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Journal

CHEST Journal, 115(2)

ISSN

0012-3692

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Publication Date

1999-02-01

DOI

10.1378/chest.115.2.390

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Peer reviewed

Survival Following Bilateral Staple Lung Volume Reduction Surgery for Emphysema*

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Study objectives: Despite numerous reports of short-term response to lung volume reduction surgery (LVRS) for treatment of emphysema, to our knowledge, longer-term survival has not been reported. We describe survival following LVRS in a large cohort of 256 patients treated with bilateral staple LVRS (n = 236 video-assisted thoracic surgery [VATS] approaches, n = 20 median sternotomy) by a single group of physicians over a 3 1/2-year period from April 1994 to November 1997.

Design: Prospective survival study. Overall survival, survival stratified by preoperative presentation, and acute postoperative response were investigated using Kaplan-Meier methods. The simultaneous effects of preoperative predictors and postoperative response variables on survival were examined using a Cox proportional hazards model.

Setting: Community hospital and university medical center.

Patients: We studied 256 consecutive patients with severe emphysema treated with LVRS.

Interventions: Bilateral staple LVRS by VATS.

Measurements and results: Overall survival information was known with certainty for 246 of 256 patients as of February 1, 1998. Median follow-up time was 623 days (range, 0 to 1,545 days). Mean FEV₁ was 0.635L ± 0.015 L preoperatively and rose to 1.068L ± 0.029 L postoperatively. By standard analysis methods (missing patients censored at the time of last contact), 1-year survival was 85 ± 2.3% compared with 83 ± 2.4% 1-year survival with "worst case" analytic methods (assuming all missing patients died). Two-year survival averaged 81 ± 2.7% by standard analysis vs 76 ± 2.9% by worst case evaluation. Survival was significantly better for patients who were younger (≤ 70 years old, p = 0.02) and with higher baseline FEV₁ (> 0.5, p < 0.03) and Po₂ (> 54, p < 0.001). Patients who had greatest short-term improvement in FEV₁ following surgery (> 0.56 L increase) also had significantly better longer-term survival following LVRS.

Conclusions: To our knowledge, this is the first longer-term survival analysis of a large series of patients who underwent bilateral staple LVRS for emphysema. Substantial long-term mortality is seen, particularly within identifiable high-risk subgroups. Careful comparison to comparably matched control patients will be needed to definitively assess the benefits and risks of LVRS. This study suggests that prospective, controlled trials may need to stratify patient randomization based on preoperative risk factors to obtain meaningful results.

(CHEST 1999; 115:390-396)

Key words: duration; emphysema; long term; LVRS; predictors; survival

Abbreviations: DLCO = carbon monoxide diffusing capacity; LVRS = lung volume reduction surgery; NIH = National Institutes of Health; VATS = video-assisted thoracoscopic surgery

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Supported in part by DOE grant DE-F603-91ER61227, ALA grant CI-030-N, and CTRDRP grant 6RT-0158.

Manuscript received May 14, 1998; revision accepted October 10, 1998.

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Numerous studies have investigated short-term responses to lung volume reduction surgery (LVRS) for palliative treatment of emphysema.¹⁻¹³

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However, the overall value of LVRS cannot be determined accurately until long-term follow-up results are known. Some recent studies investigate longer-term functional results, but to our knowledge,

long-term survival predictors following LVRS have not been reported.^{2,6,9,14-16}

The National Institutes of Health (NIH) is beginning a multicenter, randomized, prospective trial of LVRS in patients with advanced emphysema.¹⁷ In future years, the NIH trial may add valuable information regarding long-term and short-term outcomes of LVRS compared with medical management. However, there is currently limited information regarding longer-term (> 1 year) postoperative survival and survival predictors for patients undergoing LVRS.

In this study, we investigate survival following LVRS in a large cohort of patients treated with bilateral staple LVRS performed by a single group of physicians over a 3 ½-year period from April 1994 to October 1997. Overall survival, as well as survival analysis based on preoperative presentation and acute postoperative response were assessed in all patients. Current survival information was available on all but 12 (5%) of 256 patients who underwent bilateral staple LVRS during this period. Since the number of patients unavailable for follow-up was small but potentially significant, analysis was performed in two ways: (1) standard method, in which all 12 missing patients were censored at the time of last contact, and (2) a "worst case scenario," in which all 12 patients were assumed to have died after the last contact. In this way, survival is analyzed under both limits of outcome possibilities.

