Life Expectancy and Rate of Decline After Lung Volume Reduction Surgery

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KEYWORDS

• Lung volume reduction surgery • Emphysema • Long-term outcomes • Survival rates
• Heterogeneous emphysema • Homogeneous emphysema

KEY POINTS

- Five-year survival rates post–lung volume reduction surgery (LVRS) for emphysema range between 63% and 78%.
- In well-selected patients with heterogeneous emphysema, there is a significant improvement in lung function at 5-years post-LVRS.
- There are durable improvements in disease-specific quality of life at 5 years post-LVRS.
- Select patients with homogenous emphysema may benefit from LVRS provided proper care is taken in resection of damaged tissue and careful patient selection.

INTRODUCTION

Chronic obstructive pulmonary disease (COPD), characterized by a spectrum of chronic bronchitis and emphysema, is one of the most debilitating lung conditions and is the fourth leading cause of death in the United States. Current treatment guidelines for COPD are focused on pulmonary rehabilitation and medical management with bronchodilators and inhaled corticosteroids, which have only been shown to decrease symptoms without prolonging patient survival.[1,2] Supplemental oxygen and smoking cessation are the only interventions shown to provide a survival benefit.[3,4] The high prevalence and mortality associated with COPD, along with limited treatment options, have spurred research into lung volume reduction surgery (LVRS) as a new treatment modality for advanced COPD.

LVRS was first described by Otto Brantigan in 1959.[5] He enrolled 57 patients with obstructive pulmonary emphysema over a period of 8 years. The procedure involved thoracotomy followed by unilateral removal of 20% to 30% of the diseased peripheral lung tissue in patients with emphysema. If the patient still was symptomatic, then the second side was operated on. Results of the study showed that 75% of the patients had symptomatic improvement but the early mortality rate was 16%. The procedure was not widely accepted largely due to difficulties in quantitating improvement and the early mortality rate of 16%. In 1983, Gaensler and colleagues[6] suggested that local resection should not be undertaken in patients with bullous emphysema.

Proper patient selection criteria were needed for performing lung volume reduction to improve the functional status and quality of life (QOL). Success

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was reported and published in the early 1990s using thoracoscopic laser techniques. It was at times difficult to replicate these results and the LVRS techniques evolved to stapled resection of the hyperinflated diseased lung. In 1995, Cooper and colleagues[7] reported on LVRS and had performed the procedure in 20 patients without giant bullous emphysema but with very heterogeneous disease. The results showed promising improvement in lung function and QOL. Following this success, a larger study involving 150 patients with long-term follow-up was conducted.[8] All patients had severe dyspnea, increased lung capacity, hyperinflation, and heterogeneous disease. Bilateral LVRS was performed using a sternotomy with removal of 20% to 30% of the lung volume in each lung using a linear stapler and bovine pericardial strips for suture line buttressing. Most of the damaged tissue was removed from the upper lobe whereas 18 patients had lower lobe destruction warranting removal of damaged tissue. The results showed a significant increase in percentage predicted value of forced expiratory volume in 1 second (FEV_1), a decrease in percentage predicted values of total lung capacity (TLC) and residual volume (RV), improved QOL with decreased oxygen, and corticosteroid use up to 2 years postsurgery. Following these studies, multiple studies were published that showed promising results with LVRS.

The current LVRS patient selection guidelines are based on the National Emphysema Treatment Trial (NETT),[9] a prospective clinical trial of 1218 subjects randomized to LVRS or medical treatment with a follow-up between 6 months and 4.5 years. The study enrolled patients with heterogenous and homogenous emphysema and predominantly upper lobe emphysema and non–upper lobe emphysema (including predominantly affecting the lower lobes, diffuse, or predominantly affecting the superior segments of the lower lobes). All enrolled subjects underwent 6 weeks to 10 weeks of pulmonary rehabilitation prior to randomization. The study concluded that patients

Table 1
Baseline demographic characteristics, functional and clinical outcomes in patients with emphysema undergoing lung volume reduction surgery by upper lobe perfusion

