# Lung volume reduction surgery for the treatment of severe emphysema: a study in a single Canadian institution

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Objective: To evaluate lung volume reduction surgery (LVRS) and its effectiveness in improving pulmonary function, exercise capacity and quality of life in a population of emphysema patients referred to and screened in a single centre.

Design: A prospective case series.

Setting: A Canadian tertiary care hospital.

Patients: Patients with severe emphysema, significant dyspnea and impaired exercise capacity interfering with quality of life.

Interventions: Bilateral LVRS was performed through a median sternotomy.

Main outcome measures: Pulmonary function tests (preoperative forced expiratory volume in the first second [$FEV_1$], residual volume [RV]), 6-minute walk (6MW) distance, quality of life (Medical Outcomes Study 36-item short-form health survey) and degree of dyspnea (Medical Research Council of Great Britain dyspnea scale and the baseline and transitional dyspnea indices) were assessed before LVRS and at 6 and 12 months after.

Results: Fifty-seven patients were assessed for LVRS, of whom 10 were selected for surgery. Homogeneous distribution of disease was the most common reason for exclusion. Of the 10 patients operated upon, 1 died of acute cor pulmonale on the fourth postoperative day and 1 died of recurrent exacerbations of chronic obstructive pulmonary disease and chronic respiratory failure at 315 days postoperatively. In the surviving patients, the mean preoperative $FEV_1$ increased from 0.70 L before surgery to 0.90 L at 1 year, with a mean relative increase of 33.4%. The mean RV decreased from 5.57 L to 4.10 L, with a mean relative decrease of 27.6%. The 6MW distance increased from 302.7 m to 356.9 m at 1 year, with a mean relative increase of 21.6%. Quality of life and degree of dyspnea were improved significantly at 1 year after LVRS. Of the 5 patients on oxygen at home before surgery, 4 were able to reduce their requirements but not to discontinue oxygen.

Conclusions: LVRS is an effective palliative treatment for dyspnea and poor exercise tolerance in highly selected patients. Although the duration of palliation is unknown, our results show that improvements in pulmonary function, exercise, quality of life and degree of dyspnea are preserved over the first year. Only a minority of the patients screened were eligible for surgery. The 2 deaths in our series emphasize the need for even further delineation of selection criteria.

Objectif : Évaluer l'intervention chirurgicale de réduction du volume pulmonaire et son efficacité dans l'amélioration de la fonction pulmonaire, de la capacité d'exercice et de la qualité de vie dans une population de patients atteints d'emphysème qui ont été présentés et examinés à un seul et même centre.

Conception : Série de cas prospective.

Contexte : Hôpital de soins tertiaires du Canada.

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PATIENTS : Patients atteints d'emphysème grave, de dyspnée importante et d'une déficience de la capacité d'exercice qui nuisent à leur qualité de vie.

INTERVENTIONS : On a procédé à une intervention chirurgicale bilatérale de réduction du volume pulmonaire par sternotomie médiane.

PRINCIPALES MESURES DE RÉSULTATS : On a évalué avant l'intervention, et six et 12 mois après, les tests de fonction pulmonaire (volume respiratoire maximal/seconde préopératoire) [VEMS], le volume résiduel [VR]), la distance de marche en six minutes (M6M), la qualité de vie (questionnaire abrégé sur la santé à 36 questions de l'étude sur les résultats médicaux) et le degré de dyspnée (échelle de dyspnée du Conseil de recherches médicales de la Grande-Bretagne et indice de dyspnée de référence et de transition).

RÉSULTATS : On a évalué 57 patients avant de les soumettre à une intervention chirurgicale de réduction du volume pulmonaire, et l'on en a choisi dix. La distribution homogène de la maladie était la principale raison de l'exclusion. Sur les dix patients qui ont subi l'intervention chirurgicale, un est mort d'un cœur pulmonaire aigu au cours de la quatrième journée qui a suivi l'intervention et un autre est mort à cause d'exacerbations répétitives de bronchopneumopathie chronique obstructive et d'insuffisance respiratoire chronique 315 jours après l'intervention. Chez les patients qui ont survécu, le VEMS préopératoire moyen est passé de 0,70 L avant l'intervention chirurgicale à 0,90 L un an après, mais l'augmentation relative moyenne s'est établie à 33,4 %. Le VR moyen est tombé de 5,57 L à 4,10 L et la diminution relative moyenne a atteint 27,6 %. La distance de marche en six minutes est passée de 302,7 m à 356,9 m un an après l'intervention et l'augmentation relative moyenne s'est établie à 21,6 %. La qualité de vie et le degré de dyspnée se sont améliorés considérablement un an après l'intervention. Sur les cinq patients qui recevaient de l'oxygène à domicile avant l'intervention chirurgicale, quatre ont pu diminuer leurs besoins sans toutefois pouvoir cesser d'en prendre.

