The Evaluation and Preparation of the Patient for Lung Volume Reduction Surgery

Malcolm M. DeCamp¹, Jr., David Lipson², Mark Krasna³, Omar A. Minai⁴, Robert J. McKenna⁵, Jr., and Byron M. Thomashow⁶

¹Beth Israel Deaconess Medical Center, Boston, Massachusetts; ²University of Pennsylvania Medical Center, Philadelphia, Pennsylvania; ³St. Joseph’s Medical Center, Towson, Maryland; ⁴Cleveland Clinic Foundation, Cleveland, Ohio; ⁵ Cedars-Sinai Medical Center, Los Angeles, California; ⁶Columbia-Presbyterian Medical Center, New York, New York

Potential candidates for lung volume reduction surgery should undergo extensive evaluation and preparation to minimize peroperative risks and optimize surgical outcomes. Initial screening includes spirometry, diffusion capacity, lung volumes by body plethysmography, and high-resolution computerized tomography scanning. Patients who have been successfully screened must complete a preoperative pulmonary rehabilitation program of 6–10 weeks duration. During the pulmonary rehabilitation program, medical therapy should be maximized. Postrehabilitation studies include cardiopulmonary exercise testing, arterial blood gas analysis, oxygen titration, six-minute walk, and cardiac testing. The evaluation process aims at defining the severity and distribution of emphysema and attempts to eliminate those who do not meet criteria outlined by the National Emphysema Treatment Trial. Optimal candidates have upper-lobe–predominant emphysema and acceptable operative risks.

Keywords: preoperative evaluation; lung volume reduction surgery; emphysema; pulmonary rehabilitation; chronic obstructive pulmonary disease

Lung volume reduction surgery (LVRS) carries substantial risks for mortality and complications (1, 2). The evaluation process and medical preparation of potential candidates for LVRS can minimize those risks and are critical to any successful LVRS program. The goal is to identify patients most likely to have a favorable response to the surgery and then position them to attain a favorable outcome with the help of a pulmonary rehabilitation program and optimization of medical treatment.

The screening and evaluation process and medical preparation recommended for LVRS candidates are based on the processes used in the National Emphysema Treatment Trial (NETT), modified and informed with results from the NETT (3). The NETT selection criteria and results were used by the Centers for Medicare and Medicaid Services (CMS) when formulating their decision to cover LVRS for selected patients (4).

The NETT selection criteria were designed to select patients with severe bilateral emphysema without comorbidities that would preclude surgery. The NETT retrospectively identified five subgroups of patients with different risks and benefits after LVRS. Two subgroups had higher risk of mortality after LVRS compared with medical treatment and had little chance of benefit from LVRS; patients in these subgroups are not candidates for LVRS (2, 3). Patients in the remaining three subgroups identified by the NETT as benefitting from LVRS have improvement in at least one outcome category (survival, exercise capacity, or quality of life) after LVRS compared with medical treatment and are candidates for LVRS (3).

The decision to proceed with LVRS is based on careful weighing of individual risks and benefits and requires comprehensive discussions between patients, family members, and health care providers. The recommendations that follow are based on experience gained through the NETT trial and are consistent with the criteria CMS adopted for payment of LVRS for their beneficiaries.

SCREENING AND EVALUATION

Criteria for distinguishing good and poor candidates for LVRS are shown in Table 1, and the screening and evaluation procedures are listed in Table 2. This initial screen includes important historical information and basic testing. The screening process can eliminate patients as potential candidates but is only the first step of a possible approval process.

The screening process documents the presence of emphysema on clinical, radiological, and pulmonary function criteria and attempts to eliminate patients who would face unacceptable operative risks. Prior LVRS by laser or excision and previous sternotomy or lobectomy are viewed as exclusion criteria because they could significantly increase the risk for pleural adhesions and postoperative air leak. Extensive adhesions are associated with less improvement after LVRS, and air leak is the major contributor to postoperative morbidity. Medical contraindications include any conditions that increase the perioperative risk or predict a short life expectancy due to nonemphysema illnesses. A history of recurrent bronchial infection with clinically significant daily sputum production and/or clinically significant bronchiectasis are also contraindications. Myocardial infarction within 6 months with an ejection fraction less than 45%, congestive heart failure with an ejection fraction less than 45%, or uncontrolled hypertension (systolic > 200 mm Hg or diastolic > 100 mm Hg) are contraindications for LVRS. The presence of significant pleural or interstitial lung disease may also prevent LVRS. Although severe emphysema may preclude surgical resection of a pulmonary nodule, surgical techniques developed for LVRS have allowed resection of lung nodules previously believed to be unresectable because of respiratory limitations (5, 6). Reactive airway disease is not a contraindication for LVRS; however, the presence of significant airway bronchoreactivity suggests that the primary disease process may be more of an inflammatory airway disease and thus less likely to improve after LVRS.

