

Lung Volume Reduction Surgery and Pulmonary Rehabilitation Improve Exercise Capacity and Reduce Dyspnea During Functional Activities in People with Emphysema

Janna Beling, PT, PhD

Associate Professor, California State University, Northridge, Department of Physical Therapy

ABSTRACT

Purpose: The purpose of this study was to examine the therapeutic effects of lung volume reduction surgery (LVRS) and pulmonary rehabilitation on levels of dyspnea during functional activities in patients with diffuse emphysema.

Methods: Fifteen subjects who had undergone LVRS participated in this study. A visual analog scale (VAS) Activity Dyspnea Scales (VADS) measurement tool developed for this study was determined reliable in 10 subjects. The VADS was used to assess changes in dyspnea with functional activity in 10 subjects prior to and following the interventions of LVRS and pulmonary rehabilitation. **Results:** Results of this study indicate that LVRS followed by pulmonary rehabilitation significantly reduces levels of dyspnea during functional activities. **Conclusion:** The VADS developed for this study is a valid and reliable method of assessing changes in levels of dyspnea during functional activities in the LVRS population.

Key Words: breathlessness, functional capacity

INTRODUCTION AND PURPOSE

Chronic obstructive pulmonary disease (COPD), comprised of chronic bronchitis and emphysema, is progressive, inflammatory, and causes a partially reversible airflow obstruction.^{1,2} Emphysema is characterized by abnormal, permanent enlargement of airspaces distal to the terminal bronchioles, accompanied by destruction of the walls, without obvious fibrosis.³ Chronic obstructive pulmonary disease is the fourth leading cause of death in the United States and is the only leading cause of death increasing in prevalence.⁴ People with COPD experience dyspnea on exertion which is primarily the result of airflow obstruction and is the principle cause of decreased functional ability.⁵

Few effective treatment options exist for COPD, but recently lung volume reduction surgery (LVRS) has been shown to be effective in selected patients with emphysema.⁶ Lung volume reduction surgery (LVRS) increases intrathoracic space and improves compliance of the lungs allowing for a more normal diaphragmatic breathing pattern.⁷⁻⁹ Post-

LVRS, people experience less dyspnea,^{6,10,11} improved lung volumes,^{10,12-14} increased exercise tolerance,^{6,10-14} and use less supplemental oxygen.¹¹ Pulmonary rehabilitation is an integral part of the recovery from the procedure and is recommended as a component of care in current practice guidelines because it improves conditioning and quality of life.^{2,15,16}

Tools to measure the functional assessment of dyspnea have been developed, such as the Baseline Dyspnea Scale,¹⁷ Medical Research Council Dyspnea scale,¹⁸ Modified Borg Scale,¹⁹ Modified Shuttle Walking test,²⁰ Oxygen Cost Diagram,²¹ Pulmonary Functional Status and Dyspnea Questionnaire,²² and the UCSD Shortness of Breath Questionnaire.²³ Although there are several tools to measure dyspnea, there are none that assess functional activities via self-report for use upon immediate discharge from the acute care setting. The Baseline Dyspnea Scale¹⁷ and the Modified Shuttle Walking test²⁰ require assessment by an observer interviewer. The UCSD Shortness of Breath Questionnaire and Oxygen Cost Diagram (VAS) have activities on the continuum that patients immediately upon discharge from the hospital setting would not engage in such as vacuuming and briskly walking uphill.²⁴ A visual analog scale (VAS) is commonly used to assess breathlessness in patients post-LVRS.²⁵⁻²⁹ The VAS was chosen as the measurement tool for this study because it demonstrates the ability to detect small changes.²⁴ In addition, measurement tools that use categorical scales, such as the Medical Research Council Dyspnea Scale,¹⁸ Modified Borg Scale,¹⁹ and the Pulmonary Functional Status and Dyspnea Questionnaire²² may not be sensitive enough to detect small but possibly clinically important symptomatic changes.³⁰

The main purposes of this study were to evaluate the therapeutic effects of LVRS followed by a 2-week (10 daily sessions) intensive pulmonary rehabilitation program on perceived dyspnea during functional activities in selected surgical patients with emphysema. Reliability of a visual analog scale that was designed to assess subjective reporting of dyspnea during functional activities was evaluated among this selected LVRS patient population.

