Analysis of Recent Literature on Lung Volume Reduction Surgery

Daniel P. McCarthy, MD, MBA, MEM[a], Lauren J. Taylor, MD[b], Malcolm M. DeCamp, MD[c,*]

KEYWORDS

• Emphysema • Lung volume reduction surgery • COPD

KEY POINTS

- LVRS may enact clinical benefit through improvements in chest wall asynchrony, increased maximum inspiratory pressure, and reduction in inflammatory mediators.
- Recent data demonstrate that LVRS may be performed safely with 6-month mortality of 0% to 1.5% and durable functional improvements.
- Initial investigation suggests LVRS may benefit an expanded patient population, including carefully selected patients with homogenous emphysema and low DLCO.

INTRODUCTION: THE NATIONAL EMPHYSEMA TREATMENT TRIAL

Initial publication of the National Emphysema Treatment Trial (NETT) results in 2003 offered significant level I evidence in support of surgical therapy for the management of patients with severe emphysema.[1,2] This landmark prospective multicenter trial randomized a total of 1218 patients to either lung volume reduction surgery (LVRS) or medical management, marking a notable departure from the small, heterogeneous, single-center case series that comprised most of the existing data.[3–5] At the time of publication, NETT participants had a mean follow-up of 29 months and investigators reported on a range of outcomes including short- and long-term survival, maximal exercise performance, lung function, and quality of life.

Key study findings facilitated risk stratification and the ability to identify patients most likely to benefit from surgery. Based on 30-day surgical mortality, high-risk individuals were defined by forced expiratory volume in 1 second (FEV1) less than or equal to 20% predicted and a diffusion capacity for carbon monoxide (DLCO) less than or equal to 20% predicted, or a homogenous distribution of emphysema.[6] This subgroup was ultimately excluded from undergoing LVRS because they experienced an unacceptably high 30-day mortality rate of 16%. After removing these patients, statistically significant improvements in 6-minute-walk distance, FEV1% predicted, maximal exercise capacity, and disease-specific and general quality of life were found for non-high-risk patients who underwent LVRS as compared with medical therapy. Furthermore, in the subset of patients with upper-lobe-predominant emphysema and low exercise capacity, the surgery group had lower total mortality and improved exercise capacity and health-related quality of life at 24-month follow-up. Unfortunately, these benefits failed to persist for all study participants. Although patients with high exercise capacity did have a statistically significant improvement in exercise capacity and health-related quality of life, surgery

[a] Division of Cardiothoracic Surgery, Department of Surgery, University of Wisconsin-Madison, 600 Highland Avenue, Madison, WI 53792, USA; [b] Division of Cardiothoracic Surgery, University of Colorado, Anschutz Medical Campus, 12631 East 17th Avenue, Room 5401, Mail Stop C-291, Aurora, CO 80045, USA; [c] Division of Cardiothoracic Surgery, Department of Surgery, University of Wisconsin-Madison, 600 Highland Avenue, H4/340, Madison, WI 53792-0001, USA

* Corresponding author.

E-mail address: decamp@surgery.wisc.edu

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did not offer a survival benefit in this group. Furthermore, there was no surgical advantage in survival, exercise capacity, or health-related quality of life for patients with non-upper-lobe-predominant disease. In addition, analysis of postoperative outcomes suggested that only non-upper-lobe-predominant emphysema was predictive of increased operative mortality.