Since patients with severely decreased FEV₁, such as those enrolled in this study, have variable but significantly elevated mortality risks^{18,19} with standard medical management, we suspected there would be considerable long-term mortality following LVRS as well. We hypothesized that patients who had less severe underlying disease, greater preoperative oxygenation, and greatest short-term improvement in pulmonary function test results would have better long-term survival.

To our knowledge, this survival analysis represents the largest cohort to date of emphysema patients treated by a uniform bilateral staple reduction procedure and followed up for a prolonged period of time. This information should be helpful in assessing mortality risks following LVRS, prospective randomized controlled trial stratification, and may aid in patient selection for long-term LVRS benefit.

MATERIALS AND METHODS

Methods for patient selection, preoperative analysis, surgical procedures, and follow-up studies for patients undergoing bilateral LVRS in this clinical program have been described previously.^{3,20}

All patients who underwent bilateral staple LVRS at Chapman Medical Center from April 1994 to November 1997 were in-

cluded in this evaluation. Patients underwent baseline complete pulmonary function testing, including spirometry, gas exchange measures (room air arterial blood gas measurement, carbon monoxide diffusing capacity [DLCO]), plethysmography, and gas dilution lung volumes. Maximum inspiratory and expiratory flow volume curves, and thoracic gas volume were measured in a plethysmograph (Collins/Cybermedic Classic TCI and Body Plethysmograph; Warren E. Collins Inc; Braintree, MA), and compared with predicted values as previously described.^{3,20} All patients underwent LVRS at Chapman Medical Center by one or both of the two thoracic surgeons in the research group (R.J.M., R.J.F.); no procedures were performed at any other center in this protocol.

Repeated pulmonary function studies were requested from patients 3 months postoperatively, at 6 months, and at approximately 6-month intervals thereafter. Whenever possible, repeated spirometry was performed at least once at Chapman Medical Center within 3 months of surgery, but subsequent spirometry data were obtained from the referring site.

Informed consent for surgery and preoperative evaluation was obtained from all patients. Despite maximal medical management, all patients were markedly symptomatic. Chest radiographs showed hyperexpansion of the thorax with flattening or inversion of the diaphragms.

Contraindications to surgery included current cigarette smoking, age > 80 years, severe cardiac disease (congestive heart failure, significant coronary or valvular disease), history of cancer within the last 5 years, ventilator dependency, or prior thoracic surgery. Relative contraindications included age > 75 years, severe anxiety, severe depression, or CO₂ retention with resting PaCO₂ > 55 mm Hg.^{3,20}

To be accepted for the procedure, the pattern of emphysema on CT had to be severe and heterogeneous. Radionuclide lung perfusion scans were also used to confirm the heterogeneous pattern of emphysema.^{3,20}

Thoracoscopic LVRS Operative Methods

Operative procedures for bilateral thoracoscopic staple volume reduction surgery have been described previously as well.^{3,20} Patients underwent video-assisted thoracic surgery (VATS) under paralyzed general anesthesia (isoflurane) using a left-sided double-lumen tube (Mallinckrodt Anesthesia; St. Louis, MO).

Procedures were performed by one surgical group (RM, RF, MM) with patients in the lateral decubitus position. The trocar and thoracoscope were placed through the 10th intercostal space in the posterior axillary line. Three additional 1- to 2-cm incisions were made for standard instruments. Patients were turned to the contralateral decubitus position for separate sterile preparation and draping after completion of surgery on the initial side.

Preoperative lung CT scans and ventilation/perfusion scans were used to identify areas of dysfunctional or degenerated lung targeted for resection with the staples.^{3,20} Ring forceps manipulated the lung into a 60-mm endoscopic stapler (ELC 60; Ethicon; Cincinnati, OH) with bovine pericardium (Peristrips; Biovascular; Saint Paul, MN) or Instat (Johnson and Johnson; New Brunswick, NJ) to buttress the staples. The staples were fired an average of 15 times for bilateral operations. Typically, approximately half of the upper lobe was resected in patients with upper lobe disease.