Characteristics	Upper Lobe Perfusion Less than or Equal to 15% (n = 66)	Upper Lobe Perfusion Greater than 15% (n = 69)
Age, years, mean (SD)	66.4 (±7.6)	66.6 (±7.6)
BMI, kg/m^2, mean (SD)	24.9 (±4.4)	25.2 (±4.6)
Gender (female)	34 (52%)	25 (36%)
Race/ethnicity		
Non-Hispanic white	64 (98%)	66 (96%)
Non-Hispanic black	1 (2%)	3 (4%)
Smoking history		
10–19 pack-years	0 (0%)	1 (1%)
20–29 pack-years	1 (2%)	6 (9%)
30–39 pack-years	10 (15%)	6 (9%)
40–49 pack-years	8 (12%)	7 (10%)
50–59 pack-years	5 (8%)	8 (12%)
60+ pack-years	42 (64%)	39 (58%)
FVC, % predicted value	66 (53–75)	67 (52–84)
FEV_1, % predicted value	25 (22–30.5)	24.5 (21–32.3)
RV, % predicted value	215 (192–267)	216 (190–240.5)
DLCO, % predicted value	38 (28–45)	37.5 (31.3–46.8)
6MWD (ft)	1194 (1030–1400)	1200 (1038–1350)
$Paco_2$ (mm Hg)	42 (38–63)	41 (35.8–44.7)
Pao_2 (mm Hg)	69 (63–74)	68 (61–71.2)

Abbreviations: BMI, body mass index; DLCO, diffusing capacity for carbon monoxide; FEV1, forced expiratory volume in the first second; FVC, forced vital capacity; PaCO2, partial pressure of carbon dioxide; PaO2, partial pressure of oxygen; RV, residual volume; 6MWD, 6 minute walk distance test.

with both predominantly upper lobe emphysema and low baseline exercise capacity had a survival advantage. Because of the increased mortality and poor improvement in functional outcomes, patients with non–upper lobe emphysema and low baseline exercise capacity were determined as poor candidates for LVRS. Several studies with similar inclusion criteria have shown that LVRS is effective during the short-term follow-up when well selected; however, few studies have looked at long-term outcomes post-LVRS in patients with end-stage emphysema. This review looks at studies that followed-up patients for at least 24 months from the time of surgery.

HETEROGENOUS EMPHYSEMA

The NETT trial recommended LVRS for patients with predominantly upper lobe emphysema with low exercise capacity. At 24 months' follow-up, the risk of death in patients with emphysema with predominantly upper lobe emphysema with low exercise capacity undergoing LVRS was 0.47 and there was an improvement in maximum workload (W) by more than 10-W, with improvement in St. George's Respiratory Questionnaire Scores.[9] At 5 years, the risk of death was 0.67 with improvement of St. George's Respiratory Questionnaire Scores. The improvement in workload, however, was durable only up to 3 years.[10] Long-term follow-up of NETT patients showed the mortality rates in LVRS patients was significantly lower (0.11 deaths per person-year) compared with the medical group (0.13 deaths per person-year), in spite of increased early mortality in the LVRS group.[10] At 5-year follow-up, there was a sustained improvement in lung function indicators, including FEV_1 (+1.4%), forced vital capacity

Table 2
Relative change from baseline (% change) in clinical and functional outcomes in patients with emphysema undergoing lung volume reduction surgery over 5-year period by upper lobe perfusion status