Aside from supplemental oxygen, LVRS is one of few available therapies proven to improve survival in select patients with emphysema. Together with updated results from 2006,[7] findings from NETT solidified surgery in the management algorithm of patients suffering from moderate to severe emphysema. Applying NETT inclusion and exclusion criteria to examine an academic medical center's pulmonary function laboratory database and radiology archive, Akuthota and colleagues[8] estimated 15% of emphysema patients could benefit from LVRS. Yet despite these data, widespread adoption of LVRS remains meager.[9] Although a precise rationale remains elusive, the cause of this marked underuse is likely multifactorial and includes limited access to approved surgical centers and pulmonary rehabilitation programs and confusion on behalf of medical providers regarding patient candidacy for surgery.[10] LVRS may also be falsely perceived as overly complicated and costly. Because NETT was a single payer (Centers for Medicare and Medicaid Services) trial, cost-effective analyses were feasible and enlightening. Using actual data from 3 and 5 years of clinical follow-up, NETT investigators showed Incremental Cost Effective Ratios for the upper-lobe-predominant emphysema patients that were comparable with Incremental Cost Effective Ratios used to support implantable defibrillators or heart transplantation. For example, the cost-effectiveness ratio for LVRS as compared with medical therapy for upper-lobe-predominant disease was reported as $77,000 per quality-adjusted life year gained at 5 years versus $65,0000 for heart transplantation.[11] More troubling, perhaps, is a misconception that the prohibitive postoperative outcomes from the high-risk group[6] apply more broadly to all patients with emphysema, creating a stigma of surgery as an excessively risky endeavor.

These fears have spurred innovation; recent years have seen development of less invasive means of lung volume reduction and important advancements in the understanding of disease characteristics and postoperative outcomes. In this article we highlight some of the salient research performed on LVRS published after the NETT in 2003, focusing on three important areas of investigation: (1) physiologic implications of LVRS, (2) recent data regarding the safety and durability of LVRS, and (3) patient selection and extension of NETT criteria to other patient populations.

PHYSIOLOGIC IMPLICATIONS OF LUNG VOLUME REDUCTION SURGERY

Lung volume reduction has proven effective in promoting enhanced exercise capacity, lung function, and quality of life for select patients with emphysema.[1,12] Although surgery was the first available means of volume reduction, less invasive strategies including endobronchial valves, coils, and sclerosing agents are under investigation.[13–15] Regardless of the technical execution, reducing lung volume is thought to combat the primary physiologic derangements of emphysema: airflow obstruction, asynchrony, and hyperinflation.[16] The primary mechanism was believed to be via increased elastic recoil pressure coupled with decreased airway resistance resultant from surgical resection of diseased lung.[17,18] In addition, resection of heterogenous lung parenchyma may counteract the effect of hyperinflation, providing decreased work of breathing and improved alveolar gas exchange.[19] However, recent investigation offers more sophisticated insight into the physiologic implications of lung volume reduction.

Emphysema results in diaphragmatic flattening, negatively impacting ventilatory mechanics through asynchronous chest movement and recruitment of abdominal musculature.[20] Furthermore, older studies suggest correlation between chest wall asynchrony, airflow obstruction, and breathlessness.[20,21] As such, Zoumot and colleagues[22] proposed improvements in chest wall asynchrony as an advantageous outcome of LVR. The authors conducted a single-institution prospective trial and randomized 26 patients under evaluation for LVR to either surgical or bronchoscopic LVR or sham treatment, using novel optoelectronic plethysmography generated three-dimensional volume measurements to assess chest wall asynchrony. Patients in the LVR group had statistically significant improvement in exercise capacity, quality of life, lung function, and radiographic evidence of decreased lung volume. The authors report high baseline levels of asynchrony in both groups. However, LVR patients had significantly greater improvement in asynchrony 3 months post-treatment, suggesting that this may correlate with symptomatic improvement.

Beyond asynchrony, recent investigation corroborates a long-term impact of LVRS on respiratory musculature. Using prospectively collected

data from the NETT, Criner and colleagues[23] performed a retrospective analysis comparing pretreatment maximum inspiratory pressure (MIP) in patients who underwent LVRS versus medical management with MIP up to 36 months posttreatment. Patients in the LVRS group had significantly greater increase in MIP (19.8% compared with 3.2%) at 12 months. The improvement in MIP for patients who underwent LVRS peaked at 12 months but remained statistically significant at the 36-month follow-up. Male participants and those age 65 to 70 years had greater increase in MIP at all timepoints compared with their counterparts who received medical therapy. In accordance with original NETT findings, patients with upper-lobe-predominant disease and low exercise capacity also demonstrated sustained improvement in MIP at 24 months. The authors report an inverse relationship between MIP and noninvasive markers of dynamic hyperinflation, and propose that LVRS may promote clinical improvement by restoring optimal length-tension ratio of inspiratory musculature. This work builds on prior smaller studies suggesting a relationship between LVRS and improvement in MIP.[24,25]