METHODS

Subjects

A sample of 15 subjects was randomly selected from a pool of candidates for LVRS. To be included in this study all subjects were candidates who had undergone LVRS

Address correspondence to: Janna Beling, California State University, Northridge, Department of Physical Therapy, 18111 Nordhoff Street, Northridge CA 91330-8411.

and participated in pulmonary rehabilitation after LVRS at Chapman Medical Center (Orange, CA).

VAS Activity Dyspnea Scales (VADS)

A measurement tool using visual analog scales (VAS) (Figure) was developed and used to assess the subjects' perceived dyspnea and use of oxygen during functional activities at 3 specific times for this study. Questions regarding functional activities for the VAS Activity Dyspnea Scales (VADS) were developed based on Barthel Index Tasks. This index is a valid and reliable method for evaluation of functional activities and rehabilitation outcomes.³¹ The VAS design was a modified form of Nosedá et al's³² protocol using a 20-centimeter horizontal line for the subject to evaluate his/her perceived shortness of breath with each described functional activity. The VAS design was modified so that the 20 cm horizontal line's left end-point indicated the most severe level of dyspnea (20 cm) and the right end-point (0 cm) indicated presence of no dyspnea associated with the functional activity. The maximum point was placed on the left side of the continuum because dyspnea is the cardinal symptom of COPD, particularly in those with emphysema,³³ and in order to acknowledge that fact "severe" was placed as the first adjective one reads on the scale. After the subject marked the position on the scale that represented the intensity of his/her breathlessness, the investigator measured the distance from the right anchor to the participant's mark (0-20 cm).

The visual analog scale is a valid instrument for assessment of dyspnea during submaximal and maximal exercise.^{32,34,35} Specific functional activities that require metabolic equivalents (MET=multiple of resting metabolic rate, approximately equal to 3.5 ml O₂:kg body wt⁻¹:min⁻¹) in the submaximal range can be considered as submaximal forms of exercise.³⁶ The selected functional activities of the VADS are considered as submaximal levels of exercise.

Procedure

All participants provided written informed consent, and the study was approved by the Institutional Review Board at Chapman Medical Center. The procedure was explained in detail by the same physical therapist in a uniform manner to all participants. Subjects, who consented to participate in the study, completed the VAS Activity Dyspnea Scales (VADS) at Chapman Medical Center approximately 2 weeks prior to presurgical evaluation and potential surgical intervention (T₁). Surgical candidates, who met the inclusion/exclusion criteria and were formally admitted for LVRS, underwent the same preoperative physical therapy evaluation 2 days prior to surgical intervention. At this time (T₂), the VADS were given again to subjects. The mean time duration between T₁ and T₂ was 14.8 ± 1.9 days (mean ± SD) (range=11-17 days). After subjects had undergone surgery and completed 10 daily sessions (2-week period from Monday-Friday) of pulmonary rehabilitation, they completed the third VADS (T₃).

Rehabilitation

All patients underwent a similar regimen of intensive 2 week (10 daily sessions) pulmonary rehabilitation – 6

hours/day for 5 days/week at Chapman Medical Center beginning the day following hospital discharge. The actual time spent in rehabilitation (excluding meals, breaks, and transport time) approximated 3.5 to 4.5 hours per day with a total of 40 hours over the 2-week period. In accordance with evidence-based guidelines,^{15,16} the rehabilitation consisted of an intensive 2-week (10 days) outpatient regimen involving a multidisciplinary approach with physical therapy [total hours over 2 week period (15 hours)], nursing (8 hours), respiratory therapy (7 hours), dietetics (4 hours), occupational therapy (4 hours), and psychosocial services (2 hours). The physical therapist prescribed a specific exercise regimen tailored to the individual patient's needs and goals, whereas the occupational therapist taught energy conservation measures and assessed needs for prosthetic devices or wheelchairs. The respiratory therapist helped to oversee the exercise program, and taught breathing exercises, as well as the proper use of aerolized medications and oxygen. Nurses helped to oversee the education program. A dietician helped participants formulate nutritional goals and provided education on proper diet. A social worker assessed needs for home services, worked with third-party payers to help patients obtain needed benefits, and provided counseling. A psychologist was also available to provide counseling as well as instruction in coping strategies and relaxation strategies.