Survival

Survival status was assessed for all patients by contacting them directly or their referring physicians between January and Feb-

ruary, 1998. The latest date of known survival was recorded, and the date and cause of death (if known) were recorded for patients who died. Information on cause of death when available was obtained from families or referring physicians.

A total of 12 patients were unavailable for follow-up as of January 1998. For these patients, the last known date of contact was recorded and used as the censoring date in the first analysis method, and used as the potential date of death in the "worst case" scenario analyses.

Acute Response Evaluation

The change in FEV₁, FVC, and dyspnea score at the time of initial follow-up was determined for all patients whose initial follow-up visits were within 1 year of surgery. The short-term postoperative improvement was defined as the FEV₁ measured closest to 6 months following surgery.

Rehabilitation

Patients did not receive preoperative rehabilitation at Chapman Medical Center prior to LVRS. All patients underwent a similar regimen of pulmonary rehabilitation at the Medical Center, beginning immediately following hospital discharge. The rehabilitation consists of a 10-day outpatient regimen involving a multidisciplinary approach with nursing, respiratory, dietary, nutritional, psychosocial, occupational, and physical therapy. Patient education, physical exercise (walking, flexibility, and strengthening), self-monitoring, breathing retraining, and bronchial hygiene instruction are included.

Statistical Analysis

Baseline characteristics and group descriptive characteristics are reported as mean and standard errors. The overall survivor function is estimated using the Kaplan-Meier method. Differences in survival after stratification by preoperative and postoperative variables were tested using the log-rank test (Tarone-Ware test). The simultaneous importance of preoperative and postoperative variables on survival were investigated using Cox proportional hazards regression. Covariate analysis was performed, including variables found to be significant in univariate survival. Survival analyses were performed using Kaplan-Meier methods and with Cox proportional hazards analysis. Analyses were conducted using a statistical software package (Systat 7.0 for Windows; SPSS Inc; Chicago, IL).

RESULTS

Composite Results in All Patients

A total of 256 patients (165 male, 91 female) underwent bilateral staple LVRS in this program during the analysis interval. Average age was 67 ± 0.4 years. There were 13 perioperative deaths (defined as deaths within 30 days of surgery); 30-day mortality rate was $5 \pm 1.3\%$ in this group.

Baseline characteristics are summarized in Table 1. Mean FEV₁ was $0.635\text{L} \pm 0.015\text{L}$ preoperatively and rose to $1.068\text{L} \pm 0.029\text{L}$ postoperatively (at an average of 5 ± 2.5 months). Short-term improvement in FEV₁ following surgery was $0.43\text{L} \pm 0.02\text{L}$ ($41 \pm 5\%$ change from baseline). Baseline dyspnea

Table 1—Comparison of Baseline Values for VATS- vs Median Sternotomy-Treated Patients*

	VATS		Median Sternotomy		p Value
	Mean	SD	Mean	SD	
Age, yr	67	6.87	66	11.04	0.80
DLCO, mL/min/mm Hg	5.2	2.67	5.3	2.57	0.89
FEV ₁ , % predicted	24.4	8.35	25.0	5.84	0.80
FEV ₁ , L	0.6	0.23	0.7	0.23	0.23
FVC, % predicted	49.6	14.81	52.9	19.12	0.65
FVC, L	1.9	0.69	2.3	0.96	0.31
PCO ₂ , mm Hg	42.5	7.21	41.1	4.67	0.44
PO ₂ , mm Hg	65.1	11.94	63.8	7.69	0.65
RV, % predicted	201.1	57.47	192.0	39.42	0.54
RV, L	4.5	1.48	4.8	0.62	0.26
RV/TLC	0.7	0.10	0.6	0.11	0.75
TLC, % predicted	125.1	22.57	115.9	8.21	0.02
TLC, L	7.2	1.71	7.5	0.65	0.23

*RV = residual volume; TLC = total lung capacity.

score for all patients in this study was 3.1 ± 0.05 . Dyspnea score improved acutely following surgery by 1.8 ± 0.08 to 1.37 ± 0.08 in survivors.

