Changes in Arterial Oxygenation and Self-Reported Oxygen Use after Lung Volume Reduction Surgery

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Rationale: Lung volume reduction surgery (LVRS) is inconsistently reported to improve arterial oxygenation in patients with chronic obstructive pulmonary disease.

Objectives: We studied the effects of surgery on oxygenation in a large cohort and identified predictors of postoperative oxygenation improvement.

Methods: We evaluated oxygenation in 1,078 subjects with chronic obstructive pulmonary disease enrolled in the National Emphysema Treatment Trial after LVRS compared with medical control subjects, including arterial blood gases, use of supplemental oxygen during treadmill walking, and self-reported use of oxygen during rest, exertion, and sleep.

Measurements and Main Results: PaO₂ breathing room air was equal in medical and surgical subjects at baseline (64.8 vs. 65.0 mm Hg, *P* = not significant), but lower in medical subjects at 6 months (63.6 vs. 70.0 mm Hg, *P* < 0.001), 12 months (63.9 vs. 68.7 mm Hg, *P* < 0.001), and 24 months (62.4 vs. 68.0 mm Hg, *P* < 0.001). Fewer medical subjects required oxygen for treadmill walking at baseline compared with surgical subjects (46 vs. 53%, *P* = 0.02). However, more medical subjects required oxygen for this activity at 6 months (49 vs. 33%, *P* < 0.001), 12 months (50 vs. 36%, *P* < 0.001), and 24 months (52 vs. 42%, *P* = 0.02). Self-reported oxygen use was greater in medical than in surgical subjects at 6, 12, and 24 months. Multivariate modeling of preoperative characteristics showed baseline oxygenation status was the best predictor of postoperative oxygenation.

Conclusions: LVRS increases PaO₂ and decreases treadmill and self-reported use of oxygen for up to 24 months post-procedure.

Clinical trial registered with www.clinicaltrials.gov (NCT 00000606).

Keywords: oxygen inhalation therapy; emphysema; lung diseases, obstructive

Initial case series reports of modern lung volume reduction surgery (LVRS) suggested significant improvements in arterial

AT A GLANCE COMMENTARY

Scientific Knowledge on the Subject

Lung volume reduction surgery is reported to have benefits for patients with emphysema. It has been unclear whether this surgery has ameliorative effects on arterial oxygenation.

What This Study Adds to the Field

Lung volume reduction surgery improved arterial oxygenation and decreased supplemental oxygen use in a large cohort of subjects with emphysema compared with a medically treated control group.

blood oxygenation (1–3) and reduced need for supplemental oxygen after the procedure (1, 3, 4). However, improved oxygenation has not been consistently found in case series (5–7) or randomized trials of patients undergoing LVRS. Four trial reports described no significant differences in measures of arterial oxygenation after either surgical or medical treatment for emphysema (8–11), whereas two (12, 13) reported improvements in measures of oxygenation after LVRS.

Understanding the effects of LVRS on oxygenation and the corollary need for supplemental oxygen is important for several reasons. Oxygen therapy for people with chronic obstructive pulmonary disease (COPD) is expensive. One study estimated the cost at over \$2 billion annually in the United States, representing one-third of all direct costs of medical care for COPD (14). Some patients find oxygen therapy burdensome. In a study by Eaton and colleagues, 14 of 34 (41%) subjects who responded to oxygen (defined as improvement in health-related quality of life or increased six-minute-walk distance or decreased dyspnea on exertion) declined ongoing ambulatory oxygen treatment (15). Data from the National Emphysema Treatment Trial (NETT) provide an important opportunity to study the effects of LVRS on oxygenation and oxygen use over time. The NETT is a large multicenter, randomized clinical trial of maximal medical therapy compared with LVRS for severe emphysema. During the trial, investigators collected arterial blood gas data, performed a standardized oxygen titration test, and queried patients about supplemental oxygen use at baseline and at scheduled intervals after randomization to LVRS or medical therapy. Our analysis was designed to determine the following: (1) does LVRS result in a change in PaO₂, oxygen need during treadmill walking, and self-reported oxygen use during rest, exertion, and sleep; (2) does LVRS have an effect on qualification for supplemental oxygen using the most stringent commonly used indication (PaO₂ ≤ 55 mm Hg); and (3) are there

