



Lung volume reduction surgery in selected patients with severe emphysema: significant benefit with low peri-operative risk

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Abstract: Lung volume reduction surgery (LVRS) offers improvement in lung function, quality of life and even survival in patients with severe emphysema. Candidate selection is the key issue and should be performed at high volume centers with a multidisciplinary emphysema board. The technique reduces the hyperinflated lung by resecting the most destroyed emphysema parts. Regaining the shape of the diaphragm improves lung function. Nowadays video-assisted thoracoscopic surgery is the golden standard for LVRS. Besides low perioperative mortality and morbidity there are still concerns about the efficacy and safety of the procedure. This review outlines patient selection, technique and results of LVRS.

Keywords: Lung volume reduction surgery (LVRS); emphysema; video-assisted thoracoscopic surgery (VATS)

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Introduction

The National Emphysema Treatment Trial (NETT) was published in 2003 and was the first randomized multi-center trial comparing lung volume reduction surgery (LVRS) with medical treatment in patients with severe emphysema (1). With more than 1,200 patients participating, significant improvements of lung function, walking distance, quality of life and even survival was shown for the LVRS group. Also, a number of large case series reported this treatment success (2-5). Previously, the NETT reported about a high risk group of included patients who showed high mortality after LVRS (6). This report was published in 2001 and described 69 patients with very low values of forced expiratory volume in 1 second (FEV1 below 20% predicted) either with homogeneous emphysema or with a very low carbon monoxide diffusion capacity (DLCO below 20% predicted). These patients had a postoperative 30-day-mortality up to 25% and during the further on-going trial this combination of characteristics was an exclusion criterion. Nevertheless, the publication was titled "Patients at high risk of death after lung volume reduction surgery" and therefore was interpreted mistakably. The emerging

LVRS received a setback even before the promising results of the completed NETT were published two years later. This misunderstanding is still an issue and LVRS is perceived as heavily complicated (7). Many physicians remain unaware of the benefits of LVRS (8). This review emphasizes the technique of LVRS, its patient selection criteria and the results. Nowadays very low perioperative morbidity and mortality rates are achieved and this beneficial outcome may encourage thoracic surgeons and chest physicians to consider their emphysema patients as potential candidates for LVRS.

Rationale

LVRS downsizes the hyperinflated lung to a more physiologic size and the diaphragmatic dome moves upwards (9). *Figure 1* shows a MRI of a patient before and after bilateral LVRS. Maximal ventilator and exercise capacity are improved (10). Static lung volumes as functional residual capacity and residual volume (RV) are reduced while lung elastic recoil is increased. Therefore the airflow obstruction and hyperinflation are decreased (11). Both heterogeneous and homogeneous emphysema are responsible for the hyperinflation and therefore patients

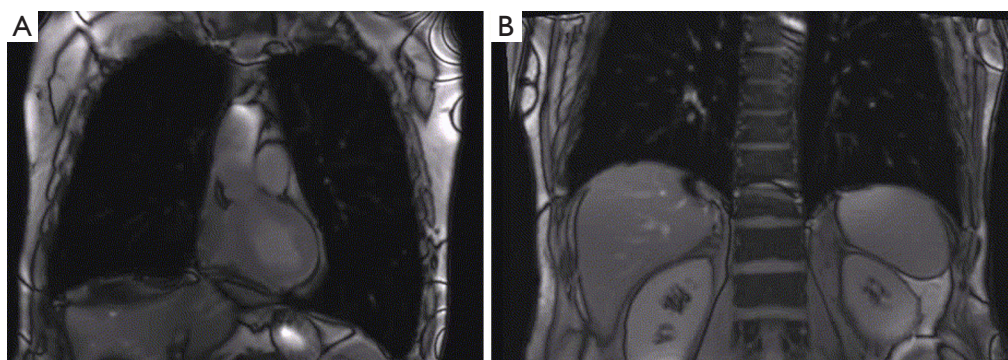


Figure 1 MRI of a patient before (left) and 3 months after bilateral LVRS. The postoperative MRI shows the regained shape of the diaphragm. LVRS, lung volume reduction surgery.



Figure 2 Pre-operative CT scan of a patient with upper-lobe predominant emphysema. CT, computer tomography.

with both types of morphology can profit from LVRS (12).

