Thoracic and Cardiovascular Surgery

Complications in Patients with Severe Emphysema

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Thoracic surgeons frequently evaluate patients with severe emphysema and concomitant pathology requiring pulmonary resection. There are no absolute guidelines defining the suitability of a given patient for resection. In this review, we outline our approach to evaluating and treating patients with severe emphysema in need of resection. We describe the lessons learned from lung volume reduction surgery and apply that knowledge to the care of the patient with severe emphysema. Careful preoperative evaluation of the patient's lung anatomy, distribution of emphysematous changes in the lung, and overall health is essential to identifying the appropriate candidate for resection and avoiding postoperative complications.
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Over 12 million Americans have some form chronic obstructive pulmonary disease (COPD). As many as 2 million of them have emphysema.[1] Emphysema is a progressive disease that results in a continued decline in pulmonary function. When pulmonary function tests document a forced expiratory volume in 1 second (FEV1) of less than 30% of the value predicted by nomograms, the 3-year mortality risk has been estimated at 40% to 50%.[2] Many of the same risk factors for the development of emphysema contribute to the development of lung cancer, so it is quite common for thoracic surgeons to evaluate and treat patients with emphysema of varying severity.

Although anatomic surgical resection is the treatment of choice in patients with non-small cell lung cancer, the presence of severe emphysema may make resection riskier or may altogether preclude resection. There are numerous reports on the association between preoperative lung function and postoperative morbidity and mortality. A number of authors have suggested different pulmonary function tests and decision thresholds to preclude or allow resection.[3] However, as we and others have demonstrated in the experience with lung volume reduction surgery (LVRS), poor preoperative PFT parameters are not, by themselves, reasons to exclude patients from beneficial lung resection. In this review, we discuss complications uniquely prevalent in patients with advanced emphysema, with emphasis on their avoidance, early detection, and management.

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Rationale for Lung Resection to Improve Function in Emphysema Patients—Lung Volume Reduction Surgery

Emphysema is defined as the dilation of the terminal lung units beyond the terminal bronchiole associated with alveolar wall destruction. Emphysema is unevenly distributed throughout the lungs, resulting in regional variation in both structure and function. The success of lung volume reduction surgery (LVRS) depends on exploiting the heterogeneous distribution of the disease. The National Emphysema Treatment Trial (NETT) has demonstrated that improvement in pulmonary function and exercise tolerance is seen only in patients with heterogeneous emphysema, particularly in those patients with upper lobe predominance of disease.[4]

In patients with severe emphysema and an underlying malignancy, the ideal candidate for resection presents with an early stage lung cancer set in a background of nonfunctioning, hyperexpanded, emphysematous lung. The rest of the lung must be relatively spared of emphysema. The goals of operation are to both treat the underlying malignancy and achieve a LVRS effect to minimize the impact of the pulmonary resection on postoperative function.

Avoiding Complications by Proper Patient Selection

The evaluation of patients for resection relies heavily on physiologic and imaging studies. The standard chest com-

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puted tomography (CT) examination provides critical information for the selection process. Most important, it provides a detailed depiction of the severity and distribution of emphysema. This is most helpful in characterizing whether the patient's limitations are secondary to emphysema or airway disease. The CT scan is also important in establishing the presence and location of target areas for resection. High-resolution CT provides increased sensitivity for revealing occult bronchiectasis or underlying interstitial lung disease, which may decrease enthusiasm for resection. The findings of bronchiectasis on CT imaging or clinical findings of copious sputum production should not be discounted. These findings are relative contraindications for safe lung resection in patients with marginal pulmonary function tests.

Because the entire lung is affected to some degree by emphysema, it may be difficult to assess whether the disease is sufficiently heterogeneous in distribution by CT scan alone. Nuclear medicine ventilation-perfusion lung scans depicting regional blood flow patterns provide a valuable visual roadmap for surgery. The absolute severity of emphysema cannot be assessed because the distribution of the perfusion agent is relative, but the presence of diffuse versus upper or lower lobe predominant disease can be assessed.

