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# Preoperative evaluation of the lung resection candidate

## ■ ABSTRACT

Lung resection provides the greatest likelihood of cure for patients with localized lung cancer, but is associated with a risk of mortality, decreased postoperative lung function, and other complications. Lung function testing using spirometry, diffusing capacity of the lung for carbon monoxide, and peak oxygen consumption helps predict the risk of postoperative complications including mortality. Predicting postoperative lung function using the proportion of lung segments to be resected, radionuclide scanning, or other methods is important for assessing surgical risk. The American College of Chest Physicians, the European Respiratory Society/European Society of Thoracic Surgeons and the British Thoracic Society guidelines provide detailed algorithms for preoperative risk assessment, but their recommended approaches differ somewhat. Smoking cessation and pulmonary rehabilitation are perioperative measures that can improve patients' short- and long-term outcomes.

**F**or patients with localized lung cancer, lung resection provides the highest likelihood of a cure. However, only about 20% to 30% of patients are potential candidates for surgical resection because of the stage at which the disease is diagnosed or because of comorbid conditions.<sup>1,2</sup> In one study, poor lung function alone ruled out more than 37% of patients who presented with anatomically resectable disease.<sup>3</sup> The poor prognosis for patients who do not undergo surgery, the likelihood of early mortality from lung resection, and the potential for loss of lung function following resection are

all important considerations in the preoperative pulmonary evaluation of candidates for anatomical lung resection.

## ■ PROGNOSIS OF LUNG CANCER POOR WITHOUT SURGICAL RESECTION

Several studies support the poor prognosis of lung cancer patients who do not undergo resection. In one study of 1,297 screen- and symptom-detected patients, the median duration of survival without surgery was 25 months for patients with screen-detected stage I lung cancer ( $n = 42$ ) and 13 months for those with symptom-detected stage I disease ( $n = 27$ ).<sup>4</sup> Another study of 799 patients with stage I lung cancer who were not treated surgically reported 5- and 10-year survival rates of 16.6% ( $n = 49$ ) and 7.4% ( $n = 49$ ), respectively.<sup>5</sup> In a study of 251 patients with squamous cell carcinoma on sputum cytology, yet negative chest imaging, the 5-year and 10-year survival rates were 53.2% and 33.5%.<sup>6</sup> Another study of 57 patients with potentially resectable disease who did not undergo surgery reported a median survival of 15.6 months, compared with 30.9 months for a group of 346 patients who underwent resection.<sup>7</sup>

## ■ PREDICTORS OF SURGICAL MORTALITY

Several large patient series describe perioperative mortality and the rate of complications for patients undergoing surgical resection for lung cancer. Reported surgical mortality rates in these studies vary from approximately 1% to 5%.<sup>2,8-10</sup> The median age of patients in most of these studies was 65 to 70 years, and many patients had significant medical comorbidity. Predictors of increased surgical mortality include pneumonectomy, bilobectomy, American Society of Anesthesiologists (ASA) Physical Status Scale rating, Zubrod performance status score, renal dysfunction, induction chemoradiation therapy, steroid use, older age, urgent procedures, male gender, forced expiratory volume in 1 second (FEV<sub>1</sub>), and body mass index.<sup>11</sup> In France, a thoracic surgery scoring system

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Dr. Mazzone reported that he has been a member of advisory committees for Boehringer Ingelheim and Oncimmune. He has research supported by Metabolomx.

This article was developed from an audio transcript of Dr. Mazzone's presentation at the "Advances in Lung Cancer Evaluation and Management" symposium held in Cleveland, Ohio, on April 30, 2011. The transcript was formatted and edited by *Cleveland Clinic Journal of Medicine* staff for clarity and conciseness and was then reviewed, revised, and approved by Dr. Mazzone.

doi:10.3949/cjcm.79.s2.04

for in-hospital mortality (Thoracoscore) was developed using data obtained from more than 15,000 patients who were enrolled in a nationally representative thoracic surgery database. Mortality risk factors included in the model were patient age, sex, dyspnea score, ASA score, performance status, priority of surgery, diagnosis, procedure class, and comorbid disease.<sup>12</sup> The model was highly accurate for the prediction of mortality, with a C statistic of 0.86. (1.00 corresponds to perfect outcome prediction.) The model was subsequently validated on 1,675 patients from the United States, where a similar accuracy was noted.<sup>13</sup> The online version of the Thoracoscore risk assessment tool is available at: <http://www.sfar.org/scores2/thoracoscore2.php>.