Distinct from mechanical changes, LVRS may also impact inflammatory mediators associated with emphysema. Low-grade chronic inflammation likely plays an important role in the pathophysiology of emphysema; preponderance of leukocytes and deranged production of inflammatory mediators including increased tumor necrosis factor-α (TNF-α) and decreased α_1-antitrypsin (α_1-AT) have been reported.[26] With this in mind, Mineo and colleagues[27] proposed that LVRS reduced inflammatory mediators by removing emphysematous parenchyma. In a case-control study, the authors measured levels of inflammatory mediators and α_1-AT from 54 patients with severe emphysema (assigned to LVRS or standard respiratory rehabilitation program) and 25 healthy control subjects. Gene expression levels of protease-antiprotease and inflammatory mediators were also assessed from specimens in surgical patients. After 12 months, patients assigned to LVRS had significantly decreased levels of inflammatory mediators including TNF-α (-22.2%) and increased α_1-AT ($+27\%$) when compared with respiratory rehabilitation. Gene expression analysis revealed protease hyperactivity and predominant inflammation in diseased specimens, suggesting that surgery reduced the inflammatory burden by removing sites where these mediators were most heavily produced. Furthermore, study findings support a significant correlation between reduction in TNF-α, augmentation of α_1-AT, and decrease in residual volume (RV).

Better understanding of the relationship between LVRS, respiratory mechanics, and distribution of disease may improve the ability to select patients most likely to benefit from surgery. To this effect, Washko and colleagues[28] examined a subset of the NETT study population who underwent preoperative thoracic high-resolution computed tomographic (CT) scanning. Physiologic measures of lung recoil and inspiratory resistance were also measured but found not to be significantly associated with improvement in surgical outcomes, namely FEV1 or maximal exercise capacity after surgery. In contrast, preoperative CT assessment of the emphysema burden and ratio of upper to lower lobe disease demonstrated a weak, albeit statistically significant, association with improvement in FEV1 and exercise capacity postoperatively. Building on this foundation, recent radiographic advancements allow greater sophistication in quantifying the emphysema burden and distribution. An automated system can calculate the upper to lower zone ratio of low attenuation areas to facilitate selection of surgical candidates and target areas of resection. Although conventional CT remains the most commonly used radiographic assessment of surgical candidacy, dual-energy CT and dynamic MRI may offer important functional information to facilitate optional patient selection.[29,30]

EXAMINING SURGICAL SAFETY AND DURABILITY

Despite the NETT results demonstrating significant postoperative benefits and survival advantage for select patient populations, controversy persists regarding use of LVRS. Much of the debate stems from concern for unacceptably high surgical morbidity and mortality. Indeed, the 2003 NETT publication reported a sobering 90-day mortality of 5.5% for non-high-risk surgical patients compared with 1.5% following medical management.[1] This trepidation undoubtedly contributed to a marked decline in patients undergoing LVRS over the past decade in the United States and internationally.[31,32] However, long-term results from the original NETT publication and subsequent institutional data reinforce surgery as a safe treatment option in the setting of appropriate patient selection (**Table 1**).