The physical therapy component of the rehabilitation program included daily exercise that was approximately 1½ hours in duration. The physical therapist reinforced strategies taught during the rehabilitation program including pursed lip breathing, coughing and secretion management, self-monitoring, stress reduction, and relaxation techniques. The exercise training program was supervised by a physical therapist and incorporated lower extremity endurance exercise by walking on a treadmill (5 minutes warm-up, 10-20 minutes exercise, and 5 minutes cool-down) and ascending/descending stairs (15 minutes) (5 times per week), supported upper extremity exercise (using an unresisted upper body ergometer for 15 minutes) and unsupported upper extremity exercise included stretching of elastic bands and/or the use of free weights (4 exercises, 3 times per week for 15 minutes), and 9 flexibility exercises (5 times per week for 15 minutes). Heart rate, blood pressure, and oxygen saturation were measured at rest, during exercise, and in recovery to monitor exercise intensity and safety. Exercise heart rate was targeted to an intensity of 50% to 75% of maximum heart rate¹⁵ and oxygen saturation to ≥90%.^{1,2} Subjects exercised at a level that gave them moderate dyspnea (modified Borg level 3).¹⁹ Pulmonary rehabilitation programs routinely use the participant's breathlessness to monitor training and training at this level has been shown to increase endurance at the end of a pulmonary rehabilitation program.³⁷ Intensity and/or duration was increased by the physical therapist when patients reported a dyspnea level of 2 (easy breathing) on the modified Borg scale. The education component was tailored to the individual patient and covered topics such as an overview of COPD, breathing training,

energy conservation, medications, nutrition, oxygen therapy, relaxation, secretion clearance, sexuality, stress management, travel, and what to do in emergencies (5 times per week for 2 hours/day).

Physiological Data

Resting physiological data were obtained prior to surgical intervention (T_2) and following surgical intervention and pulmonary rehabilitation (T_3) and included the following values: heart rate (HR), oxygen saturation (SpO_2), and pulmonary function test (PFT) results. HR, SpO_2 , distance ambulated, and amount of oxygen used were measured during the Six Minute Walk tests conducted at the same time points.

Data Analysis

All data analyses were performed using SPSS 16.0 for Windows (SPSS Inc. Chicago, IL). The Intraclass Correlation Coefficient (3,1) was performed to establish the test-retest reliability of the scores on the VAS Activity Dyspnea Scales (VADS) between T_1 and T_2 . A reliability coefficient > 0.75 was chosen as good evidence of reliability.³⁸ Walter, Eliasziw, & Donner³⁹ set optimal sample sizes for ICC based on desired power level, magnitude of the predicted ICC, and the lower confidence limit, concluding that the 0.95 confidence level, the 0.80 power level, and 2 ratings per subject would require a sample of 5. Reliability was further assessed by Cronbach's alpha, a statistic used to evaluate internal consistency, or the extent to which the different items on the VADS measure the same construct.⁴⁰ An internal consistency criterion of 0.70 was chosen as good evidence for reliability.⁴¹

The Minimum Detectable Change (MDC) using a 95% confidence interval (MDC_{95}) was calculated on the VADS using the formula⁴²

$$MDC = Z\text{-SCORE}_{\text{level of confidence}} \times SD_{\text{baseline}} \times \sqrt{2[1 - r_{\text{test-retest}}]}$$

A two-way repeated measures Analysis of Variance (ANOVA) (2x10) was used to analyze differences in dyspnea scores between times and items on the VADS at T_2 and T_3 . Post-hoc multiple comparisons were performed using the Bonferroni test. A MANOVA was done to conduct simple main effects analysis on items on the VADS. Two-tailed paired sample t-tests with Bonferroni's correction were used to analyze differences in physiologic data and distance ambulated at T_2 and T_3 . Data were considered significant at $\alpha < 0.05$.

RESULTS

Subject Characteristics

Ten subjects participated in the reliability study (T_1 - T_2). There were 4 men and 6 women with an age range of 55-73 years old. The mean age of the subjects was 62.6 ± 5.8 years. Smoking history was defined by pack-years (product of #packs[s]/day and # years smoked). All subjects were former smokers and the mean pack-years were 47.3 ± 19 pack-years, ranging from 20-74 pack-years. Prior to admission to the LVRS program, all subjects had quit

smoking on average 10.0 ± 8.7 years, ranging in time of smoking cessation from 2 to 29 years.

Five of the 10 subjects in the reliability study also completed T_3 . Ten subjects participated in the change in dyspnea scores pre- and post-LVRS (T_2 - T_3). There were 5 men and 5 women with an age range of 45 to 73 years. The mean age of the subjects was 61.7 ± 8.1 years. All subjects had a smoking history and the mean pack-years were 50.5 ± 27.1 pack-years, ranging from 20 to 105 pack-years. Prior to admission to the LVRS program, all subjects had quit smoking for a period ranging from 1 to 29 years with a mean of 10.1 ± 7.9 years. There were no significant differences in patient characteristics between reliability subjects and test subjects.

