# Bronchoscopic Lung Volume Reduction

*Armin Ernst, MD, FCCP,* and Devanand Anantham, MD, FCCP†*

Lung volume-reduction surgery is a proven palliative procedure for emphysema, and in patients with heterogeneous upper-lobe disease as well as low baseline exercise capacity, even mortality benefits can be realized. However, its application is limited by high postoperative morbidity and stringent selection criteria that effectively exclude many patients. This has been the impetus for the development of less-invasive approaches to lung volume reduction. A range of different bronchoscopic techniques, such as endobronchial blockers, airway bypass, endobronchial valves, thermal vapor ablation, biological sealants, and airway implants have been investigated. The underlying physiological mechanisms of the various endoscopic modalities differ and both homogeneous, as well as heterogeneous, emphysema have been targeted. The currently available data on efficacy of bronchoscopic lung volume reduction are not conclusive, although subjective benefit in dyspnea scores and quality of life is a frequent finding. Improvements in objective outcomes, such as spirometry or exercise tolerance, have been only modest. Refining patient selection and dose of treatment are subjects of ongoing research to improve the efficacy data. Safety profiles are more promising, with rare procedure-related mortality and fewer complications experienced than with surgical lung volume reduction. The field of bronchoscopic lung volume reduction continues to evolve, with the aim of making symptom palliation more available to a wider range of patients at lower risks.

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Bronchoscopic techniques for the management of emphysema have evolved from the success of surgical treatment. Lung volume reduction surgery involves the removal of 20%-30% of each lung and targets the most emphysematous segments. Within chronic obstructive pulmonary disease (COPD), patients with heterogeneous upper-lobe emphysema and a low baseline exercise capacity have been identified as a subgroup in whom even mortality benefits can be achieved along with improvements in spirometry, exercise capacity, and quality of life.[1] Air trapping and neuromechanical dissociation, ie, the disparity between effort and minute ventilation, are the mechanistic links being targeted by this surgical treatment.[2] In COPD, both airway narrowing and loss of elastic recoil cause expiratory airflow limitation. During exercise, increasing respiratory rate shortens expiratory time and results in air trapping. Air trapping reduces inspiratory capacity and any further increase in minute ventilation can then only be achieved by increasing respiratory rate that in turn results in a vicious cycle of more dynamic air trapping.

Lung volume reduction corrects loss of elastic recoil by reducing the volume of the most damaged lung segments (dead space) and allowing the remaining less damaged tissues to resize. By eliminating parts of emphysematous lung with the longest expiratory time constants, dynamic air trapping is reduced and exercise capacity can be increased. The operating length of respiratory muscles is also normalized by restoring the normal dimensions of both the chest wall and the diaphragm.

Increased short-term mortality of approximately 5% and postoperative morbidity are the limitations of surgical lung volume reduction.[1] The reported rate of intraoperative complications is 9% and postoperative complications is >50%. Risks include reintubation (21.8%), arrthymias (18.6%), pneumo-

*Pulmonary, Critical Care and Sleep Medicine, St Elizabeth Medical Center, Tufts University School of Medicine, Boston, Massachusetts.
†Department of Respiratory and Critical Care Medicine, Singapore General Hospital, Singapore.
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Address reprint requests to Armin Ernst, MD, FCCP, Chief of Pulmonary, Critical Care and Sleep Medicine, St Elizabeth Medical Center, VP Thoracic Disease and Critical Care Service Line, Caritas Christi Health Care, Seton 6 East, 736 Cambridge Street, Boston, MA 02135. E-mail: armin.ernst@caritaschristi.org


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nia (18.2%), readmission to the intensive care unit (11.7%), and tracheotomy (8.2%).[3] Air leaks with a median 7-day duration have also been reported in 90% of patients.[4] In the National Emphysema Treatment Trial (NETT) study, up to 28% of patients were hospitalized or living in a nursing/rehabilitation facility at 1 month after surgery.[1] Unfortunately, the price of all this morbidity and mortality does not guarantee long-term benefits after surgery. Only 30% of patients in the most favorable subgroup of COPD derived a clinically significant improvement in exercise capacity of >10 W and 48% registered a >8 point decrease in the St George's Respiratory Questionnaire (SGRQ) at 24 months.[1]