## ■ REDUCED PULMONARY FUNCTION AFTER RESECTION

Several outcome measures have been used to assess the impact of resection on pulmonary function and quality of life after surgery. Across various studies, postoperative FEV<sub>1</sub> values, diffusing capacity of the lung for carbon monoxide (DLCO) values, and peak oxygen consumption (VO<sub>2</sub> peak) were assessed at various time intervals after lobectomy or pneumonectomy. FEV<sub>1</sub> varied from 84% to 91% of preoperative values for lobectomy,<sup>14-16</sup> and 64% to 66% for pneumonectomy.<sup>14-16</sup> The DLCO was 89% to 96% of preoperative values after lobectomy and 72% to 80% after pneumonectomy.<sup>14,16</sup> VO<sub>2</sub> peak varied from 87% to 100% of preoperative values after lobectomy,<sup>14-16</sup> and 71% to 89% after pneumonectomy.<sup>14-16</sup>

Patients with chronic obstructive pulmonary disease (COPD) typically experience smaller declines in FEV<sub>1</sub> after lobectomy (0% to 8%) than those without COPD (16% to 20%). Declines in DLCO and VO<sub>2</sub> peak are more variable, with reported decreases of 3% to 20% in those with COPD, and 0% to 21% for those without the disease.<sup>17-19</sup>

Lobectomy patients continue to recover pulmonary function for approximately 6 months after surgery. In patients who undergo pneumonectomy, improvement is generally limited after 3 months.<sup>14-16</sup> Loss of lung function may vary significantly with the location of the resection. For example, resection of an emphysematous portion of the lung will probably result in less loss of function.

Few studies specifically examine quality of life after lung resection in patients with lung cancer. In general, patients who undergo resection have a lower quality of life before surgery than the general population.<sup>20</sup> Postsurgical decline in physical measures of health-

related quality of life has been reported during the month after surgery, with a return to baseline after 3 months. Mental quality of life scores did not decrease after surgery, and there was little correlation between quality of life outcomes and measures of pulmonary function.<sup>20</sup>

## ■ LUNG FUNCTION TESTING

Lung function testing helps predict the risk of postoperative complications, including mortality. The two most commonly used measures of pulmonary function are FEV<sub>1</sub> and DLCO.

Both absolute FEV<sub>1</sub> value and percent of predicted FEV<sub>1</sub> strongly predict the risk of postoperative complications. It has been difficult to identify one cutoff value below which resection should not be considered. Studies have suggested preoperative absolute FEV<sub>1</sub> values of 2 L for pneumonectomy and 1.5 L for lobectomy as cutoffs signifying increased short- and long-term surgical risk.<sup>21,22</sup> Percent predicted FEV<sub>1</sub>, which incorporates patient age, sex, and height, is more commonly used to individualize treatment, since absolute values do not take into consideration other patient-related variables. An FEV<sub>1</sub> of 80% predicted or higher has been proposed as a cutoff to proceed with resection without additional testing,<sup>23</sup> but this decision must be individualized to each patient.

Similarly, it has been difficult to identify one cutoff value for the DLCO. As one might expect, the lower the value the higher the risk for a given patient. Patients with DLCO values less than 60% predicted normal<sup>24</sup> had an increased mortality risk, longer hospital stay, and greater hospital costs in one report.

FEV<sub>1</sub> and DLCO are only modestly correlated with one another.<sup>25</sup> In one study, 43% of patients with FEV<sub>1</sub> greater than 80% of predicted had DLCO less than 80% of predicted.<sup>26</sup>

According to guidelines developed by the American College of Chest Physicians (ACCP), spirometry is recommended for patients being considered for lung cancer resection.<sup>27</sup> Patients with FEV<sub>1</sub> that is greater than 80% predicted or greater than 2 L and without evidence of dyspnea or interstitial lung disease are considered suitable candidates for resection, including pneumonectomy, without further testing. Lobectomy without further evaluation may be performed if the FEV<sub>1</sub> is greater than 1.5 L and there is no evidence of dyspnea or interstitial lung disease.