Selection criteria

Patient selection is a key issue and should be performed at high volume centers with an interdisciplinary emphysema board (13). Computer tomography should be performed in every patient with chronic obstructive pulmonary disease (COPD). With evidence of emphysema on CT scan (Figure 2) and lung function criteria as listed in Table 1 the patient should be referred and discussed at the emphysema board. Best evidence exists for patients with heterogeneous, upper-lobe predominant emphysema (1). Patients with lower-lobe predominant disease seem to profit as well

Table 1 Inclusion/exclusion criteria for LVRS

Variables	Inclusion	Exclusion
Patient	Nicotine abstinence >4 months; passed pulmonary rehabilitation	Daily steroid intake >20 mg
CT morphology	Lung emphysema	Significant bronchiectasis
Lung function	FEV1 <45%; TLC >100%; RV >150%; RV/TLC >60%	FEV1 <20% and diffusion capacity <20%
6MWD (m)	<450	<140
Gas exchange		paCO ₂ >6.7 Pa; paO ₂ <6.0 Pa

LVRS, lung volume reduction surgery; CT, computer tomography; FEV1, forced expiratory volume in 1 second; TLC, total lung capacity; RV, residual volume; RV/TLC, hyperinflation; 6MWD, 6 minute walking distance.

in a short-term after LVRS (5). The key issue in patient selection must be the hyperinflation: high total lung capacity (TLC) and RV values and a RV/TLC-ratio above 60. Ventilation-perfusion scans are helpful in identifying the most destroyed parts of the lung (Figure 3) (6).

Flattened diaphragms on coronal CT scans and X-rays help to identify the severity of hyperinflation. Patients often tell by themselves they feel bloated. Also they report about the inability to eat more than just small portions. A rigorous cardiac assessment is necessary. Echocardiography should be performed in every candidate. Patients with an ejection fraction below 30%, a history of myocardial infarction within the last 6 months and suspicion of pulmonary hypertension (>35 mmHg) should be excluded or sent for

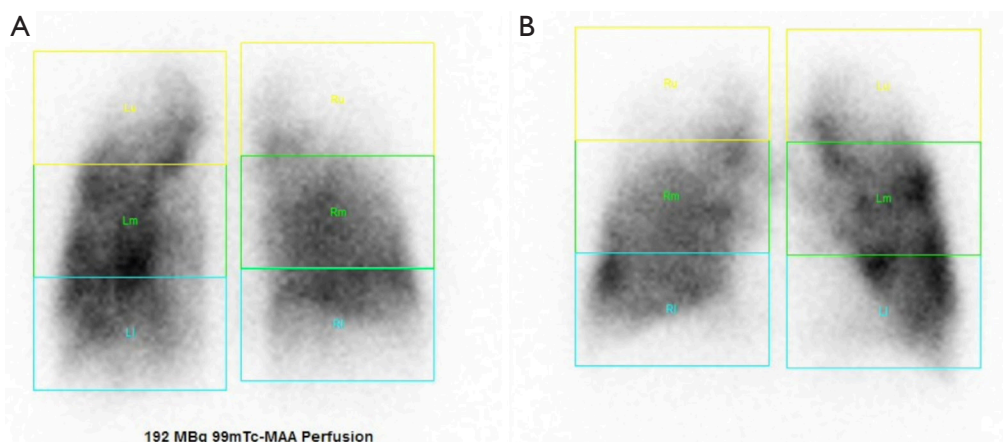


Figure 3 Pre-operative ventilation-perfusion scan in the same patient as in *Figure 2*.