CONCLUSIONS : L'intervention chirurgicale de réduction du volume pulmonaire est un traitement palliatif efficace contre la dyspnée et une tolérance médiocre à l'exercice chez les patients qui ont fait l'objet d'une sélection rigoureuse. Même si l'on ne connaît pas la durée de la palliation, nos résultats montrent que les améliorations de la fonction pulmonaire, de la tolérance à l'exercice, de la qualité de vie et du degré de dyspnée sont maintenues pendant la première année. Seule une minorité des patients examinés était admissible à l'intervention chirurgicale. Les deux décès survenus pendant la série indiquent qu'il faut définir avec encore plus de précision les critères de sélection.

Patients with severe chronic obstructive pulmonary disease (COPD) have dyspnea that limits daily activities, exercise and quality of life. Conservative measures to improve dyspnea include cessation of smoking, rehabilitation, use of bronchodilators, short courses of corticosteroids and use of oxygen at home. Therapy is often unsuccessful, particularly in the severely emphysematous patient.

Lung volume reduction surgery (LVRS) was reintroduced by Cooper and associates[1] as a method for palliation of dyspnea in selected patients with severe diffuse non-bullous emphysema. The priniciples behind LVRS were first described in 1957 by Brantigan and Mueller.[2] Patients who do not have uniform distribution of disease with target areas of gas trapping are selected.[1,3] Alveolar destruction in emphysema leads to hyperinflation of the lung, flattening of the diaphragm and decreases in the efficiency and strength of diaphragmatic contraction. Airway obstruction during expiration and nonuniform distribution of disease can lead to gas trapping within easily defined areas of the lung. These overexpanded, underperfused regions are space-occupying areas that do not participate significantly in gas exchange and cause impairment in diaphragmatic function and lung mechanics. In LVRS, the most severely affected areas of emphysema, usually 25% to 30% of each lung, are resected through a median sternotomy.

Screening of patients in LVRS is important, since many patients with severe emphysema do not qualify for this procedure. For instance, in those having upper lobe disease a median sternotomy provides easier access and they appear to have a better functional result from LVRS.[3] Patients with pulmonary hypertension, significant comorbidities or other active pulmonary disease are not candidates for LVRS. Few studies have reported on the patients screened for LVRS who are eligible or have reported the reasons for which patients are refused. The purpose of this study was to evaluate LVRS prospectively with the objective of assessing its effectiveness in improving pulmonary function, exercise capacity and quality of life, and to determine the proportion of COPD patients referred who would be eligible for LVRS, in a setting where all patients in a province are screened by a single centre.

## METHODS

### Inclusion and exclusion criteria

Between November 1995 and July 1997, patients with severe emphysema were referred to the Health Sciences Centre in Winnipeg for LVRS assessment. Inclusion and exclusion criteria are presented in Table I. Based on previous literature, we selected for pa-

tients with predominantly upper lobe distribution of emphysema.[1,3]

### Assessment

Assessment was standardized for all patients being considered for LVRS. Patients who were excluded were assessed with the minimal testing necessary to rule them out as candidates. Preoperative evaluation of pulmonary anatomy included chest radiography, high-resolution computed tomography and quantitative ventilation–perfusion radionuclide imaging. Pulmonary function testing included spirometry, plethysmography, and meadurement of diffusion capacity and arterial blood gas levels. Cardiac evaluation included electrocardiography and transthoracic echocardiography. Exercise testing included 6-minute walk (6MW) distance[4] and exercise stress test using the modified or low-level Bruce protocol.[5] Selected patients underwent pulmonary angiography with measurement of pulmonary artery pressures. All patients had a minimum of 6 weeks' preoperative physiotherapy and rehabilitation.