Reliability of Baseline Scores of VAS Activity Dyspnea Scales

Data of the first 10 subjects who completed the VAS Activity Dyspnea Scales (VADS) at T_1 and T_2 were used to assess the test-retest reliability of the VADS for the study. The ICC for test-retest reliability on the VADS was excellent at 0.92, $p < 0.05$. The 95% confidence intervals ranged from 0.72-0.98. The VADS demonstrated excellent internal consistency ($\alpha=0.96$). The MDC_{95} for the VADS was 5.02 cm.

Dyspnea Scores Before and After LVRS and Rehabilitation

A two-way repeated measures ANOVA (2X10) conducted to evaluate the effect of time and items on dyspnea scores on the VADS showed a main effect for time. Dyspnea scores were significantly improved after LVRS and rehabilitation (2.49 ± 4.04) compared to baseline (8.28 ± 6.40), $F(1,180) = 75.27$, $p < 0.05$. There was also a main effect for items on the VADS. Dyspnea scores differed significantly among the items, $F(9,180) = 6.44$, $p < 0.05$. Dyspnea scores while performing both a 6-minute walk and climbing one flight of stairs were significantly higher than mean scores at rest, getting in and out of bed/chair, and eating, $p < 0.05$. Dyspnea scores while bathing were significantly greater than mean scores at rest and getting in and out of a chair, $p < 0.05$. Additionally, there was a significant interaction between time and items, $F(9,180) = 1.94$, $p < 0.05$. The time by item interaction was analyzed using a simple main effects analysis. Dyspnea scores on all items significantly improved over time except during performance of a 6-minute walk and getting in/out of a chair, $p < 0.05$. Means and standard deviations for items are listed in Table 1.

Physiologic Data

Resting heart rate and resting values of SpO_2 did not change significantly from pre-LVRS (T_2) to post-LVRS (T_3) (Table 2). A significant increase of 166.0 ± 73.3 feet during the 6-minute walk test was seen following surgery and pulmonary rehabilitation (T_3) ($p < 0.05$). Datum of distance ambulated for one subject during the timed 6-minute walk test at T_2 was determined to be an outlier ($Z > 2$) and was removed from statistical analysis.⁴³ Peak heart rate measured during the 6-minute walk test increased significantly from 109 to 116 bpm ($p < 0.05$). Oxygen saturation and oxygen

use were not significantly different in these subjects during the 6-minute walk following surgery (T_3) compared with pre-LVRS (T_2) values (Table 2).

Table 1. Visual Analog Scale Changes in Dyspnea Between T2 and T3 (n=10)

Question No. (MET*)	Pre-LVRS (T_2) Mean±SD (cm)	Post-LVRS (T_3) Mean±SD (cm)
1. Resting (1 MET)	4.40±4.81	.40±0.54*,†
2. 6-minute walk (4 METs)	10.53±4.96	7.70±5.50†
3. 1 flight of stairs (8 METs)	13.05±6.01	5.10±5.53*,‡
4. In and out of bed (2 METs)	6.00±6.07	1.80±3.98*
5. In and out of chair (2 METs)	2.80±4.33	.90±1.71†
6. Morning hygiene and Grooming (2 METs)	8.70±6.32	1.20±2.18*
7. Bathing/showering (2 METs)	13.60±6.10	2.90±4.65*
8. Dressing (2 METs)	11.12±6.26	1.60±2.50*
9. Eating (1.5 METs)	5.70±5.47	1.20±2.34*
10. Speaking (1.0 METs)	6.90±5.34	2.10±3.48*
Mean±SD (cm)	8.28±6.40	2.49±4.04*

NOTE. Higher numbers indicate increased dyspnea.
 * = Estimates of MET levels are provided for each functional activity. Metabolic equivalent based on Ainsworth et al³⁶
 † = Significantly decreased dyspnea from T_2 , $p < 0.05$
 ‡ = Significantly less dyspnea than questions 2, 3, & 7, $p < 0.05$
 § = Significantly more dyspnea than questions 1, 4, 5, & 9, $p < 0.05$

Table 2. Change in Physiologic Parameters at T_2 and T_3 (n=10)