Although assessing FEV<sub>1</sub> values alone may be adequate in patients being considered for lung cancer resection who have no evidence of either undue dyspnea on exertion or interstitial lung disease, the

ACCP recommends also measuring DLCO when these signs are present. Guidelines from the European Respiratory Society (ERS) and the European Society of Thoracic Surgeons (ESTS) recommend routinely measuring DLCO during preoperative evaluation regardless of whether the spirometric evaluation is abnormal.<sup>28</sup> Similarly, the British Thoracic Society (BTS) recommends measuring transfer factor of the lung for carbon monoxide (TLCO) in all patients regardless of spirometric values.<sup>29</sup>

## ■ PREDICTING POSTOPERATIVE LUNG FUNCTION

Several methods have been used to predict postoperative lung function.

### Segment method

The segment method estimates postoperative lung function by multiplying baseline function by the percentage of lung sections that will remain after resection.<sup>30</sup> For example, if preoperative FEV<sub>1</sub> is 1 L and surgery will result in the loss of 25% of lung segments, the predicted postoperative FEV<sub>1</sub> is 750 mL. In a study using 19 lung segments in the calculation, the predicted postoperative lung function correlated well with actual postoperative lung function for patients undergoing lobectomy, but only modestly for patients undergoing pneumonectomy.<sup>30</sup> Another method using 42 subsegments for the calculation, and correcting for segments that were obstructed by tumor, produced very similar results.<sup>31</sup>

### Radionuclide scanning

In other studies, quantitative radionuclide scanning to identify the proportion of lung with poor perfusion produced fair to good correlations between predicted and actual postoperative FEV<sub>1</sub>.<sup>32–35</sup> Techniques that are used less often include quantitative computed tomography (CT) and measurement of airway vibration during respiration.

Studies comparing different methods for predicting postoperative pulmonary function have found that perfusion imaging outperformed other approaches, and that the segment method is not a good predictor of outcome for patients undergoing pneumonectomy.<sup>17,36</sup>

### Additional testing needed

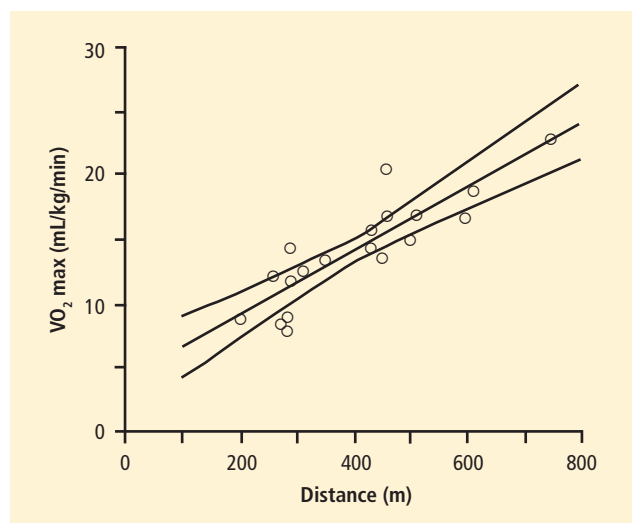
For potential lung resection patients, the ACCP guidelines recommend that if either the FEV<sub>1</sub> or DLCO is less than 80% of the predicted value, postoperative lung function should be predicted through additional testing.<sup>27</sup> The ERS recommends that predicted postoperative FEV<sub>1</sub> should not be used alone

to select lung cancer patients for lung resection, especially those with moderate to severe COPD.<sup>28</sup> These guidelines also recommend that the first estimate of residual lung function should be calculated based on segment counting, that only segments not totally obstructed should be counted, and that the patency of bronchus and segment structure should be preserved. In addition, patients with borderline function should undergo imaging-based calculation of residual lung function, including ventilation or perfusion scintigraphy before pneumonectomy, or quantitative CT scan before either lobectomy or pneumonectomy.<sup>28</sup> The BTS recommends the use of segment counting to estimate postoperative lung function as part of risk assessment for postoperative dyspnea. Ventilation or perfusion scintigraphy should be considered to predict postoperative lung function if a ventilation or perfusion mismatch is suspected. Quantitative CT or MRI may be considered to predict postoperative lung function if the facility is available.<sup>29</sup>