**Table I**

**Inclusion and Exclusion Criteria for Lung Volume Reduction Surgery**

| |
|---|
| Inclusion criteria |
| Diagnosis of severe emphysema |
| Severe dyspnea despite optimal medical treatment |
| Radiographic evidence of hyperinflation, emphysema and upper lobe predominance of disease |
| Abstinence from smoking for at least 6 mo |
| Acceptable nutritional status |
| Exercise limitation with rehabilitation potential |
| Exclusion criteria |
| Concomitant major medical problems |
| Prior chest surgery or pleurodesis |
| Ventilator-dependent respiratory failure |
| Severe hypercapnia ($PaCO_2$ > 60 mm Hg) |
| Giant bullae (occupying > 25% of a hemithorax) |
| Lack of target areas for resection |
| Chest-wall deformities |
| Active pulmonary inflammatory disease |
| Malignant lesions |
| High-dose steroids (> 10 mg/d of prednisone or equivalent) |
| Pulmonary hypertension (systolic pulmonary artery pressure > 50 mm Hg or mean pulmonary artery pressure > 30 mm Hg) |
| Right ventricular dilation, hypertrophy or dysfunction |

$PaCO_2$ = partial pressure of carbon dioxide in arterial blood.

Quality of life was evaluated using the medical outcomes study 36-item short-form health survey (MOS SF-36) scale.[6,7] The degree of dyspnea was evaluated according to the Medical Research Council of Great Britain dyspnea scale[8] and the baseline and transitional dyspnea indices.[9] The MOS SF-36 is a self-administered scale and was used to assess any changes in quality of life due to emphysema and to treatment by LVRS. The MRC dyspnea scale and the baseline and transitional dyspnea indices were used to assess changes in dyspnea from LVRS, rehabilitation or disease progression.

### Surgical technique

LVRS was performed with use of the technique decribed by Cooper and associates.[1] An epidural catheter was placed for postoperative pain control. A double-lumen endotracheal tube was placed after achieving satisfactory general anesthesia. Cefazolin, 1 g intravenously, was given 1 hour before operation. Clindamycin or vancomycin was substituted for patients with penicillin allergy. Intraoperative monitoring included placement of an arterial line, use of an oxygen saturation monitor and measurement of end-tidal carbon dioxide in all patients. The first 4 patients were also monitored with Swan–Ganz catheters. Later in the study patients were monitored by transesophageal echocardiography. Median sternotomy was performed in all patients. Wedge resections of target areas were performed using surgical staplers lined with bovine pericardial strips.[10] In 2 cases, the target areas involved the entire right upper lobe. Lobectomy was performed in both patients. Chest tubes were connected to the minimal suction necessary to achieve full lung expansion, usually 10 to 20 cm $H_2O$ suction. Patients were extubated in the operating room or in the recovery room whenever possible.

Rehabilitation was started in the early postoperative period and included walking, riding a stationary bicycle and using the exercise treadmill. This program was continued for 4 to 6 weeks after discharge from hospital.

### Follow-up

Pulmonary function, arterial blood gas levels and the 6MW distance were measured before LVRS and at 6 and 12 months postoperatively. Quality of life and degree of dyspnea were measured before LVRS and at 12 months after postoperatively.

### Statistical methods

Data are reported as the mean (and standard error of the mean). Student's paired *t*-tests were used to test differences in results in spirometry, plethysmography and 6MW test results at baseline, 6 months and 12 months. A $p$ value less than 0.05 was considered significant. Early postoperative complications were defined as those occuring within 30 days of operation. Late postoperative complications were defined as those occurring after 30 days.

### Ethics

This study protocol was approved by the Health Sciences Centre Ethics Committee.

## RESULTS

### Patient selection

Between November 1995 and July 1997, 57 patients with severe emphysema were referred to the Health Sciences Centre for possible LVRS. Forty-seven patients were excluded (Table II). Ten patients met the criteria for LVRS. Homogeneous distribution of disease and lack of target lesions for resection were the most common reasons that LVRS was refused. Evidence of right ventricular dysfunction on echocardiogram and lack of rehabilitation potential were the next most common reasons. Two patients with giant bullae were excluded. Both underwent bullectomies through posterolateral thoracotomies. Five patients who were rejected because of hypercapnia or because of right ventricular dysfunction were eligible for lung transplantation. Three patients were accepted for and received lung transplantation. Most of the patients had more than one reason for exclusion and received the minimum assessment necessary to exclude them. Baseline characteristics of the patients selected for LVRS are presented in Table III.