Overall Survival

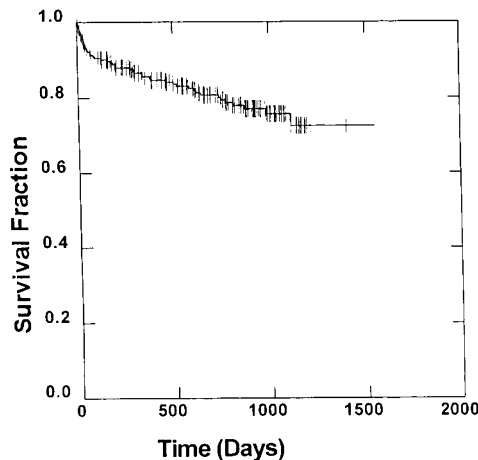
Overall survival information was known with certainty for 246 of 256 patients as of February 1, 1998. Median follow-up time was 623 days (± 23.6 days; range, 0 to 1,545 days) until cutoff date ($n = 193$), censoring when unavailable for follow-up ($n = 12$), or death ($n = 51$). The 12 patients unavailable for follow-up were followed up a mean of 391 days at the times of last contact.

Overall survival by standard and worst-case scenario analyses is shown in Figure 1. By standard analysis, 1-year survival is $85 \pm 2.3\%$ compared with $83 \pm 2.4\%$ 1-year survival with worst case analytic methods. Two-year survival averaged $81 \pm 2.7\%$ by standard analysis vs $76 \pm 2.9\%$ by worst-case evaluation. Three-year survival information is available on 24 patients. Patient survival at 3 years is $72 \pm 4.4\%$ by standard and $67 \pm 4.4\%$ by worst case analysis methods. No differences were seen in survival between men and women (Fig 2, A).

Effect of Operative Procedure

Bilateral thorascopic staple LVRS by VATS was performed in the vast majority of patients ($n = 236$). However, early in the program, 20 patients underwent LVRS via median sternotomy. Survival following median sternotomy in this series of patients was significantly worse than in patients who underwent bilateral thorascopic LVRS ($p < 0.001$) (Fig 2, B). One-year survival was $55 \pm 11\%$ for median sternot-

A. OVERALL SURVIVAL STANDARD ANALYSIS



B. OVERALL SURVIVAL WORST CASE SCENARIO

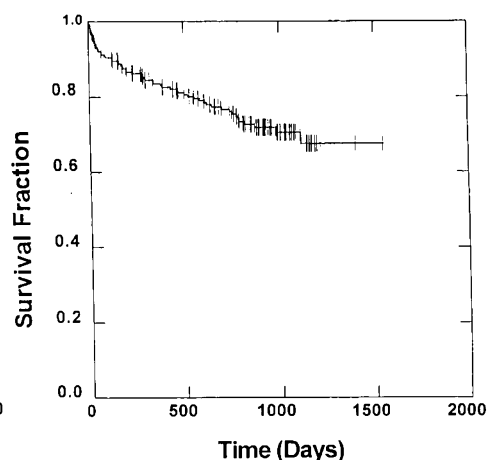


FIGURE 1. Kaplan-Meier survival curves following bilateral staple LVRS procedures. Time in days is shown on the x-axis. Fraction of original patients surviving is shown on the y-axis. Event markers denote patients censored at each time. *Left (A)*: standard analytical survival analysis in which patients unavailable for follow-up are censored at the time of last contact. *Right (B)*: “worst case” analysis methods in which patients unavailable for follow-up are assumed to have died after the last contact.

omy patients vs $88 \pm 2\%$ for thorascopic LVRS by VATS patients (standard analysis methods). Two-year survival was $40 \pm 12\%$ for median sternotomy vs $83 \pm 2.7\%$ for VATS-treated patients. Most of the mortality in the median sternotomy patients was acute, with 30-day mortality of $25 \pm 11\%$. In contrast, acute 30-day mortality rates were $3.0 \pm 1\%$ for thorascopic LVRS. For this reason, bilateral thorascopic LVRS by VATS is used almost exclusively in this program currently.

At preoperative baseline, there were no significant differences between patients who underwent VATS vs median sternotomy, except a slightly lower total lung capacity (115% predicted vs 124%) for median sternotomy patients vs VATS, respectively ($p = 0.03$).

FEV₁

Patients with higher baseline FEV₁ (> 0.50 L, $n = 172$) had improved survival compared to patients with lower baseline FEV₁ (≤ 0.50 L, $n = 79$) ($p = 0.03$) as seen in Figure 2, C. Similar findings were seen if baseline FEV₁ percent predicted (cutoff value 19% predicted) was used rather than absolute FEV₁ values ($p = 0.04$). For patients who underwent LVRS by VATS methods, 1-year survival was $81 \pm 4.7\%$ for those with FEV₁ < 0.5 L vs $90 \pm 2\%$ for those with higher baseline FEV₁.