	Upper Lobe Perfusion Less than or Equal to 15%, median (interquartile range)		
Outcomes	**Year 1 (n = 43)**	**Year 3 (n = 27)**	**Year 5 (n = 15)**
FVC, % predicted value	41.4 (23.5–62.1)[c]	28.6 (20.0–45.2)[c]	21.2 (−4.2–36.1)[a]
FEV_1, % predicted value	54.2 (26.3–72.7)[c]	22.7 (12.0–51.5)[c]	22.2 (−10.0–37.5)[a]
RV, % predicted value	−27.8 (−42.5 to −18.3)[c]	−21.9 (−30.3 to −13.6)[c]	−12.1 (−23.8 to −2.6)[a]
DLCO, % predicted value	16.2 (0.0–28.2)[c]	12.3 (−5.8–25.6)[a]	8.7 (−13.3–26.2)
6MWD (ft)	9.3 (2.2–20.0)[c]	1.4 (−5.4–16.1)	−0.6 (−29.2–9.1)
$Paco_2$ (mm Hg)	−5.3 (−16.7–2.6)[a]	2.2 (−6.3–7.0)	2.3 (−10.7–9.8)
Pao_2 (mm Hg)	7.7 (0.0–20.9)[b]	1.4 (−11.3–25.2)	2.9 (−1.8–10.8)
	Upper Lobe Perfusion greater than15%		
Outcomes	**Year 1 (n = 31)**	**Year 3 (n = 22)**	**Year 5 (n = 12)**
FVC, % predicted value	27.7 (11.1–71.4)[c]	21.0 (2.9 45.2)[b]	30.8 (12.8–74.2)[a]
FEV_1, % predicted value	23.8 (6.2–56.0)[c]	23.7 (−5.1–34.2)[a]	37.5 (6.6–61.4)[a]
RV, % predicted value	−16.8 (−32.6 to −6.93)[c]	−14.6 (−21.9–3.5)	−1.6 (−20.5–2.6)
DLCO, % predicted value	7.3 (−2.4–17.8)[a]	−4.3 (−17.2–20.0)	−2.1 (−13.9–20.3)
6MWD (ft)	2.8 (−4.9–16.3)	−12.2 (−28.1–9.1)	−2.0 (−16.5–7.3)
$Paco_2$ (mm Hg)	−4.5 (−9.8–7.5)	5.0 (−3.3–9.8)	5.6 (−12.5–20.5)
Pao_2 (mm Hg)	0.0 (−2.9–14.5)	1.5 (−5.9–14.7)	1.3 (−10.6–27.3)

Abbreviations: DLCO, diffusing capacity for carbon monoxide; FEV1, forced expiratory volume in the first second; FVC, forced vital capacity; PaCO2, partial pressure of carbon dioxide; PaO2, partial pressure of oxygen; RV, residual volume; 6MWD, 6 minute walk distance test.

[a] $P<.05$.
[b] $P<.001$.
[c] $P<.0001$.

Table 3
Quality of life utility scores—baseline and change from baseline at 1 year, 3 years, and 5 years in patients with emphysema undergoing lung volume reduction surgery by upper lobe perfusion status—

	Upper Lobe Perfusion Less than or Equal to 15%, median (interquartile range)				Upper Lobe Perfusion Greater than 15%, median (interquartile range)			
	Baseline	Change at year 1 (n = 41)	Change at year 3 (n = 37)	Change at year 5 (n = 22)	Baseline	Change at year 1 (n = 33)	Change at year 3 (n = 22)	Change at year 5 (n = 17)
EQ-5D	0.71 (0.52–0.85)	0.07 (0.03–0.21)[c]	0.04 (−0.07–0.14)	−0.00 (−0.12–0.07)	0.74 (0.60–0.81)	0.70 (0–0.12)[a]	0.00 (−0.10–0.04)	0.00 (−0.12–0.10)
SF-36								
General health	35 (30–55)	20 (0–25)[c]	0 (−10–20)	5 (−15–15)	40 (25–50)	10 (0–15)[a]	−5 (−15–0)	−6.2 (−15–0)
Physical functioning	23 (10–30)	35 (20–40)[c]	20 (5–35)[c]	2.5 (−10–35)	18 (8.8–31)	25 (5–45)[c]	5 (0–15)[a]	20 (−5–30.7)[a]
Energy/fatigue	42.5 (30–55)	25 (10–45)[c]	10 (0–30)[c]	10 (−10–20)	47.5 (33.8–55)	10 (−10–30)[a]	0 (−10–20)	0 (−5–15)
Bodily pain	90 (77.5–100)	0 (0–10)	0 (−22.5–0)	0 (−20–0)	100 (79.4–100)	0 (−20–10)	0 (0–10)	0 (−25–0)
Emotional well-being	72 (61–88)	8 (0–20)[a]	8 (−4–12)[a]	0 (−12–8)	74 (60–90.6)	0 (−4–8)	−4 (−20–4)	0 (−4–4)
Social functioning	75 (50–87.5)	12.5 (0–37.5)[b]	12.5 (−12.5–25)	−6.2 (−37.5–12.5)	75 (50–90.6)	0 (−12.5–25)	0 (−12.5–25)	0 (−12.5–37.5)
Role limitations due to physical health	0 (0–25)	50 (25–100)[c]	0 (0–75)[a]	12.5 (0–50)[a]	0 (0–50)	25 (0–50)[c]	0 (−25–25)	0 (−25–25)
Role limitations due to emotional problems	83.3 (33.3–100)	0 (0–33.3)	0 (−33.3–0)	0 (−33.3–0)	100 (33.3–100)	0 (0–0)	0 (−66.7–0)[a]	0 (−33.3–0)[a]