### Mortality

Two patients died (Table IV). The first, a 71-year-old man, died of acute pulmonary hypertension and cor pulmonale. His preoperative echocardiogram was normal, and pulmonary hypertension was not suspected. Angiography was not performed preoperatively. Intraoperative monitoring included transesophageal echocardiography, which gave normal findings during the procedure. He began to have an elevated systolic pulmonary artery pressure (to above 60 mm Hg) on the second postoperative day and right ventricular failure developed. Despite treatment with inotropic agents, he died on the fourth postoperative day. The second patient was a 67-year-old man who had recurrent pneumonia and postoperative exacerbations of COPD, which caused respiratory failure and required readmission to the intensive care unit for mechanical ventilation. He was discharged from hospital and was started on home oxygen. He died of respiratory failure 315 days postoperatively. This patient had the lowest preoperative percent predicted forced expiratory volume in the first second ($FEV_1$) of the entire study group (17.9%).

**Table II**

**Reasons for Exclusion From Lung Volume Reduction Surgery**

| Exclusion criterion | No. of patients* |
|---|---|
| Right ventricular enlargement or dysfunction | 13 |
| Physical deconditioning and lack of rehabilitation potential | 13 |
| Partial pressure of carbon dioxide > 60 mm Hg | 6 |
| Homogeneous distribution of disease | 26 |
| Giant bullous disease | 2 |
| Comorbid disease | |
| Class III–IV angina | 2 |
| Aortic stenosis | 1 |
| Bronchiectasis | 3 |
| High-dose prednisone | 2 |
| Still smoking | 1 |
| No significant functional limitation | 4 |
| Refused further assessment | 3 |
| Total | 47 |

*Most patients excluded had more than 1 reason for exclusion.

**Table III**

**Preoperative Features in 10 Patients (6 Men, 4 Women) Who Underwent Lung Volume Reduction Surgery***

| Characteristic | Mean (and standard error) | Range |
|---|---|---|
| Age, yr | 64.1 (1.7) | 57–72 |
| $FEV_1$, L | 0.72 (0.08) | 0.52–1.08 |
| $FEV_1$, % predicted | 29.42 (2.79) | 17.9–43.9 |
| FVC, L | 2.02 (0.19) | 1.41–3.34 |
| FVC, % predicted | 57.9 (3.67) | 40.2–72.6 |
| $FEV_1$:FVC, % | 33.95 (3.51) | 22.2–62.3 |
| TLC, L | 7.65 (0.50) | 5.66–10.13 |
| TLC, % predicted | 135.01 (5.16) | 106.3–158.1 |
| RV, L | 5.36 (0.41) | 3.36–6.64 |
| RV, % predicted | 245.59 (16.78) | 137.10–332.60 |
| DLCO, % predicted | 36.22 (2.26) | 25.00–49.30 |
| pH | 7.42 (0.01) | 7.38–7.50 |
| $Pa_{O_2}$, mm Hg | 68.00 (5.01) | 41–99 |
| $Pa_{CO_2}$, mm Hg | 45.50 (2.50) | 34–58 |
| 6MW, m | 302.5 (20.4) | 212.4–381.0 |

*5 patients were on home oxygen.
$FEV_1$ = forced expiratory volume in the first second, FVC = forced vital capacity, TLC = total lung capacity, RV = residual volume, DLCO = diffusion capacity of carbon monoxide, $Pa_{O_2}$ = partial pressure of oxygen in arterial blood, $Pa_{CO_2}$ = partial pressure of carbon dioxide in arterial blood, 6MW = 6-minute walk.

### Early complications

The most common early complication (in 4 patients) was prolonged air leak for more than 7 postoperative days (ranging from 10 to 32 days). Massive subcutaneous emphysema 10 days postoperatively developed in 1 patient, even though 4 chest tubes were in place. This resolved with conservative management. One patient required admission to the intensive care unit for acute uncontrolled atrial fibrillation causing congestive heart failure. The heart rate was controlled with amiodarone, but chronic atrial fibrillation developed that limited exercise capacity at 6 months. One patient required re-exploration for bleeding from the left internal mammary artery.