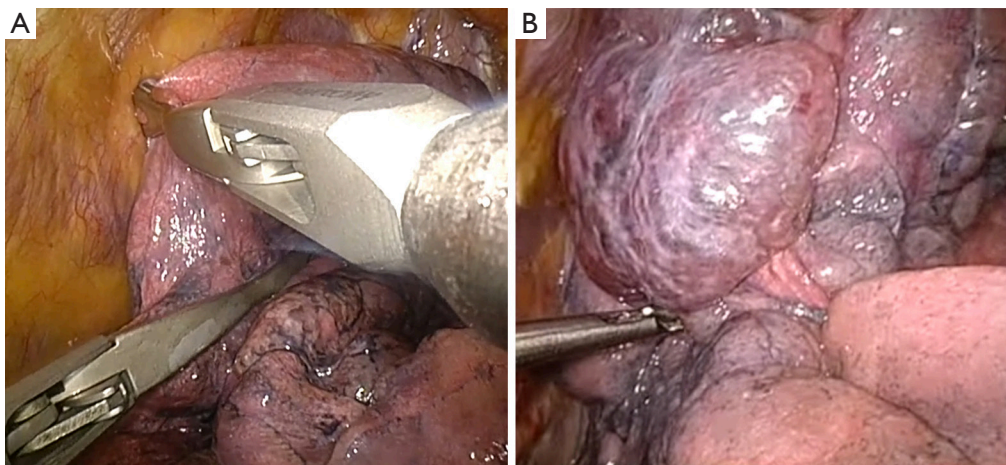


Figure 4 Preparing the resection line with lung forceps in a patient with upper-lobe predominant emphysema.

further investigation by a cardiologist (1,7,8).

Nevertheless, even significant benefits have been reported about LVRS in patients with homogeneous emphysema (14,15). This group of patients might be included after gaining large experience in patients with heterogeneous morphology.

Technique

The golden standard is the video-assisted thoracoscopic surgery (VATS) LVRS, already described in 1996 (16). Most studies describe a three-portal approach (4,5). Our group always had good results with one-staged bilateral LVRS in patients with bilateral disease but other groups might prefer bi-staged procedures (4,17).

For one-staged bilateral LVRS the patient lies in a supine position with both arms raised. Both sides can be approached without changing the patient's position. General anesthesia is performed with a double lumen tube and additional epidural anesthesia.

The defined target area is prepared with compressing the lung parenchyma along the line of the proposed staple line with a clamp or grasp (*Figure 4*). The intraoperative macroscopic appearance of the target area must correspond to the CT scan. Manipulation and contact with the lung should be limited as the emphysematous lung is very thin and even touching it with the stapler can make a hole. Before introducing the stapler, the lung should be aligned so it can slide easily across the lung. Resection with a stapler along the pre-compressed region of the lung is

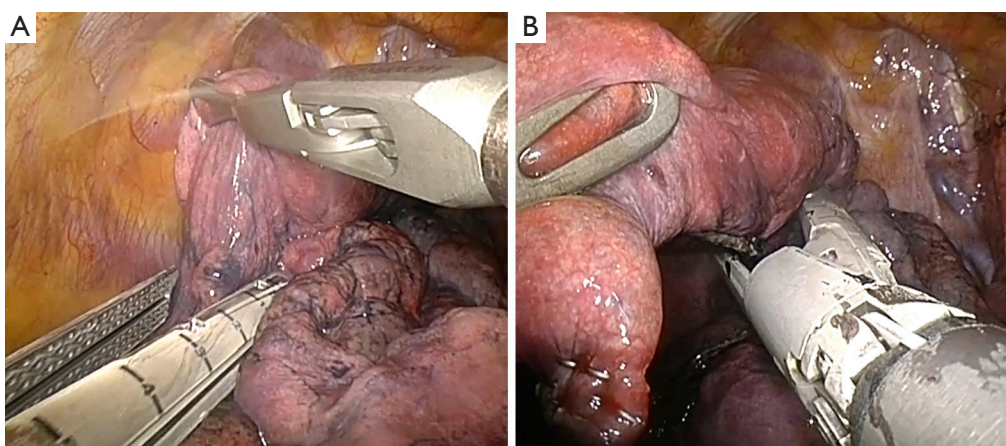


Figure 5 Resection is performed by stapler at the level of the azygos vein.

performed (*Figure 5*). We generally use a 60 mm endostapler with 4.8 mm staples. In upper-lobe predominant emphysema the resection often starts at the level of the vena azygos or the aortic arch, respectively. For resection of the dorsal part the stapler is tilted or the lung pulled upwards to keep the dome-like shape of the lung. The pulmonary ligament is released if there is a significant air space in the apical part. One chest tube is placed. When the air leak is zero or small we proceed to the contralateral side.

After operation the double lumen tube is changed to a laryngeal mask. Patients are then extubated in the operation room. The chest tubes are connected to a water seal with suction of -5 cm H_2O .

Results

The postoperative 90-day mortality in the final NETT was 5.2% (1). This mortality rate was achieved in 511 non-high-risk patients with upper-lobe predominant emphysema.