(Received in original form December 13, 2007; accepted in final form June 3, 2008)

The National Emphysema Treatment Trial (NETT) was supported by contracts N01HR76101, N01HR76102, N01HR76103, N01HR76104, N01HR76105, N01HR76106, N01HR76107, N01HR76108, N01HR76109, N01HR76110, N01HR76111, N01HR76112, N01HR76113, N01HR76114, N01HR76115, N01HR76116, N01HR76118, and N01HR76119 from the National Heart, Lung, and Blood Institute; the Centers for Medicare and Medicaid Services; and the Agency for Healthcare Research and Quality.

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This article has an online supplement, which is accessible from this issue's table of contents at www.atsjournals.org

Am J Respir Crit Care Med Vol 178, pp 339–345, 2008

Originally Published in Press as DOI: 10.1164/rccm.200712-1826OC on June 5, 2008

Internet address: www.atsjournals.org

preoperative patient characteristics that allow us to predict changes in oxygen need or use after surgery?

METHODS

Additional details on the methods of this research are available in the online supplement.

NETT Design

The NETT is a multicenter randomized clinical trial comparing maximal medical therapy to maximal medical therapy plus LVRS for treatment of advanced emphysema. NETT study design and methods have been described previously (16, 17). The protocol was institutional review board approved at each of the centers.

Oxygenation assessments. **ARTERIAL BLOOD GAS.** Arterial blood gas measurement was performed at every visit with patients resting and off supplemental oxygen 30 minutes before blood sampling.

TREADMILL OXYGEN TITRATION. An oxygen titration protocol was used to identify the amount of supplemental oxygen needed at rest and while treadmill walking at low speed (≤ 1 mile per hour [mph]) and high speed (2 or 3 mph). The high-speed treadmill walking portion was optional. The oxygen titration protocol was performed at every visit up to and including at 24-month follow-up (see the online supplement for further details).

SELF-REPORTED OXYGEN USE. At each visit, participants were asked "yes/no" questions, as follows:

1. Do you use oxygen at rest (not sleeping)?
2. Do you use oxygen on exertion?
3. Do you use oxygen when sleeping?

Statistical Analysis

Medical and surgical group endpoints were compared between groups using the two-sample *t* test and the χ^2 test. Endpoints included the following: PaO_2 ; PaCO_2 ; oxygen need at rest; oxygen need on low-speed and high-speed treadmill; self-reported oxygen use during rest, exertion, and sleep. Endpoints were compared separately between treatment groups at baseline and 6, 12, and 24 months after randomization. Data were analyzed only up to the 24-month follow-up time point because, by protocol, the oxygen titration was eliminated after that time point. We also compared the proportions of participants with $\text{PaO}_2 \leq 55$ mm Hg. The proportions were compared between the medical and surgical groups using the χ^2 test.

Association of baseline characteristics with the above endpoints was also analyzed in the surgical subjects (for the follow-up at 24 mo) using logistic regression to determine if there were characteristics that might be predictive of oxygen need or use 24 months postoperatively. Baseline characteristics evaluated included upper lobe emphysema, exercise capacity, age, sex, baseline % predicted value of FEV₁, FVC, RV, TLC, and diffusion capacity for carbon monoxide (DL_{CO}). Multivariate logistic regression models for each of the six endpoints were constructed using the above characteristics. We used forward selection with $P < 0.05$ as a criterion for entry into the models. *P* values in the final models from stepwise regressions were not adjusted for multiple testing.

Data management was performed using Stata 8.2 software (Stata Corp., College Station, TX) and statistical analysis with multiple datasets and graphical displays were computed in R 2.0.1 (R Foundation for Statistical Computing, Vienna, Austria). All *P* values were based on two-sided tests, and $P < 0.05$ was considered statistically significant.