**Table IV**

**Complications Resulting From Lung Volume Reduction Surgery**

| Complication | No. |
|---|---|
| Early complications (≤ 30 d) | |
| Hemorrhage | 1 |
| Prolonged air leak (> 7 d) | 4 |
| Massive subcutaneous emphysema | 1 |
| Acute uncontrolled atrial fibrillation | 1 |
| Exacerbation of COPD and pneumonia causing respiratory failure | 1* |
| Late complications (> 30 d) | |
| Pneumothorax | 2† |
| Congestive heart failure | 1 |
| Exacerbation of COPD | 6* |
| Stridor | 1 |
| Early death (≤ 30 d) | |
| Acute pulmonary hypertension and cor pulmonale | 1 |
| Late death (> 30 d) | |
| Recurrent exacerbation of COPD and chronic respiratory failure | 1* |

*This patient had 1 early and 3 late exacerbations of COPD.
†Both pneumothoraces occurred in the same patient.
COPD = chronic obstructive pulmonary disease.

### Late complications

Late postoperative complications included 1 patient who suffered late left-sided pneumothorax on 2 occasions, at 139 days and 378 days after LVRS. On the second occurrence a tension pneumothorax developed and the patient required tube thoracostomy and talc pleurodesis. One patient required hospital admission for congestive heart failure, which resolved with diuretics. Three patients have had repeated minor exacerbations of COPD, successfully treated with bronchodilators and oral antibiotics.

### Early extubation

Early extubation in the operating room or in the recovery room was possible in 5 of the 10 patients. Two others were extubated after less than a day of postoperative ventilation. One patient was extubated at 27 hours postoperatively and another at 76 hours. One patient , who died in the intensive care unit 4 days postoperatively, was ventilated throughout his postoperative course.

### Hospital stay

The average hospital stay in the 8 survivors was 19.9 (2.8) days (range from 11 to 30 days).

**Table V**

**Criteria for Use of Oxygen at Home**

1. Clinically stable patient receiving optimal medical management.
2. Persistent hypoxemia for at least 3 weeks, *with*
3. Room air $Pa_{O_2}$ < 55 mm Hg *or* cor pulmonale or secondary polycythemia (> 55%) and room air $Pa_{O_2}$ 56–59 mm Hg
4. In non-hypoxemic patients, oxygen is prescribed after an assessment that documents nocturnal or exercise desaturation.

$Pa_{O_2}$ = partial pressure of oxygen in arterial blood.

### Home oxygen

Five patients were on oxygen at home before operation and met our local criteria for implentation of home oxygen (Table V), based on the criterion of persistent hypoxemia with room air partial pressure of oxygen in arterial blood ($Pa_{O_2}$) less than 55 mm Hg.[11] After LVRS, 3 patients were able to have their supplemental requirements reduced, 1 from 3 L/min to 2 L/min and 2 from 3 L/min to 1 L/min, but none of them was able to discontinue their oxygen. Postoperatively, they continued to benefit from home oxygen, especially for oxygen desaturation during exercise.

### Pulmonary function

Absolute results of pulmonary function testing at 6 and 12 months are presented in Figs. 1 and 2. The mean (and SEM) relative change in $FEV_1$ at 6 and 12 months was 34.33% (13.73%) and 33.39% (16.81%) respectively. However, the absolute improvement in $FEV_1$ reached statistical significance ($p < 0.05$) only at the 6-month interval. The mean relative change and the mean absolute change in forced vital capacity, residual volume (RV) (decrease of 27.61%) and total lung capacity were improved at both intervals, reaching statistical significance ($p < 0.05$).

### Exercise

The 6MW distance improved from 302.7 (20.4) m before LVRS to 374.9 (41.8) m at 6 months and 356.9 (14.6) m at 12 months. The results reached statistical significance at 12 months ($p < 0.05$). The 6MW distance improved by 24.8% and 21.6% at 6 and 12 months respectively over the preoperative findings. The results of exercise testing include improvement from preoperative pulmonary rehabilitation.