In the wake of the initial NETT results, Naunheim and colleagues[7] published extended data in 2006, which included 40% more patients and two additional years of follow-up. This intention-to-treat study reinforced the overall survival benefit of surgery whereby the 5-year relative risk ratio for death was 0.86 ($P = .02$), with sustained improvements in

Table 1
Summary of outcomes following lung volume reduction surgery

Authors, Year of Publication	Study Design	Study Size	Procedural Morbidity and Mortality	Long-Term Outcomes
Naunheim et al,[7] 2006	Updated results from NETT (randomized controlled trial)	1218	5.5% 90-d mortality[1] 60% developed postoperative complication requiring intervention[38]	Upper-lobe-predominant low exercise capacity: 0.67 risk ratio for death at 5 y (P = .003) Symptom improvement at 5 y (P = .01) Exercise improvement at 3 y (P<.001)
Agzarian et al,[34] 2013	Retrospective observational analysis of patients randomized in the Canadian Lung Volume Reduction Surgery trial	62	0% 30-d surgical mortality Mortality at 2 y: 16% (LVRS) vs 13% (best medical care)[34]	Median survival 4.11 y 20% reduction in death rate compared with best medical care
Ginsburg et al,[36] 2016	Retrospective, single institution	91	0% 6-mo mortality 90% discharge to home Median length of stay 8 d	11% mean absolute increase in FEV1 at 5 y 4.1% increase in DLCO at 5 y 9.1 y median survival
van Agteren et al,[40] 2016	Meta-analysis	1760	Increased risk of postoperative death in short term (OR, 6.16; 95% CI, 3.22–11.79)	Decreased long-term mortality after surgery compared with medical care (OR, 0.76; 95% CI, 0.61–0.95)
Lim et al,[35] 2020	Re-evaluation of NETT data using longitudinal data methodology	1218	80.9% living independently 30 d after VATS LVRS[42]	At 5 y: 4.12 improvement in shortness of breath score (P<.001) 1.4% improvement in FEV1 (P<.001) 3.44% improvement in FVC (P<.001)

Abbreviations: CI, confidence interval; FVC, forced vital capacity; OR, odds ratio; VATS, video-assisted thoracoscopic surgery.

survival and symptoms at 5 years and exercise capacity at 3 years for patients with upper-lobe-predominant disease and low exercise capacity. These significant survival comparisons reflect a total mortality rate of 0.10 versus 0.12 deaths per person-year for patients treated surgically and medically, respectively. Furthermore, although the authors report no survival advantage for surgical patients with upper-lobe-predominant disease and high exercise capacity, these data support increased exercise capacity at 3 years and health-related quality of life at 4 years. Survival benefit was reinforced years later by the Canadian Lung Volume Reduction Surgery trial.[33] Subsequent publication of long-term follow-up results of this multicenter randomized controlled trial demonstrated superior median survival of 63 months in the surgery group compared with 47 months in patients receiving medical management.[34]

Recent work by Lim and colleagues[35] reinterpreted NETT data, positing that unclear presentation of clinical outcomes in the 2003 publication

contributed to underuse of LVRS. Using longitudinal data analyses methodology, the authors aimed to re-examine lung function variables over time to provide conclusions on longer-term outcomes that were more readily interpretable to clinicians and patients. For surgical patients, FEV1 improved immediately postoperatively compared with medical therapy. The surgical advantage declined over time but was sustained after 5 years, at which point the residual difference was +1.47% of predicted ($P<.001$). Similarly, analysis of forced vital capacity and RV showed a small but sustained advantage in favor of LVRS at 5 years (+3.44%, −19.49%, respectively).

Impact on systemic physiologic function and symptom measures echoed the trajectory of lung function parameters. The authors report that patients randomized to LVRS had initial improvement in maximum workload capacity that declined over time but still favored surgery at 5 years. Similarly, improvements in shortness of breath and overall quality of well-being score for surgical patients persisted throughout the study period. The authors argue that patient-centered outcomes, such as quality of life and dyspnea, are more meaningful to patients and therefore may be used by clinicians to counsel those who are surgical candidates.

Since the Centers for Medicare and Medicaid Services approved the National Coverage Determination for LVRS in 2003, Ginsburg and colleagues[36] collected data on postoperative outcomes over a 10-year period. This single-institution retrospective study examined 91 patients who underwent bilateral LVRS between 2004 and 2014. Eighty-six percent of these patients received a bilateral video-assisted thoracoscopic surgery approach. All participants underwent comprehensive functional and radiographic evaluation, preoperative pulmonary rehabilitation, optimal medical therapy according to Global Initiative for Chronic Obstructive Lung Disease guidelines,[37] and were discussed at an interdisciplinary LVRS meeting to determine surgical candidacy before study enrollment. Selected patients met NETT criteria of having either upper-lobe-predominant disease and low exercise capacity or upper-lobe disease with high exercise capacity.