Parameter	Pre-LVRS (T_2) Mean±SD	Post-LVRS (T_3) Mean±SD
Resting HR (bpm)	92.00±15.65	94.00±13.47
Resting SpO ₂ (%)	95.40±2.12	94.70±2.78
Resting O ₂ (L/min)	0.50±1.11	0.50±1.04
6-minute walk test (ft)	878.00±351.00	1044.00±342.00*
Peak HR (bpm)	109.00±10.59	116.00±5.50†
SpO ₂ (%)†	87.60±5.34	88.80±3.00
O ₂ (L/min)	1.00±1.68	1.33±1.90
FVC (L)	1.82±0.29	2.25±0.56‡
FEV ₁ (L)	0.65±0.11	1.04±0.21‡
FEV ₁ /FVC (%)	39.00±0.11	51.00±0.11‡

NOTE. One outlier removed from analysis from 6-minute walk data ($Z > 2$)⁴³
 * = Indicates that post-LVRS and rehabilitation values significantly greater than baseline, $p < 0.05$
 † = Oxygen saturation was continuously monitored, supplementary oxygen was supplied to keep oxygen saturation > 88%
 ‡ = Indicates that post-LVRS and rehabilitation values significantly greater than baseline, $p < 0.01$

Pulmonary Function Tests

Pulmonary function data collected pre-LVRS (T_2) and post-LVRS (T_3) were significantly increased following surgery and pulmonary rehabilitation. Forced vital capacity (FVC) increased significantly from 1.82L to 2.25L ($p < 0.05$) and forced expiratory volume in one second (FEV₁)

increased significantly from 0.65L to 1.04L ($p < 0.05$). The ratio FEV₁/FVC also improved significantly from 39% to 51% predicted volume ($p < 0.05$) among these subjects between pre-LVRS (T_2) and post-LVRS (T_3) (Table 2).

DISCUSSION

This study is the first attempt to assess levels of dyspnea with a newly developed measure of dyspnea during functional activities in people with emphysema post-LVRS and rehabilitation. The data demonstrate excellent test-retest and internal consistency reliabilities of the newly developed VADS. This study has shown that the VAS Activity Dyspnea Scales (VADS) can be used to assess dyspnea associated with activities of daily living performed immediately upon hospital discharge in patients post-LVRS. These results compare favorably to previous assessments of VAS reliability in people with COPD at submaximal^{32,34} and maximal^{32,34,44} exercise capacities.

This study has shown that LVRS followed by 2 weeks of intensive pulmonary rehabilitation can improve dyspnea in individuals with emphysema. The mean score on the VADS significantly decreased from T_2 ($X=8.28$) to T_3 ($X=2.49$). Analysis of the 10 items revealed significant improvements in levels of dyspnea at rest and during 7 of the 9 functional activities. The intervention of LVRS followed by 2 weeks (10 daily sessions) of intensive pulmonary rehabilitation positively affects the sensation of dyspnea perceived during the majority of functional activities contained in the VADS. The most significant improvements in dyspnea scores were those functional activities for questions 7 (bathing/showering), 8 (dressing), and 3 (climbing one flight of stairs) ($p < 0.05$) (Table 1). These were the same activities that elicited the most severe levels of dyspnea at baseline (T_2). Because patients' perceptions of dyspnea have improved, it follows that improvements in their abilities to function will lead to overall increases in functional capacity.

To examine the effects of an intervention, a therapist needs to know when change in an observed score indicates that real change has occurred. This is called the "minimum detectable change" (MDC) and has been defined by Haley et al⁴² as the amount of change required to be 95% confident that an observed change in scores reflects real change in the underlying variable. Scores at or above the MDC level are due to patient improvement on the measurement tool rather than measurement error. The MDC₉₅ value for the VADS was calculated as 5.02 cm. The mean dyspnea score on the VADS significantly improved 5.79 cm following LVRS and rehabilitation (from T_2 to T_3) indicating the improvement in dyspnea levels is due to patient improvement.