### Degree of dyspnea

Information regarding the degree of dyspnea was available for 7 of the 8 surviving patients. The mean modified MRC dyspnea scale score before LVRS was 3.00 (0.31), indicating that patients had to "stop for breath" after walking about 91 m or after a few minutes on the level. The mean score at 12 months after LVRS was improved to 1.29 (0.29) ($p < 0.05$), indicating that the patients were "troubled by shortness of breath when hurrying on the level or walking up a slight hill."[9]

The mean baseline dyspnea index functional impairment score before LVRS was 1.29 (0.28), indicating severe impairment. The patients were "unable to work or (had) given up most or all usual activities because of shortness of breath." At 12 months after LVRS, the transitional dyspnea index functional impairment score was +2.14 (0.26), indicating moderate improvement. The patients were "able to return to work at nearly usual pace or able to return to most activities with restriction."[9]

The majority of our patients were able to resume normal activities of daily living but continued to have respiratory impairment on moderate exertion or with prolonged activity. All surviving patients noted that their subjective perception of breathlessness had improved.

### Quality of life

Quality of life information was available for 7 of the 8 surviving patients. The MOS SF-36 transitional health index assesses whether there is an improvement in the patient's perception of overall health compared with 1 year before. The mean score before LVRS was 3.14 (0.26), compared with 1.71 (0.57) at 12 months ($p < 0.05$). This corresponds to a change from "about the same as 1 year ago" to "somewhat better" or "much better than 1 year ago."[6,7] The physical function, general health, social function and mental health indices were also significantly improved at 12 months after LVRS ($p < 0.05$).

## Discussion

The excision of bullae that cause compression and restriction of otherwise relatively normal lung is a procedure that has long been accepted in thoracic surgical practice. Such excision can improve pulmonary function and exercise.[12]

In the typical LVRS candidate, the areas of severe emphysema are not as clearly demarcated from areas of the lung with moderate emphysema. Instead, "target areas" of greater lung destruction are selected, based on the findings from chest radiography, CT and quantitative ventilation–perfusion scanning. We have found it useful to divide and quantitate ventilation and perfusion into 4 regions: right upper, right lower, left upper and left lower lung zones. Patients with predominantly upper lobe target areas were selected for the relative ease of resection through a median sternotomy. On the basis of our inclusion criteria, approximately 20% of patients referred may be suitable for LVRS. The most common reason for exclusion was insufficient target areas for resection.

The small patient sample limits the applicability of these results to a larger population. However, we can conclude that the improvements in exercise tolerance and pulmonary function after LVRS are sustained at 1 year, even with minimal postoperative rehabilitation. The durability of these improvements is unknown and the degree of improvement is variable (Figs. 1 and 2).

In our group, LVRS increased the $FEV_1$ by 33.39% and decreased RV by

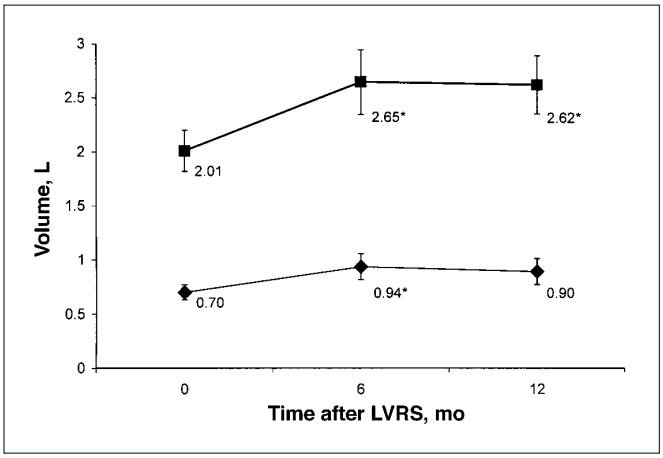


**FIG. 1. Absolute change in forced expiratory volume in the first second (diamonds) and forced vital capacity (squares) after lung volume reduction surgery (LVRS), measured by spirometry. *$p < 0.05$ (mean [and standard error]).**