RESULTS

Baseline characteristics of the study population obtained after pulmonary rehabilitation, but before random treatment assignment, are shown in Table 1. We restricted data analysis to the 1,078 non-high-mortality-risk patients identified in a prior NETT publication (18).

Patients in both treatment groups had severe obstructive lung disease with reduced DL_{CO} , hyperinflation, and reduced

TABLE 1. POSTREHABILITATION BASELINE CHARACTERISTICS OF THE STUDY POPULATION

Characteristics	Medical Therapy Group (<i>n</i> = 540)	Surgery Group (<i>n</i> = 538)
Age at randomization, yr	67.5 $\pm$ 5.8	67.5 $\pm$ 6.1
Race or ethnic group, <i>n</i> (%)		
Non-Hispanic white	511 (95)	513 (95)
Non-Hispanic black	18 (3)	17 (3)
Other	11 (2)	8 (1)
Sex, <i>n</i> (%)		
Female	200 (37)	235 (44)*
Male	340 (63)	303 (56)
Distribution of emphysema on CT, <i>n</i> (%)		
Upper lobe predominance	364 (67)	345 (64)
Non-upper lobe predominance	176 (33)	193 (36)
Heterogeneous	314 (58)	306 (57)
Homogeneous	226 (42)	232 (43)
Maximal workload, W	41.3 $\pm$ 22.2	40.0 $\pm$ 21.1
Distance walked in 6 min, ft	1,247.4 $\pm$ 309.6	1,239.4 $\pm$ 307.5
FEV ₁ after bronchodilator use, % of predicted value	27.9 $\pm$ 6.5	28.1 $\pm$ 6.8
TLC after bronchodilator use, % of predicted value	127.6 $\pm$ 14.1	127.4 $\pm$ 15.0
RV after bronchodilator use, % of predicted value	216.7 $\pm$ 43.8	214.4 $\pm$ 45.6
DL_{CO} , % of predicted value	29.5 $\pm$ 9.5	29.2 $\pm$ 9.2
PaO_2 , mm Hg	64.8 $\pm$ 10.1	65.0 $\pm$ 10.6
PaCO_2 , mm Hg	42.4 $\pm$ 5.5	42.8 $\pm$ 5.7
$\text{PaO}_2 \leq 55$ mm Hg, <i>n</i> (%)	107 (20)	109 (20)
Oxygen need with oxygen titration, <i>n</i> (%)		
At rest	40 (7)	37 (7)
Low-speed treadmill	249 (46)	287 (53)*
High-speed treadmill	333 (68)	333 (69)
Oxygen reported use, <i>n</i> (%)		
Rest (not sleeping)	280 (52)	282 (52)
On exertion	414 (77)	406 (75)
Sleeping	370 (69)	351 (65)

Baseline measurements were obtained after rehabilitation but before randomization except for carbon monoxide diffusing capacity which was obtained before rehabilitation. Plus-minus values are means $\pm$ SD.

* $P < 0.05$ difference between medical and surgical groups.

exercise capacity. The two groups were similar in all aspects except for sex (more surgical subjects were female) and need for oxygen with low-speed treadmill (more surgical subjects required oxygen with low-speed treadmill).

Arterial Blood Gases

We show the values for PaO_2 and PaCO_2 at baseline and 6, 12, and 24 months after randomization in the medical and surgical groups in Figures 1A and 1B, respectively. There was a significant increase in PaO_2 and decrease in PaCO_2 at all measured time points after LVRS.

We also looked at the proportion of patients in each group who had a $\text{PaO}_2 \leq 55$ mm Hg, the most stringent cut point for oxygen prescription (Figure 2). Although the treatment groups were nearly identical at baseline, significantly larger percentages of medical patients had a $\text{PaO}_2 \leq 55$ mm Hg at each follow-up visit compared with surgically treated patients: 22 versus 10% ($P < 0.001$) at 6 months, 22 versus 14% ($P = 0.013$) at 12 months, and 25 versus 15% ($P = 0.002$) at 24 months. Thirty-nine percent (103 of 261) of the medical group subjects had a PaO_2 at 24 months that was improved or stable compared with baseline. Sixty-five percent (210 of 321) of surgically treated subjects were improved or stable at 24 months compared with baseline ($P < 0.001$, medical vs. surgical). To further analyze the number of individuals falling above or below the

Figure 1. (A) PaO₂ values and (B) PaCO₂ values while breathing room air at baseline and 6, 12, and 24 months after randomization. Error bars are 95% confidence intervals. **P* < 0.0001.