### Predicting mortality and complications: FEV<sub>1</sub> and DLCO

The predicted postoperative FEV<sub>1</sub> value is an independent predictor of postoperative mortality and other complications. Although there is no absolute cut-off value, studies identify an increased risk of complications below predicted postoperative FEV<sub>1</sub> values ranging from 30%<sup>37</sup> to 40%.<sup>38,39</sup> Predicted postoperative DLCO is another outcome measure that can independently identify increased mortality risk in lung cancer resection patients. DLCO less than 40% has been associated with increased risk of postoperative respiratory complications even in those with predicted postoperative FEV<sub>1</sub> values above 40%.<sup>26,39</sup> One study stated that a combination of the two values, predicted postoperative FEV<sub>1</sub> and predicted postoperative DLCO—called the predicted postoperative product (PPP)—is the best predictor of surgical mortality.<sup>40</sup> Another study examined the utility of a prediction rule for pulmonary complications after lung surgery using a point system in which points were assigned based on predicted postoperative DLCO (1 point for each 5% decrement below 100%) plus 2 points for preoperative chemotherapy.<sup>41</sup> The risk of complications was 9% for those with scores less than 11, 14% for those with scores of 11 to 13, and 26% for those with scores greater than 13.

When surgery is considered, ACCP guidelines state an increased risk of perioperative mortality in those lung cancer patients with either a PPP less than 1,650, or a predicted postoperative FEV<sub>1</sub> less than 30%.<sup>27</sup> These patients should be counseled about nonstan-



**FIGURE.** Distance walked during a shuttle walking test is strongly related to maximal oxygen consumption ( $\text{VO}_2$  max).

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Eur Respir J November 1994; 7(11):2016–2020.  
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standard surgery and nonsurgical treatment options. The ERS guidelines consider a predicted postoperative  $\text{FEV}_1$  value less than 30% to be a high-risk threshold when assessing pulmonary reserve before surgery.<sup>28</sup>

## ■ EXERCISE TESTING

In general, standardized cardiopulmonary exercise testing using  $\text{VO}_2$  peak has been shown to predict postoperative complications, including perioperative and long-term morbidity and mortality.<sup>42,43</sup> Lower values are associated with a greater risk of poor outcome. Peak  $\text{VO}_2$  may not add significantly to the risk stratification of patients who have both  $\text{FEV}_1$  and  $\text{DLCO}$  values greater than 80%.<sup>44</sup>

According to ACCP recommendations for exercise testing in patients who are being evaluated for surgery, either an  $\text{FEV}_1$  or  $\text{DLCO}$  less than 40% of predicted postoperative (PPO) indicates increased risk for perioperative death and cardiopulmonary complications with standard lung resection. Preoperative exercise testing is recommended for these patients.<sup>27</sup> Maximal oxygen consumption ( $\text{VO}_2$  max) less than 10 mL/kg/min, or the combination of  $\text{VO}_2$  max less than 15 mL/kg/min with both  $\text{FEV}_1$  and  $\text{DLCO}$  less than 40% PPO, also indicates increased risk for death and complications; these patients should be counseled about nonstandard surgery or nonsurgical treatment options. Guidelines from the ERS recommend exercise testing for all patients undergoing lung cancer surgery who have  $\text{FEV}_1$  or  $\text{DLCO}$  less than 80%

of normal values.<sup>28</sup> The  $\text{VO}_2$  peak measured during incremental exercise on a treadmill or cycle should be regarded as the most important parameter.

Several studies have found that distance traveled during walking tests predicts postoperative complications and can be related to  $\text{VO}_2$  max (Figure).<sup>45</sup> According to ACCP guidelines, lung cancer patients who are potential candidates for standard lung resection are at increased risk for perioperative death and cardiopulmonary complications if they walk less than 25 shuttles on 2 shuttle walk tests or less than 1 flight of stairs. These patients should be counseled about nonstandard surgery and nonsurgical treatment options.<sup>27</sup>

Conversely, ERS/ESTS guidelines state that the shuttle walk test distance underestimates exercise capacity at the lower range, and does not discriminate between patients with and without complications.<sup>28</sup> These guidelines state that shuttle walk test distance should not be used alone to select patients for resection. It may be used as a screening test, since patients walking less than 400 m are likely to also have  $\text{VO}_2$  peak less than 15 mL/kg/min. A standardized symptom-limited stair climbing test can be a cost-effective screening method to identify those who need more sophisticated exercise tests in order to optimize their perioperative management. The 6-minute walk test is not recommended.