The authors report a 0% surgical mortality rate at 6 months. Patients spent an average of 8 days in the hospital after surgery, with 2 of those days in the intensive care unit. Remarkably, 90% of patients discharged directly home, and by the 6 month time point all patients were recovering at home. Three patients required reintubation or tracheostomy. The most common complication was prolonged air leak lasting greater than 7 days (57%), with pneumonia (4%), cardiac arrhythmia (4%), and reoperation (3%) occurring with considerably less frequency. These outcomes are particularly striking when taken in comparison with original NETT results, which reported more than 20% of non-high-risk surgical patients required reintubation and fewer than 70% were able to return home 30 days postoperatively.[38,39]

Regarding treatment durability, the authors present favorable 1-, 2-, and 5-year functional results. Reported improvements in exercise capacity and lung function 1 and 2 years postoperatively echoed the 3-year post-NETT results from Naunheim and colleagues.[7] At 5 years, 24% and 36% of patients had sustained improvement in maximal workload and FEV1, respectively. These data reveal a median survival of 9.1 years and overall survival probability of 0.99 (95% confidence interval [CI], 0.96–1.00), 0.97 (95% CI, 0.93–1.00), and 0.78 (95% CI, 0.67–0.89) at 1, 2, and 5 years, respectively.

Recent Cochrane meta-analysis published in 2016 reviewed evidence from randomized-controlled trials comparing LVRS with nonsurgical treatment.[40] Authors identified 11 studies in total, which comprised a sum of 1760 patients. Key results included increased risk of death for patients undergoing LVRS in the short term (odds ratio, 6.16; 95% CI, 3.22–11.79). However, long-term mortality favored surgery (odds ratio, 0.76; 95% CI, 0.61–0.95). Moderate-quality evidence suggested surgical patients were more likely to demonstrate improvements in lung function parameters and quality of life as compared with control subjects, but this came at the price of higher treatment costs and adverse events including air leaks and cardiopulmonary morbidity.

It is worth acknowledging that significant advancements in surgical technique occurred since the original description of a lateral thoracotomy to resect emphysematous lung by Brantigan and coworkers in 1958.[41] The advent of video-assisted thoracoscopic surgery undoubtedly contributed to decreased surgical morbidity, yet this technique represented only 30% of patients in the NETT surgical cohort.[1] Within NETT, patients who underwent bilateral LVRS by video-assisted thoracoscopic surgery experienced morbidity and mortality comparable with those who received median sternotomy but had shorter intensive care unit stays and quicker overall recovery at reduced costs.[42] In addition, some have proposed a staged rather than the conventional simultaneous bilateral approach as an alternative strategy to reduce operative risk and improve long-term outcomes.[43] Oey and colleagues[43]

conducted a comparative study suggesting improved functional improvements and 3- and 5-year survival regardless of operative timing. However, patients who underwent a staged approach had improved scores in health status questionnaires lasting up to 6 years.

BEYOND THE NATIONAL EMPHYSEMA TREATMENT TRIAL: EXTENDING SURGICAL CANDIDACY

The NETT clearly demonstrated that patients with heterogeneous upper-lobe-predominant disease and low exercise capacity responded best to LVRS[1]; these findings have been reinforced by subsequent investigation.[36] However, better understanding of disease physiology and the impact of surgery on respiratory mechanics have led investigators to push the boundaries of surgical candidacy.[44] Recent studies have explored outcomes of LVRS in patients with alternative disease morphology and pathology and the relationship between LVRS and lung transplantation.