[a] $P<.05$.
[b] $P<.001$.
[c] $P<.0001$.

(FVC) (+3.44%), and RV (−19.49%) of the predicted values. There was an overall 0.89-W improvement in maximum workload, −4.12 improvement in shortness of breath score, and 0.088 improvement in quality of well-being scores.[11] Based on the results from NETT study, LVRS was found to have a long-term durable effect on patients with emphysema with improvement in both functional and physiologic outcomes.

The authors followed 66 patients with predominantly upper lobe emphysema (ventilation-perfusion ratio [V/Q] ≤15%) for up to 5 years. Mean age was 66 years old, and 64% of the patients had a smoking history of 60 or more pack-years. All patients underwent 20 supervised pulmonary rehabilitation sessions prior to LVRS. Baseline mean values were FEV_1, 25% of predicted value; FVC, 66% of predicted value; RV, 215% of predicted value; and diffusing capacity of the lungs for carbon monoxide (DLCO), 38% of predicted value. The 6-minute walk distance (6MWD) was 1194 ft at baseline. Arterial oxygen and carbon dioxide were 42 mm Hg and 69 mm Hg, respectively (**Table 1**). At 5-year follow-up, there remained a significant improvement in FEV_1 (22%), FVC (22%), and RV (−12%) compared with baseline (**Table 2**). Improvement in DLCO was durable at 3 years whereas arterial pressure of oxygen and carbon dioxide was durable only up to 1 year follow-up (see **Table 2**). Based on the 36-item Short Form Health Survey (SF-36) QOL questionnaire, physical functioning, energy, and emotional well-being improved significantly compared with baseline and was durable up to 3 years post-LVRS. The limitation due to physical health, however, was significantly less compared with baseline values at 5-years post-LVRS (**Table 3**). Survival rates at 1 year, 2 years, 3 years, 4 years, and 5 years were 92.4%, 90.7%, 85.4%, 79%, and 69%, respectively (**Fig. 1**). The numbers of deaths at 1 year, 3 years, and 5 years post-LVRS in this group were 5 patients, 4 patients, and 7 patients. At the end of 5 years, 23 patients were lost to follow-up; however, there was no difference in baseline demographic and functional outcomes between those who did and did not complete 5-years of follow-up.

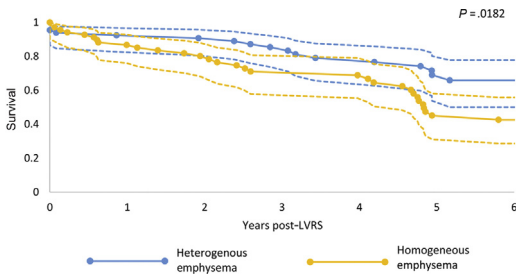

Fig. 1. Kaplan-Meier survival estimates, with 95% CI, by type of emphysema.