British Thoracic Society guidelines recommend the use of the shuttle walk test as a functional assessment in patients with moderate to high risk of postoperative dyspnea.<sup>29</sup> A distance walk of more than 400 m is recommended as a cutoff for acceptable pulmonary function. These guidelines recommend against using pulmonary function and exercise tests as the sole surrogates for a quality of life evaluation.

## ■ ALGORITHMS FOR TESTING

The ACCP, ERS/ESTS, and BTS guidelines all include algorithms for the preoperative evaluation of candidates for lung cancer resection.<sup>27–29</sup> The guidelines differ from each other in many ways, including when to obtain a  $\text{DLCO}$  and cardiopulmonary exercise test, and in some of the cutoff values for various pulmonary function measures. ACCP guidelines begin with spirometry testing, supporting lobectomy in patients with spirometry results above the cutoff value of  $\text{FEV}_1$  greater than 1.5 L and pneumonectomy in those with a cutoff value of  $\text{FEV}_1$  greater than 2 L, and greater than 80% of predicted, unless the patient has dyspnea or evidence of interstitial lung disease. Measurement of the  $\text{DLCO}$  is recommended for those who do not meet the  $\text{FEV}_1$  cutoffs, or in those with



unexplained dyspnea or diffuse parenchymal disease on chest radiograph or CT.<sup>27</sup>

A systematic review and set of treatment recommendations for high-risk patients with stage I lung cancer, developed by the Thoracic Oncology Network of the ACCP and the Workforce on Evidence-Based Surgery of the Society of Thoracic Surgeons, currently under review, will provide additional guidance regarding the use of lung function testing to evaluate risk of morbidity and mortality. These guidelines note that FEV<sub>1</sub>, DLCO, and peak VO<sub>2</sub> all predict morbidity and mortality following major lung resection. Assessment of FEV<sub>1</sub> and DLCO, including calculation of the estimated postoperative value, is strongly recommended before resection. The predictive value of peak VO<sub>2</sub> is strongest in patients with impaired FEV<sub>1</sub> or DLCO, and assessment of peak VO<sub>2</sub> before major lung resection is recommended for these patients.

## ■ INTERVENTIONS TO DECREASE PERIOPERATIVE RISK

The impact of smoking cessation on perioperative outcome has been a matter of considerable debate. One large study found that the incidence of postoperative complications was actually greater when patients stopped smoking within 8 weeks before cardiac surgery.<sup>46</sup> However, a recent meta-analysis including lung resection patients found no relationship between smoking cessation in the weeks before surgery and worse clinical outcomes.<sup>47</sup> When a shorter duration of smoking cessation is examined, thoracotomy studies note that patients who continue to smoke within 1 month of pneumonectomy are at increased risk of major pulmonary events.<sup>48,49</sup> An examination of perioperative mortality or major complications using data from the Society of Thoracic Surgeons found that smoking cessation within 1 month preceding surgery did not significantly affect perioperative morbidity or mortality, whereas longer abstention from tobacco use was associated with better surgical outcomes.<sup>50</sup> The ACCP recommends that all patients with lung cancer be counseled regarding smoking cessation.<sup>27</sup> ERS/ESTS guidelines recommend smoking cessation for at least 2 to 4 weeks before surgery, since this may change perioperative smoking behavior and decrease the risk of postoperative complications.<sup>28</sup> Pulmonary rehabilitation in the perioperative period has been shown to improve measures of activity tolerance, allowing resection of marginal candidates, and improving functional outcomes after resection.<sup>51</sup> The ERS/ESTS guidelines state that early pre- and postoperative rehabilitation may produce functional benefits in resectable lung cancer patients.<sup>28</sup>

## ■ SUMMARY AND CONCLUSIONS

Lung function testing helps predict the risk of postoperative mortality, perioperative complications, and long-term dyspnea for patients with lung cancer undergoing surgical resection. Predicted postoperative FEV<sub>1</sub> and DLCO should be evaluated in most resection candidates. Exercise testing adds to standard lung function testing in those with borderline values, discordance between standard measures, or discordance between subjective and objective lung function. Algorithms for preoperative assessment have been developed by the ACCP, the ERS/ESTS, and the BTS, which differ somewhat in the order of testing and specific testing cutoff values. Smoking cessation and pulmonary rehabilitation can help to reduce perioperative and long-term risks.