PaO₂ 55-mm Hg cut point, we constructed a 2 × 2 table of all individuals who had blood gas measurements at both baseline and 24 months postrandomization (see Table 2 for both medical subjects and for surgical subjects). Twenty-four months after randomization 8 of 48 (17%) of medical subjects with PaO₂

Figure 2. Percentage of patients with resting PaO₂ ≤ 55 mm Hg at baseline and 6, 12, and 24 months after randomization. Dark cross-hatched bars, medical; light cross-hatched bars, surgical. **P* < 0.05.

55 mm Hg or less at baseline showed an increase to a PaO₂ of greater than 55 mm Hg compared with 33 of 62 (53%) in the surgical group. Twelve percent (25/213) in the medical group and 7% (19/259) in the surgical group had a PaO₂ that fell from more than 55 mm Hg at baseline to 55 mm Hg or less at 24 months.

The initial NETT publication (17) identified subgroups of subjects with differential outcome based on distribution of emphysema (upper lobe vs. non-upper lobe) and baseline exercise capacity (high vs. low). PaO₂ at 24 months in the surgically treated subjects was most likely to be stable or improved in the upper lobe disease subgroups (Table E2 of the online supplement).

Treadmill Titration Study

Medical subjects required oxygen more frequently at almost all time points at rest and during low-speed and high-speed treadmill measurements than surgical subjects after randomization (Figure 3).

Self-Reported Oxygen Use

The percentages of subjects self-reporting use of supplemental oxygen at rest (not sleeping), on exertion, and while sleeping are displayed in Figure 4. At baseline, 50% or more of all

TABLE 2. PaO₂ ABOVE AND BELOW 55 mm Hg AT BASELINE AND AT 24 MONTHS POSTRANDOMIZATION FOR MEDICAL AND SURGICAL SUBJECTS

Baseline PaO ₂	PaO ₂ at 24 mo		Total n
	≤55 mm Hg	>55 mm Hg	
Medical subjects			
≤55 mm Hg	40	8	48
> 55 mm Hg	25	188	213
Surgical subjects			
≤55 mm Hg	29	33	62
>55 mm Hg	19	240	259

Figure 3. Percentage of patients requiring supplemental oxygen during treadmill titration at baseline and 6, 12, and 24 months after randomization. Dark shaded bars, medical; light shaded bars, surgical. * $P < 0.05$.

subjects reported using oxygen with all three levels of activity. After randomization, larger percentages of medically treated subjects self-reported supplemental oxygen use compared with surgically treated subjects at each time point. A total of 282 surgical subjects reported using oxygen at rest at the baseline assessment. At 24 months, 114 reported using oxygen at rest, 77 reported not using oxygen at rest, and 91 had no 24-month data for this outcome.

Predictors

In the surgical group alone, we tested the association of other baseline characteristics with each of the outcome measures, including PaO_2 , no oxygen need during rest, or during low-speed and high-speed treadmill tests, and self-report of no oxygen use during rest, activity, or sleep. Our goal was to define patient characteristics at baseline in the surgical arm of the study that predicted no oxygen need or use at 24 months post-procedure. Upper lobe emphysema, low exercise capacity, baseline FEV_1 , baseline TLC, baseline DL_{CO} , and baseline oxygen needs and use (defined as resting $\text{PaO}_2 > 55$ mm Hg and no oxygen need or use with the specified levels of activity) were associated with some of the outcome measures (Table 3). The baseline oxygen need or use was most consistently associated with the various outcome measures; lack of need or use of oxygen at baseline predicted lack of use of oxygen post-LVRS.