Surviving patients whose FEV₁ improved most at initial follow-up (increase in FEV₁ > 0.56 L, $n = 56$) appeared to have significantly lower long-term mor-

tality ($p < 0.04$) than the 154 patients with short-term follow-up visits revealing an increase in FEV₁ of ≤ 0.56 L over baseline. Findings were similar when evaluated as increases in percent predicted FEV₁; patients whose conditions improved $> 16\%$ of predicted ($n = 89$) from baseline had significantly greater long-term survival than patients whose conditions did not improve as much ($n = 113$) at early follow-up ($p = 0.04$) (Fig 2, D and E).

Age

As expected, younger patients ≤ 70 years old ($n = 176$) had improved long-term survival (1 year, $88 \pm 2.5\%$; 2 year, $85 \pm 3\%$) compared with older patients > 70 years old ($n = 76$, 1-year survival, $80 \pm 4.6\%$; 2-year survival, $72 \pm 5\%$) ($p = 0.02$, Fig 2, F).

Gas Exchange

Baseline hypoxemia ($\text{PaO}_2 \leq 55$, $n = 47$) also predicted poorer long-term survival ($p = 0.001$) (Fig 2, G). For VATS-treated patients, $\text{PaO}_2 \leq 55$ mm Hg was $75 \pm 6.6\%$ at 1 year vs $90 \pm 2.3\%$ survival in patients with preoperative $\text{PaO}_2 > 55$. Baseline PaCO_2 showed trends toward worsening survival with elevated PaCO_2 , but did not reach statistical significance (Fig 2, H). Preoperative DLCO levels were not significantly associated with long-term survival at any cut point.