Given that LVRS improves pulmonary mechanics through reduction of hyperinflated lung parenchyma, Weder and colleagues[45] hypothesized that this benefit would extend to patients with homogeneous emphysema. To test this, the authors selected 266 consecutive patients with severe emphysema who underwent bilateral LVRS and assessed disease distribution using CT and lung perfusion scintigraphy. The cohort of 138 patients with homogeneous disease demonstrated significant symptomatic and functional improvements at 3 months postoperatively. Specifically, FEV1 increased by 35% predicted and hyperinflation, as measured by the ratio of RV to total lung capacity, decreased by 15%. In addition, an increase in walking distance persisted for up to 2 years and dyspnea scores remained lower than baseline for up to 4 years. Although initial improvements were less pronounced compared with the heterogeneous emphysema cohort, duration of benefit was similar. Importantly, perioperative and 3 month mortality rates were similar between groups, suggesting that patients with homogeneous emphysema should not be categorically excluded from surgical therapy. In addition, recent investigation suggests volume reduction using endobronchial coils may provide similar benefit in the setting of severely hyperinflated homogeneous emphysema.[46]

Similarly, liberalizing the NETT criteria for DLCO and disease location has shown favorable results. In 33 patients with preoperative DLCO less than 20% and nonhomogeneous morphology, 90-day postoperative mortality was 0%.[44] In these patients the most common perioperative complication was prolonged air leak, occurring in nearly 50% of the cohort. Patients demonstrated significant improvement in median DLCO from 15% to 24% after surgery. Similarly, single-institutional data from the United Kingdom demonstrated improvement in FEV1 and ratio of RV to total lung capacity at 3 and 6 months postoperatively in 36 patients with lower-lobe-predominant disease.[47] Although these studies are undoubtedly small, nonrandomized investigations, they call into question the belief ingrained since the initial NETT publication that LVRS benefits only a small subset of patients with severe emphysema.

The role of LVRS for patients with α_1-AT disease has been less clear and previously overlooked. As such, Stoller and colleagues[48] analyzed outcomes of patients with α_1-AT disease within the NETT. Of 1218 patients, 1.3% were found to have severe α_1-AT disease. Ten of these patients underwent LVRS. In this small cohort, patients had decreased exercise capacity and shorter duration of improved FEV1 when compared with α_1-AT-replete individuals. Importantly, 2-year mortality was 20% and 0% in α_1-AT-deficient patients who underwent LVRS versus medical management, respectively, raising concern for use of surgical therapy in this population. More robust surgical data are unfortunately lacking; however, early investigation into the use of endobronchial coil treatment suggests more favorable results with significantly less procedural risk.[49]

Pulmonary hypertension was considered an absolute surgical contraindication in the NETT and this criteria persists in subsequent studies. However, newer data suggest that some of these patients may also benefit from surgery. Initial exclusion of patients with pulmonary hypertension was based on the theory that lung resection would exacerbate the condition because of anatomic reduction in the vascular bed. Yet, this anatomic alteration may be counteracted by decreased pulmonary vascular resistance from improved respiratory mechanics after LVRS.[50] Single-institution retrospective data from Switzerland reviewed 51 surgical patients who had undergone preoperative transthoracic echocardiography, 10 of whom had systolic pulmonary artery pressure greater than 35 mm Hg and heterogeneous emphysema.[51] The authors report 0% 90-day mortality in the pulmonary hypertension group and median systolic pulmonary artery pressure decreased from 41 mm Hg to 37 mm Hg. Significant improvements in FEV1% predicted and hyperinflation were also noted. Subsequent investigation from the United States compared in-hospital and 1-year outcomes in 124 patients who underwent LVRS.[52] In the 56 patients with pulmonary

hypertension (defined by mean systolic pulmonary artery pressure greater than 35 mm Hg on right heart catheterization), the authors report no significant difference in hours of mechanical ventilation, intensive care days, prolonged air leak, or hospital length of stay when compared with patients without pulmonary hypertension. Furthermore, functional outcomes and quality-of-life scores were similar between groups at 1 year. Despite these encouraging findings, current evidence is limited to small retrospective analyses causing some to favor lung transplant over LVRS in this patient population.[53] Surgical management should proceed with caution; analysis of lung transplant following LVRS found severe pulmonary hypertension to be a significant risk factor for post-transplant mortality.[54]

