 0.64% in a large series of 2,340 patients. Their mortality for pneumonectomy was 4.97%, for lobectomies 0.39%, for wedge resections 0.13, and for exploratory thoracotomies 0.59%. These excellent results may have been achieved, in part, through fairly rigorous patient selection, as for a pneumonectomy the FEV₁ had to be > 2 L, and the FEV₁-ppo > 1 L. A further very low mortality rate of 0.9% was reported by K earney and coworkers in a series of 331 patients (7). The bulk of the literature shows that there is a clear correlation between the extent of resection and postoperative morbidity and mortality. Segmental or wedge resections have the lowest and pneumonectomies the highest risk (1, 4, 11-14). In a large series by Loddenkemper comprising 433 patients, the mortality rates after pneumonectomy were 9.4% and after lobectomy 5.1% (12). In Markos's study the rates were 16.7% and 0% (1). At our institution an early series had respective rates of 7 and 4% for the years 1972-1978 (13), and 10 and 2.2% for the years 1991-1992 (4). In recent years, the mortality rates after lung resection have generally decreased although the limits of operability have been extended. In our opinion, these results have been achieved through better functional evaluation before lung resection, but also through improved perioperative care.

The two patients who died after a lobectomy in our study were known high-risk candidates with borderline operability. These two patients, as well as the three patients in our previous study (3) who died, all had an absolute VO₂max-ppo value of < 10 ml/kg/min. We therefore slightly amended our algorithm in excluding patients with an absolute VO₂max-ppo value of < 10 ml/kg/min, even if their percentage of predicted value was > 40%. On the other hand, we could lower the percentage of predicted VO₂max-ppo value from 40% to 35%, as some patients had survived resections with values between 35-40% of predicted, provided that the absolute value was ≥ 10 ml/kg/min. In practice, this change makes it more diffi-
The latest development in the field of thoracic surgery is lung volume reduction surgery (LVRS) to improve pulmonary function in patients with severe emphysema (19). Such patients—deemed inoperable according to our algorithm—might become eligible again through a combination of LVRS and simultaneous pulmonary nodules removed by wedge resection. With this new concept the limits of functional operability will potentially be taken another step further. It must be emphasized, however, that most of the resected patients—deemed inoperable according to our algorithm—might have been fatal to them. We therefore think that the introduction of our algorithm did not unnecessarily exclude patients from surgery. The comparison with our previous study should be largely unbiased, as the baseline patient data were comparable to the current study, and the surgical team and technique as well as the perioperative management were identical. Thus the better outcome reflects the impact of the algorithm.

A n important aspect is the cost involved in the preoperative investigation. Half of all patients had a normal ECG, and an FEV1 and DLCO of ≥ 80% of predicted and thus qualified for a resection of up to a pneumonectomy without further investigations. A mother 51 of the remaining 68 also qualified for a resection up to that extent after exercise testing. Thus 118 (86%) patients were potentially operable for a pneumonectomy after noninvasive cardiopulmonary testing. The need for radionuclide studies was reduced to 17 (12%) patients only. In our institution, exercise testing is about 20% cheaper than a radionuclide study and can be conducted in the pulmonary function laboratory. We therefore prefer to use it before radionuclide studies. This is in contrast to algorithms proposed by Bechard (16) and Nakahara and colleagues (17), where radionuclide studies are done before exercise testing. Overall, we think that our algorithm is economical especially when taking into account the spared costs due to the improved complication rates. Video-assisted thoracoscopic surgery (VATS) has been reported to be associated with lower complication rates than open thoracotomy (18), and might therefore help in further lowering the threshold of functional operability. Whether VATS can provide adequate intraoperative cancer staging is uncertain. Therefore, this procedure cannot become established as routine practice for lung cancer surgery as long as long-term survival rates are not available.

The latest development in the field of thoracic surgery is lung volume reduction surgery (LVRS) to improve pulmonary function in patients with severe emphysema (19). Such patients—deemed inoperable according to our algorithm—might become eligible again through a combination of LVRS and simultaneous cancer surgery. First reports by Gonzalez Munoz and coworkers (20), Cooper and coworkers (21), and McCenna and coworkers (22) have shown the feasibility of this approach by removing functionally poor “target zones” of the lung with LVRS and simultaneously pulmonary nodules which were either within or outside these target zones. Some of these nodules were stage I lung cancer, which were mostly removed by wedge resection. With this new concept the limits of functional operability will potentially be taken another step further. It must be emphasized, however, that most of the reported patients (22, 23) had been scheduled for LVRS and their cancers were chance discoveries on preoperative computed tomographic (CT) scans; patients who primarily present