## ■ REFERENCES

1. Damhuis RA, Schütte PR. Resection rates and postoperative mortality in 7,899 patients with lung cancer. *Eur Respir J* 1996; 9:7–10.
2. Little AG, Rusch VW, Bonner JA, et al. Patterns of surgical care of lung cancer patients. *Ann Thorac Surg* 2005; 80:2051–2056.
3. Baser S, Shannon VR, Eapen GA, et al. Pulmonary dysfunction as a major cause of inoperability among patients with non-small-cell lung cancer. *Clin Lung Cancer* 2006; 7:344–349.
4. Sobue T, Suzuki T, Matsuda M, Kuroishi T, Ikeda S, Naruke T. Survival for clinical stage I lung cancer not surgically treated: comparison between screen-detected and symptom-detected cases. The Japanese Lung Cancer Screening Research Group. *Cancer* 1992; 69:685–692.
5. Motohiro A, Ueda H, Komatsu H, Yanai N, Mori T; National Chest Hospital Study Group for Lung Cancer. Prognosis of non-surgically treated, clinical stage I lung cancer patients in Japan. *Lung Cancer* 2002; 36:65–69.
6. Sato M, Saito Y, Endo C, et al. The natural history of radiographically occult bronchogenic squamous cell carcinoma: a retrospective study of overdiagnosis bias. *Chest* 2004; 126:108–113.
7. Loewen GM, Watson D, Kohman L, et al. Preoperative exercise VO<sub>2</sub> measurement for lung resection candidates: results of Cancer and Leukemia Group B Protocol 9238. *J Thorac Oncol* 2007; 2:619–625.
8. Allen MS, Darling GE, Pechet TT, et al. Morbidity and mortality of major pulmonary resections in patients with early-stage lung cancer: initial results of the randomized, prospective ACOSOG Z0030 trial. *Ann Thorac Surg* 2006; 81:1013–1020.
9. Meguid RA, Brooke BS, Chang DC, Sherwood JT, Brock MV, Yang SC. Are surgical outcomes for lung cancer resections improved at teaching hospitals? *Ann Thorac Surg* 2008; 85:1015–1025.
10. Memtsoudis SG, Besculides MC, Zellos L, Patil N, Rogers SO. Trends in lung surgery: United States 1988 to 2002. *Chest* 2006; 130:1462–1470.
11. Kozower BD, Sheng S, O'Brien SM, et al. STS database risk models: predictors of mortality and major morbidity for lung cancer resection. *Ann Thorac Surg* 2010; 90:875–883.
12. Falcoz PE, Conti M, Brouchet L, et al. The Thoracic Surgery Scoring System (Thoracoscore): risk model for in-hospital death in 15,183 patients requiring thoracic surgery [published online ahead of print January 9, 2007]. *J Thorac Cardiovasc Surg* 2007; 133:325–332. doi:10.1016/j.jtcvs.2006.09.020
13. Chamogeorgakis TP, Connery CP, Bhora F, Nabong A, Toumpoulis IK. Thoracoscore predicts midterm mortality in patients undergoing thoracic surgery. *J Thorac Cardiovasc Surg* 2007; 134:883–887.
14. Bolliger CT, Jordan P, Soler M, et al. Pulmonary function and exercise capacity after lung resection. *Eur Respir J* 1996; 9:415–421.