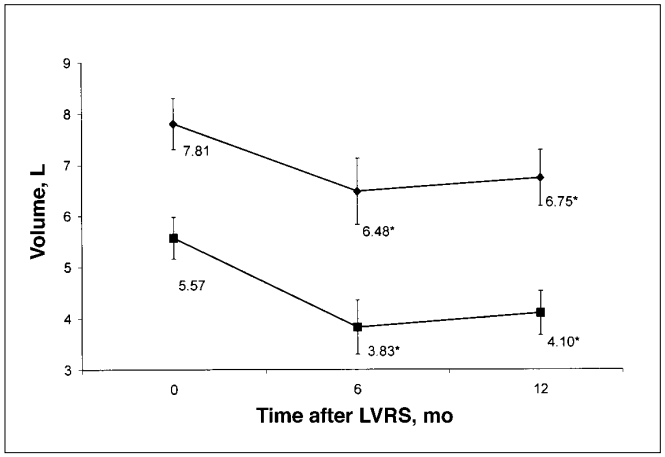


**FIG. 2. Absolute change in total lung capacity (circles) and residual volume (squares) after LVRS, measured by spirometry. *$p < 0.05$ (mean [and standard error]).**

27.61% at 1 year. These results are similar to other reported results. Cooper and associates[13] reported an increase in $FEV_1$ of 51% and a decrease in RV of 28% at 6 months after LVRS in 150 patients. Daniel and associates[14]reported an increase in $FEV_1$ of 49% and a decrease in RV of 30% at 3 months after LVRS in 17 patients. Kotloff and colleagues[15] reported an increase in $FEV_1$ of 41.4% and a decrease in RV of 28.3% in 56 patients at 3 to 6 months after LVRS by median sternotomy, and an increase in $FEV_1$ of 36% and a decrease in RV of 23.2% after bilateral thoracoscopic LVRS. The change of $FEV_1$ seen in our series was less than in other reported series. This may represent a learning curve phenomenon for the operation or a difference in the patients selected for surgical therapy between our centre and other centres.

Thoracoscopic approaches are being studied as less invasive methods of performing LVRS. However, the study designs of 2 major multicentre randomized LVRS trials use median sternotomy as an accepted or standard approach. Our group is now participating in the Canadian Lung Volume Reduction Surgery Trial, which uses LVRS through a median sternotomy as the approach in the treatment arm.[16] The National Emphysema Treatment Trial is an American multicentre trial, and 8 of 17 centres are performing LVRS with a sternotomy, 3 with bilateral thoracoscopy, and 6 with both in a randomized fashion.[17]

In our series, 3 of 5 patients on preoperative supplemental oxygen were able to decrease the amount of oxygen required for activities of daily living and exercise. However, none were able to discontinue their supplemental oxygen usage entirely. Cooper and associates[13] reported discontinuation of home oxygen as a commonly achieved goal after LVRS, with 70% of patients no longer requiring continuous oxygen and 52% of patients no longer requiring supplemental oxygen with maximal exercise. We speculate that the original criteria for home oxygen may have differed between our centre and other centres. Other reported series of LVRS have not explicitly stated their criteria for starting home oxygen.

There were 2 deaths in our series, pointing to the need for more specific exclusion criteria. The patient who died at 315 days had a history of COPD exacerbations and heavy sputum production before LVRS. His baseline percent predicted $FEV_1$ was the lowest of the group (17.9%, group mean 29.42% [2.79]%). His baseline $P_{CO_2}$ was also the highest of the group (58 mm Hg, mean 45.50 mm Hg [2.50 mm Hg]). The patient who died on the fourth postoperative day had also had a high baseline $P_{CO_2}$ (56 mm Hg), although his baseline percent predicted $FEV_1$ was higher (40.3%). Based on this early experience, we have screened later patients and have excluded all patients with a $P_{CO_2}$ greater than 55 mm Hg and those with a predominant or major component of chronic bronchitis.

Our surviving patients showed improved quality of life and dyspnea scores at 12 months after LVRS. Part of this improvement can be attributed to the effects of surgery. However, the effect of preoperative physiotherapy was not specifically measured in our study design.

LVRS is a potential treatment for patients with severe emphysema who are symptomatic despite all other standard therapy. A number of questions remain to be answered about the procedure.[18] These include the role of preoperative exercise, the mechanism of benefits, the duration of improvement and the optimal selection criteria. It is not clear if patients with diffuse emphysema and without target areas benefit from resection. The effect of LVRS on survival and prognosis of patients with severe emphysema is not known. Based on these early and limited results, our group concludes that the improvements in pulmonary function and exercise are sustained over the first 12 months after LVRS.

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