Multivariate logistic regression was then used to model independent predictors and six multivariate models for each of the six endpoints were identified. These data are presented in Table 4. Upper lobe emphysema, higher DL_{CO} , and the baseline status of the oxygen need or use measurement were the most frequent predictors of outcome at 24 months.

DISCUSSION

The major findings of this study are that arterial blood oxygenation as measured by three separate methods of assessment (two objective and one subjective) improved after LVRS when compared with medically treated subjects for up to 24 months after randomization to treatment.

Previously reported data concerning the effect of LVRS on arterial oxygenation and oxygen use have been conflicting. Nonrandomized case series have reported varying effects of LVRS (1–7, 19–23) on indices of oxygenation and it is clear from our analysis that the medical control group is important in analyzing temporal changes in oxygenation. As we show in Table 2, PaO_2 can vary significantly over time in individuals with COPD. Thirteen percent of those in the medical control group had a change in PaO_2 that moved them above or below the 55-mm Hg cut point at 24 months. Therefore, interpretation of findings from case series reports should be made cautiously. Previous randomized controlled trials of LVRS have shown varying results, with four studies reporting no change in oxygenation (8–11) whereas two reported some improvement in oxygenation (12, 13). It is possible that the conflicting results relate in part to the smaller sample size in most of the studies, which prevented the investigators from detecting changes. Different methods of assessing oxygenation and diverse periods of follow-up may also contribute to the varied results. In the initial publication from the Brompton trial, there were no differences in median PaO_2 between medically and surgically treated subjects at 12 months of follow-up (9). However, longer follow-up (mean follow-up of 27.9 mo) assessing both immediate impact and change over time showed statistically significant improve-

Figure 4. Percentage of patients self-reporting supplemental oxygen use during rest, activity, and while sleeping at baseline and 6, 12, and 24 months after randomization. Dark shaded bars, medical; light shaded bars, surgical. * $P < 0.05$.

TABLE 3. UNIVARIATE MODELS (SURGICAL PATIENTS ONLY) FOR PaO₂ GREATER THAN 55 mm Hg OR NO OXYGEN NEED WITH SPECIFIED ACTIVITY AT 24 MONTHS

Outcome Variable at 24 mo	Predictors															Value of Outcome [‡] at Baseline		
	Upper Lobe Emphysema			Low Exercise Capacity*			Baseline FEV ₁ (% predicted) [†]			Baseline TLC (% predicted) [†]			Baseline DL _{CO} (% predicted) [†]					
	OR	95% CI	P Value	OR	95% CI	P Value	OR	95% CI	P Value	OR	95% CI	P Value	OR	95% CI	P Value	OR	95% CI	P Value
PaO ₂ > 55 mm Hg	2.34	1.26–4.36	0.007	0.82	0.44–1.53	0.5	1.60	1.00–2.58	0.052	0.74	0.60–0.92	0.005	1.33	0.93–1.91	0.12	11.1	5.60–21.99	<0.0001
No rest O ₂ need (treadmill)	1.28	0.51–3.19	0.6	1.69	0.64–4.47	0.3	0.71	0.38–1.32	0.3	0.82	0.61–1.09	0.20	1.21	0.73–2.03	0.5	5.64	1.84–17.36	0.003
No O ₂ need (low-speed treadmill)	1.67	1.05–2.66	0.03	0.91	0.58–1.43	0.7	1.23	0.89–1.70	0.2	0.89	0.77–1.03	0.13	1.51	1.16–1.96	0.002	3.18	2.00–5.04	<0.0001
No O ₂ need (high-speed treadmill)	1.44	0.85–2.45	0.2	1.38	0.85–2.25	0.2	1.20	0.85–1.71	0.3	0.90	0.76–1.07	0.2	1.76	1.32–2.36	0.0001	4.33	2.52–7.47	<0.0001
No resting O ₂ use (self-report)	1.95	1.27–2.99	0.002	0.61	0.40–0.93	0.02	1.63	1.19–2.22	0.002	0.95	0.83–1.10	0.5	1.76	1.36–2.27	<0.0001	6.32	3.99–10.02	<0.0001
No O ₂ use on exertion (self-report)	1.67	1.06–2.63	0.03	1.06	0.70–1.62	0.8	1.30	0.96–1.76	0.09	0.99	0.86–1.14	0.9	1.43	1.12–1.82	0.003	5.65	3.45–9.26	<0.0001
No sleep O ₂ use (self-report)	1.69	1.09–2.62	0.02	0.70	0.46–1.06	0.09	1.30	0.97–1.75	0.08	1.04	0.90–1.19	0.6	1.76	1.37–2.25	<0.0001	7.55	4.75–12.00	<0.0001