15. Nezu K, Kushibe K, Tojo T, Takahama M, Kitamura S. Recovery and limitation of exercise capacity after lung resection for lung cancer. *Chest* 1998; 113:1511–1516.
16. Brunelli A, Xiumé F, Refai M, et al. Evaluation of expiratory volume, diffusion capacity, and exercise tolerance following major lung resection: a prospective follow-up analysis. *Chest* 2007; 131:141–147.
17. Smulders SA, Smeenk FW, Janssen-Heijnen ML, Postmus PE. Actual and predicted postoperative changes in lung function after pneumonectomy: a retrospective analysis. *Chest* 2004; 125:1735–1741.
18. Edwards JG, Duthie DJ, Waller DA. Lobar volume reduction surgery: a method of increasing the lung cancer resection rate in patients with emphysema. *Thorax* 2001; 56:791–795.
19. Bobbio A, Chetta A, Carbognani P, et al. Changes in pulmonary function test and cardiopulmonary exercise capacity in COPD patients after lobar pulmonary resection [published online ahead of print September 6, 2005]. *Eur J Cardiothorac Surg* 2005; 28:754–758. doi:10.1016/j.ejcts.2005.08.001
20. Brunelli A, Refai M, Salati M, Xiumé F, Sabbatini A. Predicted versus observed FEV<sub>1</sub> and DLCO after major lung resection: a prospective evaluation at different postoperative periods. *Ann Thorac Surg* 2007; 83:1134–1139.
21. Boushy SF, Billig DM, North LB, Helgason AH. Clinical course related to preoperative and postoperative pulmonary function in patients with bronchogenic carcinoma. *Chest* 1971; 59:383–391.
22. Wernly JA, DeMeester TR, Kirchner PT, Myerowitz PD, Oxford DE, Golomb HM. Clinical value of quantitative ventilation-perfusion lung scans in the surgical management of bronchogenic carcinoma. *J Thorac Cardiovasc Surg* 1980; 80:535–543.
23. Wyser C, Stulz P, Solèr M, et al. Prospective evaluation of an algorithm for the functional assessment of lung resection candidates. *Am J Respir Crit Care Med* 1999; 159:1450–1456.
24. Bousamra M II, Presberg KW, Chammas JH, et al. Early and late morbidity in patients undergoing pulmonary resection with low diffusion capacity. *Ann Thorac Surg* 1996; 62:968–975.
25. Ferguson MK, Little L, Rizzo L, et al. Diffusing capacity predicts morbidity and mortality after pulmonary resection. *J Thorac Cardiovasc Surg* 1988; 96:894–900.
26. Brunelli A, Refai MA, Salati M, Sabbatini A, Morgan-Hughes NJ, Rocco G. Carbon monoxide lung diffusion capacity improves risk stratification in patients without airflow limitation: evidence for systematic measurement before lung resection [published online ahead of print February 14, 2006]. *Eur J Cardiothorac Surg* 2006; 29:567–570. doi:10.1016/j.ejcts.2006.01.014
27. Colice GL, Shafazand S, Griffin JP, Keenan R, Bolliger CT; American College of Chest Physicians. Physiologic evaluation of the patient with lung cancer being considered for resectional surgery: ACCP evidenced-based clinical practice guidelines (2nd edition). *Chest* 2007; 132(suppl 3):161S–177S.
28. Brunelli A, Charloux A, Bolliger CT, et al. ERS/ESTS clinical guidelines on fitness for radical therapy in lung cancer patients (surgery and chemo-radiotherapy). *Eur Respir J* 2009; 34:17–41.
29. Lim E, Baldwin D, Beckles M, et al. Guidelines on the radical management of patients with lung cancer. *Thorax* 2010; 65(suppl 3):iii1–iii27.
30. Zeiher BG, Gross TJ, Kern JA, Lanza LA, Peterson MW. Predicting postoperative pulmonary function in patients undergoing lung resection. *Chest* 1995; 108:68–72.
31. Nakahara K, Monden Y, Ohno K, Miyoshi S, Maeda H, Kawashima Y. A method for predicting postoperative lung function and its relation to postoperative complications in patients with lung cancer. *Ann Thorac Surg* 1985; 39:260–265.
32. Kristersson S, Lindell SE, Svanberg L. Prediction of pulmonary function loss due to pneumonectomy using 133 Xe-radiospirometry. *Chest* 1972; 62:694–698.