Both LVRS and lung transplantation represent potential treatment options for patients with end-stage emphysema. Deciding between surgical treatment options requires careful consideration of complex clinical and social factors catered to the individual patient.[53] Retrospective analysis conducted by Weinstein and colleagues[55] offers a head-to-head comparison of these surgical therapies. One year following surgery, transplant patients had statistically significant improvement in FEV1% predicted (43.4% vs 2.2%) and modified BODE index (−5.7 vs −2.0) when compared with LVRS. However, this came at the cost of lower long-term survival and greater mean total costs. Not surprisingly, transplant patients spent more time in the hospital and required more frequent outpatient follow-up.

In addition to stand-alone therapy, LVRS may be considered as a strategy to delay transplant listing or as a bridge to transplant; however, the data remain mixed.[56] Contemporary analysis raised concerns regarding inferior graft function and increased postoperative complications in patients who were transplanted following LVRS.[54] In addition, work by Backhus and colleagues[57] revealed inferior post-transplant survival associated with transplant following LVRS. Although 30-day mortality was similar between groups, median post-transplant survival diverged in favor of transplant alone (49 months vs 96 months for transplant following LVRS and transplant alone, respectively). The authors attribute this discrepancy at least in part to increased operative times and hospital length of stay associated with transplantation after LVRS. Post-LVRS survival was equivalent regardless of whether the patient went on to receive a transplant, which may speak to the role of transplantation in extending lifespan in more severely ill patients following LVRS. These findings are in contrast with a recent report from the Registry of the International Society for Heart and Lung Transplantation, which demonstrates similar 1- and 5-year survival regardless of surgical approach.[58] Similarly, single-institution survival analysis of patients undergoing lung transplant between 1993 and 2014 reported 10% in-hospital mortality, which was unrelated to prior receipt of LVRS. Furthermore, improved median survival trended in favor of transplant following LVRS (107 vs 86 months) but this was not statistically significant.[59]

SUMMARY

Since publication of the initial findings of the NETT in 2003, great strides have been made in the understanding and provision of surgical treatment of patients with moderate and severe emphysema. Greater sophistication of surgical technique and deeper insight into the physiologic implications of lung volume reduction have paved the way for improved outcomes and innovative therapeutic alternatives. These findings have important implications for surgeons, researchers, and patients.

For researchers, increased understanding of the mechanisms by which volume reduction alters pulmonary mechanics to enact meaningful clinical benefit facilitates development of less invasive treatments. Significant work is already underway in the development and testing of endobronchial valves and coils that portend symptomatic improvement with less morbidity than surgery.[13,15] Furthermore, technological advancements in preoperative imaging offer enhanced precision in patient selection for surgery.

For surgeons, recent investigation reinforces the benefit and durability of LVRS. Institutional data suggesting operative 6-month mortality rates of 0% with a favorable morbidity profile[36] and functional improvements extending to 5 years postoperatively[7,35] may aid in reversing the nihilism regarding surgery that contributed to underuse. Early exploration into expanded patient eligibility, particularly in terms of homogeneous disease distribution and pulmonary hypertension, should encourage surgeons to evaluate each patient individually before determining candidacy for surgery.

Finally, and most importantly, recent literature suggests that surgery may offer patients with emphysema the opportunity for improved quality of life, pulmonary function, and overall survival. These benefits may be achieved at a lesser cost in terms of morbidity and mortality and be applicable to a broader selection of patients than previously thought. Recent data regarding surgical risks and longer-term outcomes may facilitate preoperative counseling to ensure that patients enter a treatment pathway with a better understanding of the implications of surgery.

CLINICS CARE POINT

- In appropriately selected patients, bilateral LVRS provides durable physiologic, functional and quality-of-life benefits which exceed those achieved with best medical therapy.

DISCLOSURE

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