Definition of abbreviations: CI = confidence interval; OR = odds ratio.

Values shown in bold are statistically significant.

* Maximum work on the post-rehabilitation, pre-randomization bicycle ergometer test of ≤25 W for female subjects and ≤40 W for male subjects.

† For values with % predicted, the OR is for a 10% increase in the value.

‡ Baseline outcome indicates baseline PaO₂ > 55 mm Hg or no O₂ use with the specified activity.

ments in oxygen saturation in the surgically treated subjects (13).

A major strength of NETT in addressing this issue is the large number of subjects enrolled in the trial and the fact that we had a number of measures of arterial oxygenation and oxygen use.

An important objective of this analysis was to attempt to identify preoperative characteristics that would allow us to predict which individuals requiring preoperative oxygen therapy might be able to discontinue oxygen therapy after surgery. Univariate models for each of the oxygenation endpoints were constructed and identified a number of predictors. Multiple logistic regression analysis yielded several models with more than one covariate. As would be expected, baseline PaO₂ greater than 55 mm Hg or no oxygen use or need with each of the specified activities strongly predicted that same outcome 24 months postrandomization. Upper lobe emphysema was a pos-

itive predictor for no need for or use of oxygen for several of the outcome measures. A better outcome has been associated with upper lobe disease in other reports (1, 17, 24, 25), and it is perhaps not surprising that we found this association with oxygenation as well. We found that a higher DL_{CO} was predictive of no need for oxygen with low- and high-speed treadmill activity and self-report of no use of oxygen at rest or while sleeping. A higher DL_{CO} likely represents the presence of less severe tissue destruction of the lung in emphysema and it may be that improvement in those with less severe disease may result in a lesser need for supplemental oxygen. The percent predicted TLC was a negative predictor for a postsurgical PaO₂ greater than 55 mm Hg. The reason for this is not intuitively clear; however, it is possible that a lower TLC is indicative of less severe disease and physiologic derangement and therefore is associated with a higher baseline PaO₂.

TABLE 4. MULTIVARIATE LOGISTIC REGRESSION MODELS FOR PaO₂ GREATER THAN 55 mm Hg OR NO OXYGEN USE WITH SPECIFIC ACTIVITY AT 24 MONTHS (SURGICAL PATIENTS ONLY)

Model (for specified outcome at 24 mo)	Upper Lobe Emphysema	No Baseline Oxygen Use with Specific Activity	Baseline PaO ₂ > 55 mm Hg	Baseline DL _{CO} (% predicted)*	Baseline TLC (% predicted)*	Low Exercise Capacity
Predict PaO ₂ > 55 mm Hg	—	—	12.0 (5.94–24.4)	—	0.74 (0.59–0.93)	—
Predict no O ₂ need (low-speed treadmill)	2.01 (1.22–3.32)	2.98 (1.83–4.83)	—	1.35 (1.02–1.78)	—	—
Predict no O ₂ need (high-speed treadmill)	1.82 (1.00–3.29)	3.82 (2.16–6.76)	—	1.82 (1.29–2.56)	—	2.06 (1.15–3.70)
Predict no O ₂ at rest (self-report)	2.42 (1.48–3.95)	5.97 (3.68–9.68)	—	1.49 (1.13–1.98)	—	—
Predict no O ₂ use on exertion (self-report)	1.91 (1.16–3.14)	6.03 (3.64–9.99)	—	—	—	—
Predict no O ₂ with sleep (self-report)	2.30 (1.37–3.85)	7.37 (4.50–12.07)	—	1.44 (1.09–1.91)	—	—

Models presented are those with more than one covariate. Candidate variables included: upper lobe emphysema, exercise capacity, age, sex, baseline % predicted value of FEV₁, FVC, RV, TLC, and diffusion capacity for carbon monoxide (DL_{CO}). Values presented are odds ratios and 95% confidence intervals in parentheses. Values shown in bold are statistically significant. Dashes indicate nonsignificant values.