33. Bria WF, Kanarek DJ, Kazemi H. Prediction of postoperative pulmonary function following thoracic operations: value of ventilation-perfusion scanning. *J Thorac Cardiovasc Surg* 1983; 86:186–192.
34. Ali MK, Mountain CF, Ewer MS, Johnston D, Haynie TP. Predicting loss of pulmonary function after pulmonary resection for bronchogenic carcinoma. *Chest* 1980; 77:337–342.
35. Corris PA, Ellis DA, Hawkins T, Gibson GJ. Use of radionuclide scanning in the preoperative estimation of pulmonary function after pneumonectomy. *Thorax* 1987; 42:285–291.
36. Bolliger CT, Gückel C, Engel H, et al. Prediction of functional reserves after lung resection: comparison between quantitative computed tomography, scintigraphy, and anatomy. *Respiration* 2002; 69:482–489.
37. Nakahara K, Ohno K, Hashimoto J, et al. Prediction of postoperative respiratory failure in patients undergoing lung resection for lung cancer. *Ann Thorac Surg* 1988; 46:549–552.
38. Markos J, Mullan BP, Hillman DR, et al. Preoperative assessment as a predictor of mortality and morbidity after lung resection. *Am Rev Respir Dis* 1989; 139:902–910.
39. Ribas J, Diaz O, Barberà JA, et al. Invasive exercise testing in the evaluation of patients at high-risk for lung resection. *Eur Respir J* 1998; 12:1429–1435.
40. Pierce RJ, Copland JM, Sharpe K, Barter CE. Preoperative risk evaluation for lung cancer resection: predicted postoperative product as a predictor of surgical mortality. *Am J Respir Crit Care Med* 1994; 150:947–955.
41. Amar D, Munoz D, Shi W, Zhang H, Thaler HT. A clinical prediction rule for pulmonary complications after thoracic surgery for primary lung cancer [published online ahead of print October 27, 2009]. *Anesth Analg* 2010; 110:1343–1348. doi:10.1213/ANE.0b013e3181bf5c99
42. Benzo R, Kelley GA, Recchi L, Hofman A, Sciurba F. Complications of lung resection and exercise capacity: a meta-analysis [published online ahead of print April 3, 2007]. *Respir Med* 2007; 101:1790–1797. doi:10.1016/j.rmed.2007.02.012
43. Jones LW, Eves ND, Kraus WE, et al. The lung cancer exercise training study: a randomized trial of aerobic training, resistance training, or both in postsurgical lung cancer patients: rationale and design. *BMC Cancer* 2010; 10:155.
44. Larsen KR, Svendsen UG, Milman N, Brenøe J, Petersen BN. Exercise testing in the preoperative evaluation of patients with bronchogenic carcinoma. *Eur Respir J* 1997; 10:1559–1565.
45. Singh SJ, Morgan MDL, Hardman AE, Rowe C, Bardsley PA. Comparison of oxygen uptake during a conventional treadmill test and the shuttle walking test in chronic airflow limitation. *Eur Respir J* 1994; 7:2016–2020.
46. Warner MA, Divertie MB, Tinker JH. Preoperative cessation of smoking and pulmonary complications in coronary artery bypass patients. *Anesthesiology* 1984; 60:380–383.
47. Myers K, Hajek P, Hinds C, McRobbie H. Stopping smoking shortly before surgery and postoperative complications: a systematic review and meta-analysis [published online ahead of print March 14, 2011]. *Arch Intern Med* 2011; 171:983–989. doi:10.1001/archinternmed.2011.97
48. Vaporciyan AA, Merriman KW, Ece F, et al. Incidence of major pulmonary morbidity after pneumonectomy: association with timing of smoking cessation. *Ann Thorac Surg* 2002; 73:420–426.
49. Barrera R, Shi W, Amar D, et al. Smoking and timing of cessation: impact on pulmonary complications after thoracotomy. *Chest* 2005; 127:1977–1983.
50. Mason DP, Subramanian S, Nowicki ER, et al. Impact of smoking cessation before resection of lung cancer. A Society of Thoracic Surgeons General Thoracic Surgery Database study. *Ann Thorac Surg* 2009; 88:362–371.
51. Cesario A, Ferri L, Galetta D, et al. Pre-operative pulmonary rehabilitation and surgery for lung cancer. *Lung Cancer* 2007; 57:118–119.

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