### TABLE 4

**PATIENTS WITH POSTOPERATIVE COMPLICATIONS**

<table>
<thead>
<tr>
<th>Age</th>
<th>Sex</th>
<th>FEV1 (L)</th>
<th>FEV1 (% pred)</th>
<th>PVV (L)</th>
<th>PVV (% pred)</th>
<th>DlCO (ml/min/mm Hg)</th>
<th>DlCO (% pred)</th>
<th>VO2max (mL/kg/min)</th>
<th>VO2max (% pred)</th>
<th>Operation</th>
<th>Complications</th>
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<tbody>
<tr>
<td>1</td>
<td>58</td>
<td>M</td>
<td>2.8</td>
<td>81</td>
<td>3.6</td>
<td>84</td>
<td>39.4</td>
<td>134</td>
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<td>L</td>
</tr>
<tr>
<td>2</td>
<td>66</td>
<td>M</td>
<td>3.2</td>
<td>104</td>
<td>4.8</td>
<td>120</td>
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<td>F</td>
<td>2.4</td>
<td>139</td>
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<td>104</td>
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<td>RUL</td>
<td>Atelectasis</td>
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<td>M</td>
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<td>19.2</td>
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<td>M</td>
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<td>84</td>
<td>14.1</td>
<td>83</td>
<td>RUL</td>
</tr>
</tbody>
</table>

**Mean**

|                  | 2.4 | 87 | 3.5 | 98 | 26.8 | 103 | 17.0 | 77 |

**SD**

|                  | 0.4 | 24 | 0.6 | 24 | 7.3  | 25  | 4.6  | 12 |

**Definition of abbreviations:** L = left side; LLL = left lower lobe; LUL = left upper lobe; R = right side; RLL = right lower lobe; RUL = right upper lobe.

* = Test not necessary according to algorithm.

† Death arrhythmia = symptomatic supraspinal or ventricular arrhythmias requiring treatment.

‡ Atelectasis = at least one lobe requiring bronchoscopy.

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### TABLE 5

**MORBIDITY AND MORTALITY**

<table>
<thead>
<tr>
<th></th>
<th>1/93–9/96 (n = 132)</th>
<th>1/91–12/92* (n = 80)</th>
</tr>
</thead>
</table>

**Morbidity**

<table>
<thead>
<tr>
<th></th>
<th>15 (11%)</th>
<th>16 (20%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myocardial infarction</td>
<td>0</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>Arrhythmia</td>
<td>3 (2%)</td>
<td>7 (9%)</td>
</tr>
<tr>
<td>Stroke</td>
<td>0</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>1 (1%)</td>
<td>4 (5%)</td>
</tr>
<tr>
<td>Atelectasis</td>
<td>10 (8%)</td>
<td>4 (5%)</td>
</tr>
<tr>
<td>Respiratory failure</td>
<td>1 (1%)</td>
<td>3 (4%)</td>
</tr>
<tr>
<td>Mortality</td>
<td>2 (1.5%)</td>
<td>3 (3.8%)</td>
</tr>
</tbody>
</table>

* From Bolliger and coworkers (4).
with lung cancer and are secondarily found to be functionally inoperable may have more advanced cancer, which might be less amenable to minimal resections. The long-term follow-up will therefore have to carefully assess whether sublobar resections, which have been shown to be fraught with clearly higher local recurrence rates (24), will remain feasible in such patients. One good argument in favor of limited resections is that "functionally inoperable" patients might have a better out-

Figure 2. Proposed algorithm for the assessment of the cardiopulmonary reserves of lung resection candidates. Patients undergo successive steps from top to bottom, until they qualify for varying extents of resection or are deemed inoperable. The "safety loop" for patients with cardiac problems is indicated in the upper left-hand corner. The dashed line leading from exercise testing back to the cardiac workup is for patients with a negative cardiac history and a normal ECG, who show symptoms or signs of ischemia during exercise. Tl = thallium; Tc = technetium. (With permission from Reference 15.)
come in terms of pulmonary function and even survival when offered LVRS with limited resection in comparison with a nonsurgical treatment modality, such as radiotherapy, chemotherapy, or just best supportive care.

In summary, our results have shown that adherence to our algorithm for preoperative functional evaluation before lung resection reduced morbidity and mortality by half without unnecessarily excluding patients from surgery. For patients with normal or only slightly abnormal PFT (FEV₁ and DLCO) and a negative cardiac history, lung resections up to a pneumonectomy are clearly feasible without exercise or split function studies.

References