* The odds ratio is for a 10% increase in the value.

We cannot comment on the mechanism of improvement of oxygenation post-LVRS because this study was not designed to determine the mechanism of improvement. PaCO_2 did decrease as PaO_2 increased, indicating that perhaps increased ventilation contributed in part to the improvement in PaO_2 . This is also supported by a slight increase in the alveolar to arterial oxygen gradient (Table E3). Previous studies have provided a possible alternative explanation for increased PaO_2 with reductions in V_D/V_T during exercise (26). Albert and coworkers postulated that changes in ventilation-perfusion heterogeneity as opposed to changes in mean alveolar ventilation explained the effect of LVRS on arterial blood gas values (27).

There are limitations to our study. First and most notable is the fact that there was differential follow-up between the medical and surgical groups. More surgically treated subjects than medically treated subjects completed the various oxygen outcome measures in follow-up. Previously published studies have noted greater numbers of comorbid conditions (28, 29) and poorer pulmonary function (30) in people who do not complete study follow-up compared with those who do—leading to speculation that sicker people do not complete study follow-up. However, examining baseline characteristics of the NETT subjects who did not complete any part of the 24 months of follow-up compared with those who completed at least some part of the 24 months of follow-up, we noted that, overall, the groups had similar baseline characteristics. There were very slight differences noted in that medically treated subjects not completing any follow-up tended to have higher baseline PaO_2 but achieved a smaller maximal workload on baseline bicycle ergometry, whereas surgically treated subjects not completing 24 months of follow-up had shorter mean six-minute-walk distance at baseline (Table E1). A second limitation is that the self-report of oxygen use is subject to substantial bias because this was an unblinded surgical trial. Those who underwent LVRS might expect in advance to discontinue supplemental oxygen post-procedure and might stop using this whether or not they objectively required oxygen. Bousamra and colleagues noted that some patients discontinued supplemental oxygen after LVRS despite demonstrated desaturation with activity (31). Because we include objective measures of oxygenation in addition to self-report, we believe that this helps to mitigate this concern. We noted that 77 surgical subjects who self-reported using oxygen at rest at the baseline assessment, and who also had 24-month data for this outcome reported no resting oxygen use at 24 months. Seventy (of the 77) also had 24-month PaO_2 data and only one subject's PaO_2 was less than 55 mm Hg. Finally, the NETT was performed at academic centers that had significant experience with LVRS before the study. Whether our results can be generalized to other centers remains to be determined.

In conclusion, we found that LVRS increases PaO_2 , and decreases treadmill and self-reported use of oxygen for up to 24 months post-procedure. The major predictor of not needing or using oxygen after LVRS was not needing or using oxygen preoperatively.

Conflict of Interest Statement: M.L.S. does not have a financial relationship with a commercial entity that has an interest in the subject of this manuscript. C.H.G. does not have a financial relationship with a commercial entity that has an interest in the subject of this manuscript. B.N. does not have a financial relationship with a commercial entity that has an interest in the subject of this manuscript. N.L.P. does not have a financial relationship with a commercial entity that has an interest in the subject of this manuscript. Z.M. received lecture fees from AstraZeneca in 2006 and 2007 (less than \$5,000 total), Pfizer in 2007 (\$2,000), and Boehringer Ingelheim in 2007 (\$3,000). R.A.W. does not have a financial relationship with a commercial entity that has an interest in the subject of this manuscript. A.P.F. does not have a financial relationship with a commercial entity that has an interest in the subject of this manuscript. J.O.B. does not have a financial relationship with a commercial entity that has an interest in the subject of this manuscript.

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