Active or recent smoking not only increases perioperative risks (7); it also increases the chances for postoperative re-accumulation of smoking. Because smoking leads to more rapid

(Received in original form July 3, 2007; accepted in final form August 17, 2007)

The National Emphysema Treatment Trial (NETT) is supported by contracts with the National Heart, Lung, and Blood Institute (N01HR76101, N01HR76102, N01HR76103, N01HR76104, N01HR76105, N01HR76106, N01HR76107, N01HR76108, N01HR76109, N01HR76110, N01HR76111, N01HR76112, N01HR76113, N01HR76114, N01HR76115, N01HR76116, N01HR76118, and N01HR76119), the Centers for Medicare and Medicaid Services (CMS), and the Agency for Healthcare Research and Quality (AHRQ).

Correspondence and requests for reprints should be addressed to Byron M. Thomashow, M.D., Columbia-Presbyterian Medical Center, Herbert Irving Pavilion, Suite 311, 161 Fort Washington Avenue, New York, NY 10032. E-mail: bmt1@columbia.edu

DOI: 10.1513/pats.200707-087ET
Internet address: www.atsjournals.org
deterioration in lung function, smoking after LVRS would likely lead to more rapid loss of any functional gains. Candidates for LVRS should be nonsmokers for more than 4 months. The 4-month requirement recognizes that all candidates are required to complete 6–10 weeks of pulmonary rehabilitation and must remain nonsmokers through this period. The combined duration of abstinence is therefore at least 6 months, which is consistent with the findings of smoking cessation research that the rate of recidivism does not stabilize until at least 6 months after cessation (8). Documentation of smoking status with plasma cotinine or arterial carboxyhemoglobin levels may be required.

Elevated body mass index (BMI) can limit lung function and may increase postoperative respiratory complications, so patients should be at or below the upper limit of acceptable BMI before surgery (Table 1). The NETT required a BMI of less than 31.1 kg/m² for male patients and less than 32.3 kg/m² for female patients.

The screening process attempts to evaluate severity of functional limitation, severity of airflow limitation, and degree of air trapping. As a gauge of functional limitation the NETT required a postrehabilitation six-minute-walk distance of over 140 m. Investigators believed that patients with more severe limitations would face higher operative risks. Pulmonary function testing, including pre- and post-bronchodilator spirometry, lung volumes measured by body plethysmography, and carbon monoxide diffusing capacity, must meet criteria that define severe airflow obstruction and hyperinflation (Table 1). In the NETT, preoperative values for total lung capacity and residual volume were not predictive of differential outcome by treatment.

NETT investigators found that two types of assessments of the distribution of emphysema as seen on high-resolution computerized tomography (HRCT) were predictive of outcome after LVRS (3). Assessment of the heterogeneity of the emphysema is needed; the NETT found that postrehabilitation, post-bronchodilator FEV₁ ≤ 20% predicted, and nonheterogeneous emphysema on HRCT or DL_{CO} ≤ 20% predicted defines a subgroup at high risk of mortality after LVRS (16% 30-d mortality) with little chance of benefit (2). Assessment of the cranio-caudal distribution of emphysema also predicts LVRS outcome when combined with postrehabilitation exercise capacity; patients with non–upper-lobe–predominant emphysema and high exercise capacity postrehabilitation have higher mortality after LVRS than those treated with medical therapy only. Many LVRS centers use quantitative perfusion nuclear lung scans, in addition to HRCT, to help gauge emphysema heterogeneity. However, the NETT failed to show any improvement in predictive value using lung perfusion scans to predict outcome.

The screening evaluation should also check for α₁-antitrypsin deficiency. Although α₁-antitrypsin deficiency is not a contraindication for LVRS, NETT data suggest that patients with this enzyme deficiency, especially patients with basilar predominant emphysema, receive limited benefit from LVRS (9).