Five-year survival rates in patients undergoing LVRS for heterogeneous emphysema range between 63% and 78% (**Table 4**).[12–18] There was a significant improvement in overall QOL, measured using EuroQol-5D (EQ-5D) and SF-36 questionnaires up to 1 years to 3 years post-LVRS; however, studies have shown improvement in disease specific modified Medical Research Council scale and St. George's Respiratory Questionnaire up to 5-years post-LVRS.[10,12,13,15] The 6MWD improved significantly beyond year 1 and was durable up to 5-years.[14,19] There is a significant improvement in lung function up to 5-years of follow-up post-LVRS.[11,13,14] In well-selected patients with heterogeneous emphysema, LVRS has a durable long-term outcome up to 5-years of follow-up.

HOMOGENOUS EMPHYSEMA

It is postulated that improvements in lung function post-LVRS are due to reduction in RV and functional RV, leading to increased elastic recoil, thereby reducing airflow obstruction and hyperinflation. These benefits do not depend on lung morphology and hence improvement post-LVRS should be measurable not only in patients with heterogeneous emphysema but also in select patients with homogeneous emphysema. In patients with homogeneous emphysema, however, resection of damaged tissue may involve removal of some healthy parenchyma, leading to compensatory hyperinflation.

In the NETT study, 69 patients who had FEV_1 less than 20% of the predicted value with either homogeneous emphysema on CT or DLCO of less than 20% of their predicted value were considered a very-high-risk group. The 30-day mortality in these patients was 16% and hence the data monitoring board stopped recruiting these high-risk patients. Based on the results from already enrolled patients, there was minimal improvement in 6MWD and FEV_1, percentage of predicted value, at 6 months with no improvement in QOL.[20]

Weder and colleagues,[21] in 1997, published post-LVRS outcomes in 17 patients (mean age of 66 years) with homogeneous emphysema, with a baseline FEV_1 of 27% of predicted value, FVC 66% of predicted value, and RV 251% of predicted value. At 3-months' follow-up there were significant improvements in FEV_1, FVC, and RV. There also was significant improvement in arterial O_2 content and decline in CO_2 content. There was no mortality among these patients (**Table 5**).

Table 4
Inclusion criteria and outcomes post–lung volume reduction surgery in patients with heterogeneous emphysema

Study	Mean Age, Years	Heterogeneous Emphysema Diagnosis	Outcomes Time Points	Forced Expiratory Volume in the First Second of Expiration, Percentage of Predicted Value	Forced Vital Capacity, Percentage of Predicted Value	Residual Volume, Percentage of Predicted Value	Diffusing Capacity of the Lungs for Carbon Monoxide, Percentage of Predicted Value	Six-minute Walk Distance, Feet	Quality of Life	Survival (%)
Yusen et al,[15] 2003	61	Computed tomography	Baseline (n = 200) 12 mo (n = 185) 36 mo (n = 139) 60 mo (n = 33)	25		282	29	345 meters	mMRC 2.4 - 1.9 2.1	Survival 93 83 63
Horwood et al,[18] 2019	63	Computed tomography	Baseline (n = 135) 24 mo (n = 69) 60 mo (n = 31)	29	75	218	35.5	807		Survival 91 71
Ginsburg et al,[17] 2016	62.5		Baseline (n = 91) 24 mo (n = 41) 60 mo (n = 18)							Survival 97 79
Agzarian et al,[16] 2013	64		Baseline (n = 32)	25		5.4 L	31	340 meters		Survival 48 mo - 56 72 mo - 42 96 mo - 37
Ciccone et al,[14] 2003	62	Computed tomography	Baseline (n = 249) 12 mo (n = 225) 36 mo (n = 178) 60 mo (n = 106)	26 38 34 30		277 193 198 222	33 39 36 34	1142 1341 1271 1154		Survival 93 84 67
Fujimoto et al,[13] 2002			Baseline (n = 88) 12 mo (n = 57) 24 mo (n = 46) 36 mo (n = 26) 60 mo	27.5 31.1 30.3 30.1				285 m 390 m 349 m 334 m	mMRC 1.5 2.0 2.1	Survival 83 71
Hamacher et al,[12] 1999	66	Computed tomography	Baseline (n = 18) 24 mo (n = 18)	31 41		217 172		252 m 352 m	mMRC 3.4 3.4 1.9	

Weder et al,[19] 2009	64	Computed tomography and lung perfusion scintigraphy	Baseline (n = 112)	29	38.8	797	Survival
			12 mo (n = 70)	39	43	1263	96
			24 mo (n = 58)	38	43	1233	93
			36 mo (n = 38)	33	41	1266	77
			60 mo (n = 27)	33	38.7	1207	40

All follow-up values presented in the table are significant compared with baseline value.