The restrictive selection criteria coupled with the relatively high morbidity have been the likely reasons for the decrease in patients undergoing surgical lung volume reduction since the publication of the NETT data.[5] This situation persists in the United States despite established criteria for Medicare coverage and has served as an incentive for the development of less invasive modalities. Bronchoscopic lung volume reduction has pursued various approaches, such as blockers, stents, valves, thermal vapor ablation, sealants and implants. The physiological basis of each modality is not identical and in some cases distinct from even conventional lung volume reduction surgery. The ideal indications also differ with airway bypass stents targeting homogenous emphysema while valves and thermal vapor ablation target heterogeneous emphysema. Biological sealants and endoscopic coil implants have been used in both homogenous and heterogeneous emphysema.

## ENDOBRONCHIAL BLOCKERS

Endobronchial blockers effect resorption atelectasis by occluding airways leading to emphysematous lung segments. Initially silicone vascular balloons filled with radio-opaque contrast were inserted before the advent of custom-built stainless steel stents with a central occlusive sponge.[6] However, the high rates of endobronchial blocker migration, postobstructive pneumonia and the need for repeated endoscopic procedures have limited further development of this technique.[6]

## AIRWAY BYPASS STENTS

Airway bypass involves the creation of extraanatomic bronchial fenestrations to deflate emphysematous lung parenchyma. This technique relies on the presence of collateral ventilation which is the ventilation of alveoli through anatomic channels that bypass the airways. These channels include interalveolar pores, accessory bronchiole-alveolar connections, accessory respiratory bronchioles and interlobar pathways across fissures.[7] Although collateral ventilation plays an insignificant role in normal lungs, in emphysema where there is increased airway resistance, severely obstructed lung segments are ventilated by these channels. Homogeneity of emphysema is also likely to correlate with the degree of collateral ventilation.[8] In endoscopic airway bypass, newly created low resistance bronchial fenestrations allow trapped air to escape by bypassing high resistance obstructed airways. Distal, emphysematous lung segments are drained via collateral ventilation through these fenestrations resulting in a reduction of dead space and air trapping.[9,10]

Airway bypass procedures are performed on patients with homogenous emphysema. There are 3 steps that are performed via flexible bronchoscopy: identification of an area of the segmental bronchi that is free from blood vessels using a mini Doppler probe, fenestration of the airways with a needle balloon-catheter; and placement of a paclitaxel-eluting stent. Paclitaxel is a mitotic inhibitor that prevents granulation tissue from obstructing the stent. The current data on airway bypass include a multicenter, open labeled study on 35 patients, as well as a completed and soon to be published randomized, double-blind study involving 208 patients in the intervention arm (Table 1).[11,12] Efficacy data at 6 months was found to be limited with no significant changes on spirometry, 6-minute walk, and SGRQ. Stent patency at 6 months ranged from 24% to 69%.[11,12]

One death from hemoptysis has been reported with airway bypass procedures.[11] Safety monitoring board review of the fatal hemoptysis had the following recommendations, which were incorporated into subsequent procedures: placement of an endobronchial balloon blocker in the main bronchus, as well as mini Doppler rescanning between fenestration creation and stent deployment. Failure to implant stents is another possible intraoperative problem because of either excessive peribronchial blood vessels or markedly increased airway wall thickness.[11] Postprocedure complications occurred in 14%-59% of cases, including COPD exacerbations, pneumomediastinum and respiratory infections (Table 1).[11]

## ENDOBRONCHIAL VALVES

Endobronchial valves are designed to exclude the worst-affected emphysematous regions from ventilation and if segmental or lobar resorption atelectasis can be induced, a physiological effect similar to surgical lung volume reduction can be expected. Therefore, patients with heterogeneous emphysema are ideal candidates for endobronchial valve therapy.