# Lung Volume Reduction Surgery in Nonheterogeneous Emphysema

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**KEYWORDS**

- Homogeneous emphysema
- Lung volume reduction surgery • Bullae
- Hyperinflation • Pulmonary mechanics

Lung volume reduction surgery (LVRS) is an established, successful, palliative surgical therapy for carefully selected patients with advanced emphysema. Although the experience with LVRS has grown over the last few years, the selection of patients suitable for LVRS is still a matter of major controversy and differs widely between centers. On the basis of the early work from Brantigen[1] and that was revived by Cooper,[2] the procedure was recommended to be performed as a nonanatomic resection of the most severely destroyed, functionless tissue to reduce lung volume by 20% to 30%. Patients with a homogeneous type of emphysema were not considered suitable for LVRS. Most centers exclusively selected patients with a heterogeneous emphysema, preferentially located in the upper lobes as assessed by CT scans or by perfusion scintigraphy.

The mechanisms of action of LVRS relate mainly to changes in respiratory mechanics. The reduction in hyperinflation results in an increase in elastic recoil of the lungs, which reduces airflow obstruction and restores the chest cavity, including the shape of the diaphragm, thereby improving its length-tension relationship. These effects have a positive impact on shortness of breath, quality of life,[3,4] lung function and exercise capacity as shown in several prospective single-center case studies[5–7] and a few randomized, controlled trials.[8–12] Particularly, the results of the large national emphysema treatment trial (NETT) confirmed that properly selected patients may experience better functional improvements and quality of life after surgery than with medical treatment. This was especially the case for patients with upper lobe predominant destruction of the lungs and a poor exercise capacity. The trial did not exclude, but also did not support the fact that patients with homogeneous emphysema may also benefit from LVRS since only a few patients with such morphology were included in the NETT. In most centers, patients who did not show heterogeneity as the emphysematous destruction seen on CT were either excluded from surgery or thought to experience only minor benefits. In these patients, distinct areas of non- or poorly perfused lung could not be identified on perfusion scans as targets for resection, and they were, therefore, not considered candidates for LVRS. Since the favorable effects of LVRS are mainly caused by the improvement of respiratory mechanics, we postulated that well-selected patients with severe hyperinflation and airflow obstruction should benefit in dyspnea, quality of life, lung function, and physical performance, even if their emphysema was nonheterogeneously distributed.

## RATIONALE OF LUNG VOLUME REDUCTION SURGERY IN HETEROGENEOUS AND NONHETEROGENEOUS EMPHYSEMA

The pathophysiological mechanisms responsible for improvements after LVRS are multifactorious

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and still not fully understood. The major early effects of LVRS are a reduction in static lung volumes, particularly functional residual capacity and residual volume (RV), associated with an increase in lung elastic recoil, which leads to a reduction in the degree of airflow obstruction and hyperinflation, and hence, a reduced work of breathing. Measurements of elastic recoil before and after LVRS support this assumption. In 20 subjects undergoing LVRS, 16 experienced an increase in elastic recoil.[13] These patients had a significantly greater improvement in exercise capacity than those in whom elastic recoil didn't change. In addition to its effects on respiratory mechanics, LVRS improves global inspiratory muscle strength[14–17] and the contribution of the diaphragm to inspiratory pressure generation and tidal volume both at rest and during exercise.[18,19] Thus, by decreasing respiratory muscle load and by increasing diaphragmatic strength, LVRS enhances diaphragmatic neuromechanical coupling.[17] Since LVRS makes the diaphragmatic dome move upward and increases the area of muscle apposed to the rib cage,[20] it reduces dyspnea, and improves maximal ventilatory and exercise capacity by optimizing the match between size of the lungs and the rib cage.[21] These effects are independent from the emphysema morphology, and therefore, patients with homogeneous emphysema should also benefit from LVRS. There have been concerns that in patients with homogeneous emphysema who undergo LVRS, parenchyma contributing to gas exchange will be resected. This disadvantage of surgery has to be compensated by a beneficiary effect of downsizing the hyperinflated lung to a more physiologic size.

## THE ROLE OF EMPHYSEMA MORPHOLOGY IN LUNG VOLUME REDUCTION SURGERY

Emphysema is defined anatomically. In its severe form it can be easily detected on a plain posteroanterior and lateral chest radiograph. However, the most reliable method of obtaining information on the degree and distribution of emphysema is chest CT scanning. This imaging method plays a major role in the selection process. It is obvious that LVRS would be particularly beneficial in patients with a heterogeneous distribution of emphysematous destruction, such as in patients with large bullae beside areas that are well preserved. Earlier experience with bullectomy in patients with emphysema supported such a concept. Most groups, especially in North America,[6,22] preferentially select patients with marked differences in the severity of emphysema in their lung. They argue that these areas are functionless and should be chosen as target areas for resection. However, a few European groups have also operated on patients with completely a homogeneus distribution pattern of emphysema[23–25] and have studied this concept prospectively.

Different morphologic grading systems have been developed to quantify the type, severity, and distribution of emphysema as a help in identifying candidates for LVRS, although no internationally accepted standardized radiological classification exists. Slone and Gierada[26] based their analysis on a sophisticated classification system of emphysema morphology that showed good correlations with functional outcome. Favorable radiological features included marked heterogeneity of emphysema, particularly upper lobe predominance accompanied by mildly affected lung areas, and the presence of compressed lung. This classification system was modified by Wisser and colleagues[27] to achieve a higher degree of reproducibility and a mathematical quantification of heterogeneity and severity of disease. The morphology of emphysema was quantified using standard chest radiographs and CT imaging on the basis of four variables: degree of hyperinflation, degree of impairment in diaphragmatic mechanics, degree of heterogeneity, and severity of parenchymal destruction. Other authors have concluded from qualitative visual analysis of the chest radiography, from the CT or quantitative CT densitometry,[28,29] or from analysis of perfusion scans,[30] that emphysema heterogeneity indicates favorable outcome. A specifically LVRS oriented classification system based on CT findings was proposed by Weder and colleagues[31,32] distinguishing between homogeneous, moderately heterogeneous, and markedly heterogeneous emphysema distribution, and the predominance of the involved side was considered. The following definitions were applied (**Fig. 1**): Markedly heterogeneous emphysema occurs when a distinct regional difference in the severity of emphysema (ie, decreased density, loss of vascular lung structure) is present in at least two adjacent lung segments of either lung. Intermediately heterogeneous emphysema occurs when a distinct regional difference in severity of emphysema may be present maximally in the area of one or more than one, but not in adjacent lung segments of either lung. Markedly heterogeneous emphysema occurs when a distinct regional difference in the severity of emphysema is present in at least the area of two adjacent lung segments of either lung. This classification system is easy to apply, helps to select patients for LVRS, and allows comparison of outcome.