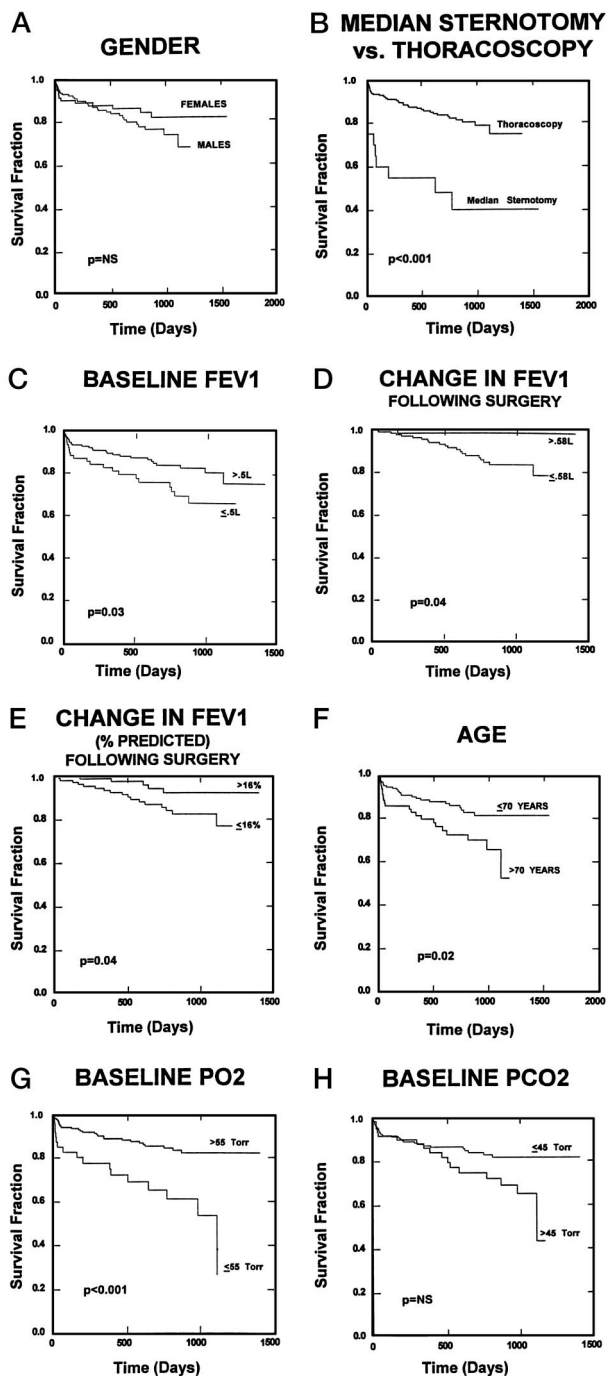


FIGURE 2. Kaplan-Meier survival curves following bilateral staple LVRS procedures with subgroup analysis based on predictive variables. Time in days is shown on the x-axis. Fraction of original patients surviving is shown on the y-axis. Cut points for individual continuous variables were selected at levels that maximize survival discrimination. A: survival based on gender (n = 165 male, 91 female); B: by operative procedure—median sternotomy (n = 20) vs thoracoscopic VATS (n = 236); C: by preoperative baseline FEV₁ (cut point 0.5 L); D: by magnitude of improvement in FEV₁ following surgery (cut point 0.56 L); E: by change in FEV₁ percent predicted following surgery (cut point 16% improvement); F: by age (cut point 70 years); G: by preoperative room air PaO₂ (cut point 54 mm Hg); H: by preoperative room air PaCO₂ (cut point 45 mm Hg).

Multivariate Survival Analysis

Multivariate analysis using the preoperative variables found to be significant in univariate testing (PaO₂, age, FEV₁ percent predicted, procedure approach) revealed all variables to be significant independent predictors of outcome (all p < 0.01) except for FEV₁ percent predicted (p = 0.14).

DISCUSSION

Numerous recent studies report early pulmonary function and symptomatic improvement in selected patients following bilateral staple LVRS procedures for relief of emphysema symptoms.^{2,3,5-7,10,11,21-26} Operative mortality rates have generally been reported between 0 and 8%.^{3,5,6,10,11,13,15,24-27} However, to our knowledge, longer-term survival studies and factors associated with long-term mortality have not been published.

Long-term survival information for patients undergoing LVRS is important for providing prognostic information, selecting patients for surgery, and defining success following surgery. We hypothesized that certain subgroups of patients undergoing LVRS would have long-term survival advantages. Preoperatively, we predicted that patients with lesser degrees of overall emphysema, younger age, and higher levels of oxygenation would be better able to survive for longer periods of time postoperatively. Additionally, we thought that patients who experienced greatest short-term improvement following surgery would also have improved long-term survival.

Most of the survival analysis results of this study are not surprising, though the magnitude of survival impact differences based on preoperative variables was impressive for a number of variables. As expected, low preoperative FEV₁, hypoxemia, and advanced age were clearly associated with reduced long-term survival.

Surviving patients who experienced the greatest incremental improvements in FEV₁ shortly following surgery also had improved long-term survival prognosis. The added reserve acquired from surgery may contribute to the increased long-term outcomes in these cases.

Mortality with median sternotomy was higher than bilateral LVRS by VATS in this series, with most deaths occurring within 30 days of surgery. There were far fewer median sternotomy procedures (20) than thoracoscopic procedures (236). The median sternotomy procedures were performed early in the bilateral LVRS program and may represent a learning curve phenomenon. However, the surgeons were already very experienced with unilateral LVRS by

VATS,⁴ and they had performed many median sternotomies for other indications. Thus, it remains unclear why median sternotomy results were higher in this series than in VATS, or higher than results reported from other centers.^{2,11,28,29}

Multivariate analyses confirm the independent significance of the univariate predictors of survival, although the preoperative FEV₁ did not reach statistical significance.

There are many issues involved in defining improved short-term response to LVRS procedures that complicate assessment of the relationship between short-term improvement and long-term survival. Postoperative improvement can be defined by a number of objective and subjective variables. Improvement in flows, volumes, gas exchange, or dyspnea can all be considered outcome variables. In this study, we focused on FEV₁ and dyspnea scale score improvements. FEV₁ has been shown to correlate with long-term survival in patients with emphysema. Dyspnea scores are subjective but are clinically relevant to patients. Improvement in outcome variables can be measured as absolute changes following surgery from baseline, or as the percent improvement compared with baseline values. We chose to examine absolute improvement measures rather than percent changes from baseline, because percent change measurements are greatest in patients with the lowest baseline values and “exaggerate” changes in the most compromised patients who would not be expected to survive longest.