Results of change in dyspnea scores between pre-LVRS (T_2) and post-LVRS (T_3) were significantly improved for all functional activities except for the activity of getting into and out of a chair and during a 6-minute walk (Table 1). The level of dyspnea experienced by subjects while getting in and out of a chair was similar to resting levels of dyspnea at both time periods. No improvement can be detected in a subject who has the best possible score prior to the intervention. Ten percent of subjects reported no dyspnea at baseline (T_2) while getting in/out of a chair at baseline (T_2). Lack of

improvement in dyspnea score for this activity suggests that there was a floor effect. Conversely, the 6-minute walk is the longest in duration of the functional activities described in the VADS. Subjects experienced the highest level of dyspnea during this activity post-LVRS and pulmonary rehabilitation (T_3). Distance ambulated during the 6-minute walk test pre-LVRS (T_2) and post-LVRS (T_3) improved significantly by 166 feet (50.6 meters) ($p < 0.05$) comparing favorably with previous findings in this patient population.^{6,10,11,13,45,46} The improvement in distance surpassed the minimal clinically important distance of 35 m (~115 feet).⁴⁷ The increased duration of activity on the 6-minute walk post-LVRS also demonstrated a significantly higher heart rate indicating an increased demand on aerobic capacity. Lung volume reduction surgery followed by 2 weeks (10 daily sessions) of pulmonary rehabilitation may not necessarily improve the overall aerobic capacity sufficiently for increases in duration of activity and therefore dyspnea scores may not be significantly improved in this short time period. Previous reports have documented reduced dyspnea on the 6-minute walk test in people with emphysema 6 months post-LVRS.^{45,46w}

Although subjects' perceived shortness of breath at rest were significantly improved, resting HR and SpO_2 at post-LVRS (T_3) were not significantly improved compared to pre-LVRS (T_2) values ($p < 0.05$). Lung volume reduction surgery followed by only 10 daily sessions of pulmonary rehabilitation may not be sufficient time to see physiological changes in these parameters in these patients. Previous research in people post-LVRS show significant improvement in SpO_2 after 3 to 6 months.^{45,46} No significant changes in SpO_2 percentages or oxygen use were found during the 6-minute walk test. Peak HR, measured during the 6-minute walk test did show a significant increase (from 109 to 116 bpm) when comparing pre- (T_2) and post-LVRS (T_3) values (Table 2). Decreased levels of dyspnea may increase the ability to reach higher peak HR during activity and suggests an increased ability to function at higher metabolic equivalents.

Pulmonary function as indicated by FVC, FEV_1 and FEV_1/FVC at pre-LVRS (T_2) and post-LVRS (T_3) were improved after LVRS and pulmonary rehabilitation ($p < 0.05$). Significant improvements in pulmonary function tests have been documented by several other investigators in this patient population.^{6,10-14} Mean FEV_1 scores in this study improved significantly by 390 ml following LVRS and rehabilitation. This is greater than the reported threshold of clinical significance of 200 ml⁴⁸ or within-subject variability of 160 ml.⁴⁹ These improvements are purportedly multifactorial and include an increased lung elastic recoil following resection of the diseased lung tissue.⁵⁰ In addition, the diaphragm,^{8,9} and accessory inspiratory muscles^{51,52} may have an improved length-tension relationship due to the reduced lung volume. Fessler et al⁷ hypothesized that LVRS improves lung function by reducing the lungs' hyperinflation and thus improving expiratory airflow. It is not known which, if any, physiological parameters specifically influence dyspnea.⁵³ The NHANES survey showed that only 60% of people with moderately reduced FEV_1 reported symptoms.⁵⁴ It is not known from this study what the individual contribution

of LVRS and pulmonary rehabilitation was towards the reduction of dyspnea. Both LVRS^{6,10,11} and pulmonary rehabilitation^{16,55,56} relieve dyspnea. Patients recovering from LVRS represent a selected group of patients with advanced chronic respiratory disease. These patients typically have severe ventilatory limitation and disability. Pulmonary rehabilitation is routinely provided to these patients because a strong scientific rationale for it exists.^{2,15,16} It has been suggested that a shift in focus from the pathophysiology of emphysema to assessment and relief of symptoms may provide more meaningful benefits for the individual patient in terms of quality of life.⁵⁷

The goal of this study was to present a new measurement tool (VADS) to assess dyspnea during selected functional activities and then apply the VADS to a clinical population of people with emphysema before and after LVRS and pulmonary rehabilitation. The newly developed VADS involves self-reporting and offers an easy, time-efficient, and cost-effective option for reliably measuring dyspnea. The MDC_{95} can help clinicians and researchers to decide whether this tool is likely to be a sensitive measure for use in their own clinical studies.