Review of the surgical results of LVRS reveals several predictors of surgical mortality. Most notably, the NETT initially favored broad inclusion of patients with hyperexpansion and emphysema, many of whom did not meet the criterion of "target areas" that formed the basis of patient selection in the earliest reports. The early broad inclusion criteria of the NETT allowed identification of some high risk patients: patients with FEV1 $<$20% of predicted *and* either homogenous distribution of emphysema on CT scan *or* carbon monoxide diffusion capacity (DLCO) $<$20% predicted.[5] These patients had no change in exercise ability, no improvement in FEV1, no change in 6-minute walk distance, and no improvement in quality of life; they had a 16% 30-day mortality rate. The mortality seen in these high-risk patients prompted a modification of the NETT protocol to exclude from randomization any patient meeting these criteria. Retrospective review of patients meeting the NETT "high risk" criteria for FEV1 and DLCO by Meyers and colleagues in their own series of patients with heterogeneous emphysema did not demonstrate excess mortality and showed improvement in respiratory function.[6] Subgroup analysis of the NETT high-risk patients also confirmed that the greatest risk of mortality came to those lacking target areas. These two observations suggest that presence of suitable anatomic heterogeneity may be the most important determinant of outcome. In the follow-up publication on the morbidity and mortality experienced by patients undergoing LVRS, the NETT investigators reported 5.5% 90-day mortality among the 511 non-high risk patients who were randomized to surgery and underwent LVRS. Non-upper lobe predominant emphysema was the only predictor of 90-day mortality.[7]

Preoperative Medical Management

Foremost among medical interventions is the cessation of smoking. Studies have documented a decreased incidence of pulmonary complications if a patient has been abstinent for at least 4 weeks before lung resection.[8,9] Patients who quit smoking in a shorter interval before surgery may not achieve the same benefits of smoking cessation.[10] However, smokers should still be counseled to stop smoking, regardless of the time remaining between smoking cessation and the planned operation. Barrera and colleagues have subsequently documented no paradoxical increase in pulmonary complications in patients who quit smoking shortly before lung resection.[10] This important finding is in contrast to work that has been previously reported suggesting that short-term quitters actually did worse than those who continued to smoke until the day of surgery.[9]

In addition, all patients with severe emphysema should be enrolled in a structured pulmonary rehabilitation program. The comprehensive program should include exercise training, optimization of medical management, patient education, psychosocial assessment and treatment, and optimization of nutrition. It is generally believed that such a program has multiple benefits, including the actual physical training that is received by the patient as well as the screening effect it has on preventing unmotivated or profoundly disabled patients from being exposed to the risk of operation.

A graded exercise program is essential to pulmonary rehabilitation. Many patients with COPD are dyspneic and fear overexertion. As a result, these patients become increasingly sedentary, leading to progressive deconditioning. Patients then experience a diminished exercise tolerance, and a self-replicating cycle continues. Therefore, a graded exercise program should be initiated immediately for all patients with severe COPD. In our own experience of lung cancer resection combined with LVRS, the majority of patients were enrolled in a pulmonary rehabilitation program.[11] Exercise training is designed to decrease exertional dyspnea and to increase endurance and maximal exercise capacity. Exercise therefore acts as a cornerstone of the patient's return to a more active lifestyle. A detailed description of the program used in the NETT is provided by Ries and coworkers.[12]

Assessment of cardiac function is a critical portion of the evaluation for lung resection in the setting of emphysema. Cigarette smoking that caused the emphysema is also responsible for increasing the risk for coronary artery disease. Many patients with severe emphysema are sufficiently sedentary so that critical coronary occlusive disease remains masked or asymptomatic. Rest and exercise dobutamine echocardiography, radionuclide ventriculograms, thallium imaging, and other similar studies may provide useful information for risk stratification. However, these noninvasive tests of cardiac function are often limited. Exercise testing is often not useful because of the patient's inability to exercise to heart rate limits. Echocardiography may not provide adequate information because of chest hyperinflation, resulting in poor visu-

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