There are a number of limitations to this study. When we analyzed preoperative variables to predict long-term survival outcome, “cut points” must be interpreted with caution. Clearly, they do not represent fixed “cutoff” values for acceptable or unacceptable outcomes. Statistically, they represent points on a continuum of statistical probability where greater likelihood of improved outcome exists on one side compared with another side of the cut. Individual judgment must be retained in making decisions regarding outcome and treatment of patients.

While it is useful to examine the variables that influence survival outcomes following LVRS in this study, it is not possible to compare survival in these patients who underwent LVRS procedures to patients who have been medically managed. A comparable control group can realistically be obtained only by a controlled trial such as the upcoming NIH study. However, since marked differences in survival are seen based on preoperative parameters in the current investigation, it may be necessary to stratify patients during prospective randomization based on preoperative risk group categories or spurious results may occur in prospective trials.

Most importantly, one cannot conclude that sub-

groups of patients who are identified as having poor long-term survival following LVRS are poor candidates for LVRS therapy, since they may be the same patients who would also have poor long-term survival chances with medical management. Only comparison with a comparably matched control group can answer these important questions.

There are additional limitations of this study. Patients involved in this study met very specific, narrowly defined selection criteria. Any findings from this study do not apply to and cannot be extrapolated to patients who do not meet the entry criteria of this study. In particular, the large proportion of patients with relatively homogeneously distributed emphysema were excluded from LVRS in this study, and their response to LVRS cannot be inferred.

We examined expiratory flow as the primary outcome measure to define short-term LVRS operative success for correlations with long-term survival. There is evidence that lung volume, gas exchange, and exercise measurements may be of equal or greater clinical importance.

The follow-up survival information is relatively complete from this very large group of patients in this study. However, the 12 patients who were unavailable for follow-up do affect overall mortality statistics as can be seen by the “best” and “worst case scenarios” analyzed in this study.

To our knowledge, this study represents the first report of a large cohort of patients studied for longer-term survival following bilateral staple LVRS. The group of patients is unique in that all patients were treated by one group of physicians, at a single center, with relatively complete longer-term survival follow-up information. Substantial long-term mortality is seen, particularly within identifiable high-risk subgroups. Careful comparison to comparably matched control patients, stratified by risk category, with longer-term follow-up will be needed to definitively assess the benefits and risks of LVRS.

REFERENCES

- 1 Cooper JD, Trulock EP, Triantafillou AN, et al. Bilateral pneumectomy (volume reduction) for chronic obstructive pulmonary disease. *J Thorac Cardiovasc Surg* 1995; 109:106–116; discussion 116–119
- 2 Cooper JD, Patterson GA, Sundaresan RS, et al. Results of 150 consecutive bilateral lung volume reduction procedures in patients with severe emphysema [see comments]. *J Thorac Cardiovasc Surg* 1996; 112:1319–1329; discussion 1329–1330
- 3 McKenna RJ Jr, Brenner M, Fischel RJ, et al. Should lung volume reduction for emphysema be unilateral or bilateral? *J Thorac Cardiovasc Surg* 1996; 112:1331–1338; discussion 1338–1339
- 4 McKenna RJ Jr, Brenner M, Gelb AF, et al. A randomized, prospective trial of stapled lung reduction versus laser bul-