In 2003, Ciccone and colleagues reported a 90-day mortality of 4% in 250 patients with heterogeneous emphysema (5). Ginsberg and colleagues even reported a zero 6-month mortality rate in 91 consecutive patients with upper-lobe predominant emphysema (18). In 2014, Rathinam and colleagues published a 30-day mortality rate of 3% in 265 VATS patients (19). Additional evidence was made for patients with severe hyperinflation and airflow obstruction to benefit from LVRS even if their emphysema was non-heterogeneously distributed. 30-day mortality rates between 2.4% (15) and 9.3% (20) were reported.

Pulmonary complications concern mainly postoperative airleaks. We define a prolonged airleak as chest tube

duration longer than 7 days. In our own experience this has to be expected in about at least 30% of all patients after LVRS. Ginsburg *et al.* report a rate of 57% (18) whereas in the NETT (information available for 522 patients) median air leak duration was 7 days and in 12% of patients it lasted at least 30 days (21). The 4.4% of all patients underwent re-operation due to air leak.

The mainly published median postoperative hospitalization time is between 8 and 14 days (5,18,19,22).

In the NETT, a substantial survival advantage was found after LVRS compared with medical therapy (8). Lung function improves significantly after LVRS. The beneficial effect remains but declines during 5 years (3,5,13). 94% of the 250 patients with heterogeneous emphysema from Ciccone *et al.* had a significant postoperative improvement (5). The mean increase of FEV1 was 54% after six months. After 5 years, the mean change in FEV1 was still an improvement of 7%, and 53% of patients still had an increase relative to the preoperative value. The 6 minute walking distance (6MWD) improve by 46% after 6 months and was still increased by 25% after 5 years. The Zurich group showed a mean change in FEV1 of 41% after 6 months including patients with heterogeneous and homogeneous emphysema (4). Brenner and colleagues (2) showed an mean improvement of 69% after 6 months in their study with 269 patients with heterogeneous emphysema.

LVRS and transplantation

Lung transplantation (LTx) also offers significant improvement of quality of life in selected patients with emphysema compared to medical therapy (23). Usually,

LQRS is offered at a less progressed stage of disease. Nevertheless, a highly selected group of patients might profit from both procedures (24). Facing the problems with organ shortage, LQRS can be a bridge to transplantation. The experience from Zurich shows no survival disadvantage for LTx patients with previous LQRS (4).

Perspective

Nowadays endoscopic lung volume reduction (ELVR) procedures are emerging and also show promising results.

Endobronchial valve treatment in heterogeneous emphysema shows improvement of 24.8% in FEV1% predicted after 3 months (25) and of 17% in homogeneous emphysema (26). Pneumothorax rates between 8% and 25.6% were reported. During the first 3 months, 2 deaths occurred in the BeLieFeR-HIFi-Study (25 patients with valve treatment) and no deaths in the IMPACT-study (43 patients with valve treatment). The VENT trial randomized 220 patients to endobronchial valve treatment and 110 patients to standard medical care. There was a 6-months mortality rate of 2.8% after endobronchial valve treatment (6 patients of 220) (27). Coils are another well researched endobronchial treatment procedure. One recent multicenter randomized study shows a median improvement of its primary endpoint at 12 months, the 6MWD of 10.3 meters (28). The recent published REVOLENS-trial, another multicenter randomized trial, showed an at least 54 m gain in 36% of patients treated with endobronchial coils compared with medical-care-only patients (29). Improvement of FEV1% predicted differs between 3.8% and 9% in these two trials. Major complications (i.e., pneumonia, pneumothorax, hemoptysis, COPD exacerbations) occurred in 34.8% and 52%, respectively.

Regarding ELVR results, LQRS still remains the gold standard for lung volume reduction. Bronchoscopic procedures, especially valves show impressive results but also have to deal with major complications.

The initially discussed concerns about the high mortality and morbidity of LQRS are not justified regarding the literature. With its promising improvements of lung function and its advantages for survival LQRS should be considered in every emphysema patient matching the proper selection criteria.

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Footnote

Conflicts of Interest: The author has completed the ICMJE uniform disclosure form (available at <http://dx.doi.org/10.21037/jxym.2017.05.04>). The author has no conflicts of interest to declare.

Ethical Statement: The author is accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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