### TABLE 1. CRITERIA FOR DETERMINATION OF CANDIDACY FOR LUNG VOLUME REDUCTION SURGERY

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Good Candidates</th>
<th>Poor Candidates</th>
</tr>
</thead>
<tbody>
<tr>
<td>History and physical examination</td>
<td>Age &lt; 75 yr</td>
<td>Age ≥ 75 yr</td>
</tr>
<tr>
<td></td>
<td>Emphysema by clinical evaluation</td>
<td>History of recurrent bronchial infections with increased sputum production</td>
</tr>
<tr>
<td></td>
<td>Ex-smoker &gt; 4 mo*</td>
<td>Cardiovascular comorbidities including significant coronary artery disease, recent MI, CHF, or uncontrolled hypertension or arrhythmias</td>
</tr>
<tr>
<td></td>
<td>Clinically stable on no more than 20 mg prednisone daily</td>
<td>Pulmonary hypertension at rest</td>
</tr>
<tr>
<td></td>
<td>Significant functional limitation after 6–12 wk of pulmonary rehabilitation on optimal medical therapy</td>
<td>Nonpulmonary comorbidities causing significant functional limitation (morbid obesity) or that could limit survival (e.g., cancer)</td>
</tr>
<tr>
<td></td>
<td>Demonstrated compliance with medical regimen</td>
<td>History of thoracic surgery or chest wall deformity that could interfere with pulmonary resection</td>
</tr>
<tr>
<td>Laboratory evaluation</td>
<td>Post-bronchodilator FEV₁ &lt; 45% predicted for all ages and &gt;15% if age &gt;70 yr</td>
<td>FEV₁ &lt; 20% predicted and either DL_{CO} &lt; 20% predicted or homogeneous distribution of emphysema on HRCT scan</td>
</tr>
<tr>
<td></td>
<td>Hyperinflation demonstrated by TLC ≥ 100% predicted and RV &gt; 150% predicted</td>
<td>Non-upper-lobe distribution of emphysema with high exercise capacity postrehabilitation (democratic by maximal achieved cycle ergometry watts)</td>
</tr>
<tr>
<td></td>
<td>Postrehabilitation 6MWD &gt; 140 m</td>
<td>Significant pleural or interstitial changes on HRCT</td>
</tr>
<tr>
<td></td>
<td>Low exercise capacity (demonstrated by maximal achieved cycle ergometry watts)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HRCT demonstrating bilateral severe emphysema, ideally with upper-lobe predominance</td>
<td></td>
</tr>
</tbody>
</table>

### Definition of abbreviations: CHF = congestive heart failure; DL_{CO} = carbon monoxide diffusing capacity; HRCT = high-resolution computed tomography; MI = myocardial infarction; RV = residual volume; 6MWD = six-minute-walk distance; TLC = total lung capacity.

### Phase I: Screening

| History, physical examination, chest roentgenogram, and basic laboratory studies |
| α₁-Antitrypsin testing |
| High-resolution computed tomography scan |
| Pulmonary function testing: spirometry (pre- and post-bronchodilator), lung volumes (by body plethysmography), carbon monoxide diffusing capacity |

### Phase II: Formal evaluation—postrehabilitation

| Dyspnea evaluation: University of California, San Diego, Shortness-of-Breath Questionnaire, or Modified Medical Research Council scale |
| Arterial blood gas level on room air for 10 min |
| Cardiopulmonary exercise testing |
| Oxygen titration and six-minute walk |
| BODE* score |
| Quantitative perfusion nuclear lung scan |
| Cardiac evaluation: echocardiogram, dobutamine-radionuclide cardiac scan |
| Evaluation by medical team including pulmonologists, surgeon, nursing, and rehabilitation staff |