- lectomy for diffuse emphysema [see comments]. *J Thorac Cardiovasc Surg* 1996; 111:317–321; discussion 322
- 5 Scieurba FC, Rogers RM, Keenan RJ, et al. Improvement in pulmonary function and elastic recoil after lung-reduction surgery for diffuse emphysema [see comments]. *N Engl J Med* 1996; 334:1095–1099
 - 6 Stammberger U, Thurnheer R, Bloch KE, et al. Thoracoscopic bilateral lung volume reduction for diffuse pulmonary emphysema. *Eur J Cardiothorac Surg* 1997; 11:1005–1010
 - 7 Argenziano M, Thomashow B, Jellen PA, et al. Functional comparison of unilateral versus bilateral lung volume reduction surgery. *Ann Thorac Surg* 1997; 64:321–326; discussion 326–327
 - 8 Bagley PH, Davis SM, O'Shea M, et al. Lung volume reduction surgery at a community hospital: program development and outcomes. *Chest* 1997; 111:1552–1559
 - 9 Cordova F, O'Brien G, Furukawa S, et al. Stability of improvements in exercise performance and quality of life following bilateral lung volume reduction surgery in severe COPD. *Chest* 1997; 112:907–915
 - 10 Hazelrigg SR, Boley TM, Naunheim KS, et al. Effect of bovine pericardial strips on air leak after stapled pulmonary resection. *Ann Thorac Surg* 1997; 63:1573–1575
 - 11 Kotloff RM, Tino G, Bavaria JE, et al. Bilateral lung volume reduction surgery for advanced emphysema: a comparison of median sternotomy and thoracoscopic approaches. *Chest* 1996; 110:1399–1406
 - 12 Miller JI Jr, Lee RB, Mansour KA. Lung volume reduction surgery: lessons learned [see comments]. *Ann Thorac Surg* 1996; 61:1464–1468; discussion 1468–1469
 - 13 Szekely LA, Oelberg DA, Wright C, et al. Preoperative predictors of operative morbidity and mortality in COPD patients undergoing bilateral lung volume reduction surgery. *Chest* 1997; 111:550–558
 - 14 Yusen RD, Trulock EP, Pohl MS, et al. Results of lung volume reduction surgery in patients with emphysema: the Washington University Emphysema Surgery Group. *Semin Thorac Cardiovasc Surg* 1996; 8:99–109
 - 15 Gelb AF, Brenner M, McKenna RJ Jr, et al. Lung function 12 months following emphysema resection. *Chest* 1996; 110:1407–1415
 - 16 Scieurba FC. Early and long-term functional outcomes following lung volume reduction surgery. *Clin Chest Med* 1997; 18:259–276
 - 17 Benditt JO, Albert RK. Surgical options for patients with advanced emphysema. *Clin Chest Med* 1997; 18:577–593
 - 18 Traver GA, Cline MG, Burrows B. Predictors of mortality in chronic obstructive pulmonary disease: a 15-year follow-up study. *Am Rev Respir Dis* 1979; 119:895–902
 - 19 Burrows B, Bloom JW, Traver GA, et al. The course and prognosis of different forms of chronic airways obstruction in a sample from the general population. *N Engl J Med* 1987; 317:1309–1314
 - 20 Gelb AF, Zamel N, McKenna RJ Jr, et al. Mechanism of short-term improvement in lung function after emphysema resection. *Am J Respir Crit Care Med* 1996; 154(pt 1):945–951
 - 21 Brenner M, McKenna R Jr, Gelb A, et al. Objective predictors of response for staple versus laser emphysematous lung reduction. *Am J Respir Crit Care Med* 1997; 155:1295–1301
 - 22 Cooper JD, Patterson GA. Lung-volume reduction surgery for severe emphysema. *Chest Surg Clin North Am* 1995; 5:815–831
 - 23 Daniel TM, Chan BB, Bhaskar V, et al. Lung volume reduction surgery: case selection, operative technique, and clinical results. *Ann Surg* 1996; 223:526–531; discussion 532–533
 - 24 Keller CA, Ruppel G, Hibbett A, et al. Thoracoscopic lung volume reduction surgery reduces dyspnea and improves exercise capacity in patients with emphysema. *Am J Respir Crit Care Med* 1997; 156:60–67
 - 25 Martinez FJ, de Oca MM, Whyte RI, et al. Lung-volume reduction improves dyspnea, dynamic hyperinflation, and respiratory muscle function. *Am J Respir Crit Care Med* 1997; 155:1984–1990
 - 26 Argenziano M, Moazami N, Thomashow B, et al. Extended indications for lung volume reduction surgery in advanced emphysema. *Ann Thorac Surg* 1996; 62:1588–1597
 - 27 Fujita RA, Barnes GB. Morbidity and mortality after thoracoscopic pneumonoplasty. *Ann Thorac Surg* 1996; 62:251–257
 - 28 Weder W, Schmid RA, Russi EW. Thoracoscopic lung volume reduction surgery for emphysema. *Int Surg* 1996; 81:229–234
 - 29 Stamatis G, Teschler H, Fechner S, et al. Bilateral lung volume reduction in patients with severe pulmonary emphysema [see comments]. *Pneumologie* 1996; 50:448–452