Table 5
Inclusion criteria and outcomes post–lung volume reduction surgery in patients with homogeneous emphysema

Study	Inclusion/ Exclusion Criteria	Mean Age, Years	Homogeneous Emphysema Diagnosis	Outcomes Time Points	Forced Expiratory Volume in the First Second of Expiration, Percentage of Predicted Value	Forced Vital Capacity, Percentage of Predicted Value	Residual Volume, Percentage of Predicted Value	Diffusing Capacity of the Lungs for Carbon Monoxide, Percentage of Predicted Value	Six-minute Walk Distance, Feet	Quality of Life	Survival (%)
Weder et al,[19] 2009	Inclusion: FEV_1 <40% predicted value TLC >120% predicted value mMRC $\geq$ grade 2 Exclusion: FEV_1 <20% predicted value and DLCO <20% predicted value and advanced parenchymal destruction	64	Computed tomography and lung perfusion scintigraphy	Baseline (n=138) 12 mo (n = 78) 24 mo (n = 57) 36 mo (n = 37) 60 mo (n = 21)	28 35 36	75 87 91		39.9 43 45	807 1141 1119	mMRC 3.46 1.7 2.1	Survival 96 88 70 48

Bloch et al,[22] 2002	Inclusion: FEV_1 <40% predicted value RV >200% predicted value Exclusion: DLCO <20% predicted value		Computed tomography	Baseline (n=27) 12 mo (n = 20) 24 mo (n = 16)	25 35 31						
NETT Research Group, 2001,[20] and Kaplan et al, 2014[24]	NETT selection criteria	63	Computed tomography	Baseline (n=70) 30-d (n = 58) 52 mo	17.1		267.4	20.5	1038	Quality of well-being scale, 0.58	mortality 16%
Hamacher et al,[12] 1999	—	66	Computed tomography	Baseline (n=12) 3 mo 24 mo	26 38 32		234 193 203		274 meters	mMRC 3.5 1.6 2.0	
Weder et al,[21] 1997	Inclusion: FEV_1 <1.2 L TLC >130% predicted value Exclusion: $Paco_2$ >55 mm Hg DLCO <201%	62	Computed tomography	Baseline (n=17) 3 mo (n = 17)	27 ~36.9	66	251		249 meters	mMRC 3.6	

Abbreviations: DLCO, diffusing capacity for carbon monoxide; FEV1, forced expiratory volume in the first second; mMRC, modified medical research council scale; NETT, national emphysema treatment trial; PaCO2, partial pressure of carbon dioxide; RV, residual volume; TLC, total lung capacity.

All follow-up values presented in the table are significant compared with baseline value.

Hamacher and colleagues,[12] in 1999, performed LVRS in 12 patients with homogeneous emphysema with a mean age of 66 years. Baseline FEV_1 was 26% of predicted value and RV was 234% of predicted value. Both FEV_1 and RV significantly improved at 3-months and 2 years post-LVRS, with increase in arterial O_2 and decrease in CO_2. Survival rate at 2-years was approximately 50%. Bloch and colleagues,[22] in 2002, also showed that there was a significant improvement in functional outcomes at 2-years post-LVRS in 27 patients with homogeneous emphysema with a baseline FEV_1 of 25% of predicted value and FVC of 79% of predicted value. The first study with a larger sample size, of 138 patients, with homogeneous emphysema was conducted by Weder and colleagues,[23] in 2009. Baseline FEV_1 was 28% of predicted value, FVC was 75% of predicted value, DLCO was 40% of predicted value, and 6MWD was 807 ft. All values improved significantly over the first 2 years post-LVRS. The values were still above the baseline value at 5 years, even though there was a lack of statistical significance probably due to a very small number of patients (n = 21) at 5-year follow-up. Survival rate was 96% at year 1, 70% at year 3, and 48% at year 5 of follow-up.