### Definition of abbreviations: BODE = Body-mass index, airflow Obstruction, Dyspnea, and Exercise capacity index.

* Mortality risk based on body mass index, airflow obstruction (FEV₁), dyspnea (using the Modified Medical Research Council dyspnea scale), and exercise capacity (measured by six-minute walk).
If screening suggests that a patient may be a potential surgical candidate, additional testing is required. An oxygen requirement at rest or during ambulation exceeding 6 L/minute to keep oxygen saturation at 90% or greater is considered a contraindication for LVRS. Cardiac evaluation includes an echocardiogram and a dobutamine-radiouclide cardiac scan. If peak systolic pulmonary artery pressures (Ppa) on echocardiogram are estimated to be 45 mm Hg or greater, a right heart catheterization is required to rule out significant pulmonary hypertension. Echocardiograms notoriously overestimate the degree of pulmonary hypertension in patients with advanced lung disease (10). In the NETT, echocardiographic estimates did not accurately reflect actual pulmonary pressures (11). Mean Ppa on right heart catheterization greater than 35 mm Hg or peak systolic Ppa greater than 45 mm Hg were viewed as contraindications for LVRS to avoid the development of postoperative pulmonary hypertension. Evaluation by a cardiologist for LVRS should be obtained if the dobutamine-radiouclide cardiac scan indicates coronary artery disease or ventricular dysfunction, if the left ventricular ejection fraction is less than 45%, or significant arrhythmia or ectopy are detected at the time of evaluation.

The NETT used the University of California, San Diego, Shortness-of-Breath Questionnaire as a gauge for dyspnea (12). Although the NETT did not use this questionnaire for patient selection, improving dyspnea is one of the major goals of LVRS and an important criterion to consider. Other investigators have used the Modified Medical Research Council (MMRC) dyspnea scale (Table 3) to evaluate the level of dyspnea (13). Celli and colleagues have described a multidimensional grading system for chronic obstructive pulmonary disease (COPD) severity (i.e., the BODE [body-mass index, airflow obstruction, dyspnea, and exercise capacity] index) (14). It assesses mortality risk based on body mass index, airflow obstruction (FEV1), dyspnea (using the Modified Medical Research Council dyspnea scale), and exercise capacity (measured by six-minute walk) and has been found to be better than FEV1 alone in predicting risk of death. Several recent publications have suggested the potential value of the BODE index or a modification of it in assessing and following patients with LVRS (15, 16).

### MEDICAL PREPARATION OF THE CANDIDATE AND FINAL EVALUATION FOR LVRS

If the evaluation suggests that a patient may be a potential LVRS candidate, the patient must complete a preoperative pulmonary rehabilitation program of 6–10 weeks duration. NETT investigators observed significant improvements in exercise capacity, dyspnea, and health-related quality of life after pulmonary rehabilitation (17). By optimizing preoperative physical and emotional function, pulmonary rehabilitation in the NETT helped select appropriate patients for surgery. Approximately 10% of NETT patients improved sufficiently during the rehabilitation program that they became unwilling to accept surgical risks (17). During rehabilitation, other patients who initially seemed appropriate for surgery were too ill or fragile to undergo the procedure. The pulmonary rehabilitation program should include 16 to 20 sessions, each lasting a minimum of 2 hours and including education and exercise components. The program must be consistent with the care plan developed by the treating physician and arranged, monitored, and performed under the coordination of the center where the surgery takes place.

During the pulmonary rehabilitation program, all efforts should be made to maximize medical therapy. Several guidelines are available, including those from the Global Initiative for Chronic Obstructive Lung Disease and the American Thoracic Society and the European Respiratory Society (18, 19). All available guidelines stress the importance of using and potentially combining bronchodilator therapy, preferably long-acting inhaled bronchodilators. Recent data suggest that combining inhaled tiotropium with inhaled salmeterol/fluticasone can be an effective and well-tolerated regimen for advanced COPD (20). Systemic corticosteroids should be weaned off or decreased to the lowest possible tolerated dosage before surgery. Regular systemic corticosteroid therapy seems to be widely used in advanced COPD even though data suggest its only role is for short-course therapy during exacerbations (21). NETT investigators found that systemic corticosteroid use increased postoperative cardiovascular morbidity (odds ratio, 1.72; \( P = 0.04 \)) (1). Therefore, patients should be clinically stable on 20 mg prednisone (or equivalent) or less daily dosing to be considered for LVRS.

By eliminating patients with significant chronic bronchitic, asthmatic, or bronchiectatic components from LVRS consideration, the incidence of acute exacerbations pre- and postsurgery should be limited. However, the risk of exacerbations among patients with COPD increases with an FEV1 less than 50% (22), a threshold all potential LVRS candidates must meet. Over 24% of patients in the NETT were hospitalized or seen in an emergency ward for a COPD exacerbation in the year before study enrollment, and 19.2% required hospitalization (23). Any exacerbation during evaluation for LVRS should be treated aggressively, and surgery should be delayed at least 4–6 weeks after resolution of the exacerbation to allow stabilization.