After a careful review of the literature, the authors performed LVRS in 69 patients categorized as homogeneous emphysema based on V/Q. All patients underwent 20 supervised sessions of cardiopulmonary rehabilitation. If the V/Q for the upper lobe was greater than 15%, then they were considered as having homogeneous emphysema. The median FEV_1 percentage of predicted value was 24.5 (interquartile ratio [IQR]: 21–32.3), DLCO of 37.5% of the predicted value (IQR: 31.3–46.8), FVC percentage predicted value of 67% (IQR: 52–84), RV was 216 of percentage of predicted value, and 6MWD was 1200 ft (see **Table 2**). Mean age of the sample was 66 years and approximately 60% of them had a smoking history of 60 or more pack-years. All baseline demographic, functional, and clinical outcomes were similar to those of patients undergoing LVRS with heterogeneous emphysema (V/Q $\leq$15%).

At the end of 1 year, both FEV_1 percentage of predicted value and FVC percentage of predicted value improved compared with baseline and the improvement lasted for up to 5 years post-LVRS (see **Table 3**); although RV and DLCO improved at first 2 years, the improvement was not durable beyond year 2. QOL improved during year 1 based on EQ-5D questionnaire, but there was no improvement beyond year 1. Similar results were seen with the general health component of the SF-36 questionnaire. The physical functioning component of SF-36 questionnaire, however, significantly improved from baseline up to 5 years of follow-up. There were 9 deaths, 9 deaths, and 12 deaths at years 1 year, 3 years, and 5 years, respectively. At year 1, 2 patients sent the QOL questionnaire by mail and could not come for testing for lung functions; likewise, 5 patients sent in their QOL questionnaire but did not come for measuring functional outcomes at year 5. At the end of 5 years, 16 patients were lost to follow-up; however, there were no significant differences in baseline and functional outcomes between patients who did and did not complete 5 years of follow-up. There was a steady decline in survival percentage from 87% at year 1 to 71% at year 3 and 45% at year 5 (**Fig. 1**).

Based on the results from Weder and colleagues[23] and from the authors' center, select patients with homogeneous emphysema might benefit from LVRS with improved survival, functional, and QOL outcomes. Patients with homogeneous emphysema with baseline FEV_1 greater than 20% of predicted value and DLCO greater than 20% of predicted value may have better outcomes with LVRS provided proper care is taken in resection of damaged tissue with minimal removal of healthy parenchyma, thereby preventing compensatory hyperinflation. Future studies with larger sample size, improved selection of patients, appropriate resection of damaged tissue, and long-term follow-up will help in identifying eligible patients with homogeneous emphysema for LVRS.

SUMMARY

Most of the survival data pertain to heterogeneous disease. It seems that typically the improvement from LVRS with regard to pulmonary function tests is sustained for 3 years to 5 years. Five-year survival rates range from 63% to 78%. It would be expect patients follow expected survival in a similar medically treated population after that point.

The maturation of the VATS approach since the publication of the NETT trial, coupled with increased experience with LVRS at high-volume centers, has acted both to continuously improve long-term outcomes and to decrease surgical mortality. Data from the authors' study, coupled with recently published data from other centers, further bolster the broader usage of LVRS in patients appropriately selected for the surgery with end-stage emphysema. More importance should be given in selection of

patients, as described by the NETT study; however, some select patients with homogeneous emphysema with hyperinflation may benefit from LVRS. Due to the unavailability of long-term data, the number of LVRSs performed have declined over the years. Based on the available data, LVRS seems a durable alternative for end-stage emphysema in patients not eligible for lung transplantation.

CLINICS CARE POINTS

- Five-year survival post-LVRS ranges from 63% to 78%.
- There are durable improvements in QOL, even at 5 years post-LVRS.
- Some carefully selected homogeneously distributed emphysema patients can benefit from LVRS.
- LVRS is a durable and effective option for patients with heterogeneous disease. It probably is underutilized.

DISCLOSURE

The authors have nothing to disclose.

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