Patients should be educated before surgery regarding the postoperative course, including postoperative pain issues, pain control regimens, the need for early mobilization, and the importance of postoperative rehabilitation. Oxygen requirements can transiently increase after LVRS, and patients must understand that this does not reflect surgical failure.

On completion of pulmonary rehabilitation, the postrehabilitation six-minute-walk distance must be greater than 140 m, and patients must be able to complete 3 minutes of unloaded pedaling in exercise tolerance testing. The NETT defined the importance of preoperative, symptom-limited maximal cardiopulmonary exercise testing in the LVRS decision-making process. Exercise capacity is measured by incremental, maximal, symptom-limited exercise with a cycle ergometer using a 5 or 10 W/minute ramp on 30% oxygen after 3 minutes of unloaded pedaling. The NETT defined patients with low exercise capacity as those whose maximal postrehabilitation exercise capacity is no greater than 25 W for women and no greater than 40 W for men (maximal workload at or below the gender-specific 40th percentile). High exercise capacity was defined as a maximal workload above this threshold. Combining results from HRCT and postrehabilitation cardiopulmonary exercise testing allows categorizing potential candidates into subgroups (Table 4).

Upper-lobe, low-exercise patients treated with LVRS have lower mortality, greater exercise, and greater improvement in symptoms compared with those treated with medical therapy.
Upper-lobe, high-exercise patients have similar mortality but greater exercise capacity and greater improvement in symptoms compared with those treated medically. Non–upper-lobe, low-exercise patients treated with LVRS have similar mortality to medically treated patients and similar exercise capacity, but those after LVRS are more likely to have fewer symptoms in the first 1–2 years after surgery compared with those treated medically. CMS has approved LVRS for patients in all three of these groups; however, longer-term NETT follow-up has revealed that the quality of life benefit in the non–upper-lobe group wanes by 3 years (24). The NETT also found that the long predictor for increased operative mortality after LVRS was the presence of non–upper-lobe predominant emphysema. Most LVRS centers have tended to only offer LVRS to patients with upper-lobe–predominant disease.

Even if the patient has successfully completed pulmonary rehabilitation and meets all selection criteria, the final decision regarding LVRS requires discussion among the entire LVRS team, the patient, and family members. If the decision is made to proceed to LVRS, several therapeutic interventions could decrease postoperative morbidity. Discontinuing inhaled corticosteroids perioperatively seems prudent because NETT results revealed that preoperative use of inhaled but not oral corticosteroids increased postoperative air leaks (25). Perioperative stress corticosteroid coverage may be needed for patients on chronic systemic corticosteroids. Considering that the incidence of postoperative cardiac arrhythmias of 23.5% (with 8.6% requiring treatment) approaches that seen after coronary bypass surgery, cardiac monitoring for the initial postoperative period should be considered. The use of prophylactic pharmacologic prevention for perioperative cardiac arrhythmias has yet to be studied in this setting.

CONCLUSIONS

Although the NETT has shown that LVRS provides advantages over medical management for selected patients, LVRS carries significant potential risks and, even with the NETT experience to guide practitioners, there are no guarantees of a successful result. Following a careful evaluation process and maximizing medical status before surgery should help minimize postoperative complications and improve the chances of longer-term benefits.

Conflict of Interest Statement: M.D. does not have a financial relationship with a commercial entity that has an interest in the subject of this manuscript. D.L. at the time of writing and drafting the manuscript worked full time at the University of Pennsylvania. Currently he is an employee of GlaxoSmithKline. He does not have a financial relationship with a commercial entity that has an interest in the subject of this manuscript. M.K. does not have a financial relationship with a commercial entity that has an interest in the subject of this manuscript. O.M. does not have a financial relationship with a commercial entity that has an interest in the subject of this manuscript. R.M. runs VATS lobectomy courses for thoracic surgeons. The surgeons hear a lecture with videos and then spend the day in the operating room to observe. B.M.T. attended an advisory board meeting for Boehringer Ingelheim (BI)/Pfizer in 2006. B.M.T. is on the speakers bureau for BI, Pfizer, and GlaxoSmithKline.

References


13. Bestall JC, Paul EA, Garrod R, Garnham R, Jones PW, Wedzicha JA. Usefulness of the Medical Research Council (MRC) dyspnea scale as...