CONCLUSIONS

The excellent test-retest reliability and high internal consistency indicate that the VADS is a valuable measure to monitor responsiveness to change in patients with emphysema. Dyspnea appears to be the major contributing factor that limits function in people with emphysema and LVRS and subsequent pulmonary rehabilitation appears to improve dyspnea to effectively improve function. Improvements in dyspnea during the majority of functional activities assessed by the VADS, increases in peak HR during longer ambulation distances, and improved pulmonary function indicate an increased ability to perform ADLs in this patient population. It is concluded that these functional and physiological gains, if maintained over time, may increase the overall function and aerobic capacity in this selected patient population.

REFERENCES

1. Celli BR, MacNee W. Standards for the diagnosis and treatment of patients with COPD: a summary of the ATS/ERS position paper. *Eur Respir J*. 2004;23:932-946.
2. Rabe KF, Hurd S, Anzueto A, et al. Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease. GOLD executive summary. *Am J Crit Care Med*. 2007;176:532-555.
3. Piquette CA, Rennard SI, Snider GL. Chronic bronchitis and emphysema. In: Murray JF, Nadel JA, eds. *Textbook of Respiratory Medicine*. 3rd ed. Philadelphia, PA: W.B. Saunders; 2000:1188-1245.
4. Mannino DM, Homa DM, Akinbami LJ, Ford ES, Redd SC. Chronic obstructive pulmonary disease surveillance-United States, 1971-2000. *MMWR Surveill Summ*. 2002;51(6):1-16.
5. Reishtein JL. Relationship between symptoms and functional performance in COPD. *Res Nurs Health*. 2004;28(1):39-47.

6. Fishman A, Martinez F, Naunheim K, et al. A randomized trial comparing lung-volume-reduction surgery with medical therapy for severe emphysema. The national emphysema treatment trial research group. *N Engl J Med*. 2003;348:2059-2073.
7. Fessler HE, Scharf SM, Ingenito EP, McKenna RJ, Jr., Sharafkhaneh A. Physiologic basis for improved pulmonary function after lung volume reduction. *Proc Am Thorac Soc*. 2008;5:416-420.
8. Lando Y, Boiselle PM, Shade D, et al. Effect of lung volume reduction surgery on diaphragm length in severe chronic obstructive pulmonary disease. *Am J Respir Crit Care Med*. 1999;159:796-805.
9. Bellemare F, Cordeau MP, Couture J, Lafontaine E, Leblanc P, Passerini L. Effects of emphysema and lung volume reduction surgery on transdiaphragmatic pressure and diaphragm length. *Chest*. 2002;121:1898-1910.
10. Pompeo E, Marino M, Nofroni I, Matteucci G, Mineo TC. Reduction pneumoplasty versus respiratory rehabilitation in severe emphysema: a randomized study. *Ann Thorac Surg*. 2000;70:948-954.
11. 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.
12. Geddes D, Davies M, Koyama H, et al. Effect of lung-volume-reduction surgery in patients with severe emphysema. *N Engl J Med*. 2000;343:239-245.
13. Miller JD, Berger RL, Malthaner RA, et al. Lung volume reduction surgery vs medical treatment: for patients with advanced emphysema. *Chest*. 2005;127:1166-1177.
14. Miller JD, Malthaner RA, Goldsmith CH, et al. A randomized clinical trial of lung volume reduction surgery versus medical care for patients with advanced emphysema: a two-year study from Canada. *Ann Thorac Surg*. 2006;81(1):314-321.
15. Nici L, Donner C, Wouters E, et al. American Thoracic Society/European Thoracic Society statement on pulmonary rehabilitation. *Am J Respir Crit Care Med*. 2006;173(12):1390-1413.
16. Ries AL, Bauldoff GS, Carlin BW, et al. Pulmonary rehabilitation: joint ACCP/AACVPR evidence-based clinical practice guidelines: update. *Chest*. 2007;131(5 Suppl):4S-42S.
17. Mahler DA, Weinberg DH, Wells CK, Feinstein AR. The measurement of dyspnoea. *Chest*. 1984;85:751-758.
18. Mahler DA, Rosiello RA, Harwer A, Lentine T, McGovern JF, Daubenspeck A. Comparison of dyspnoea ratings and psychophysical measurements of respiratory sensation in obstructive airway disease. *Am Rev Respir Dis*. 1987;135:1229-1233.
19. Borg GA. Psychophysical bases of perceived exertion. *Med Sci Sports Ex*. 1982;14:377-381.
20. Singh SJ, Morgan MDL, Scott S, et al. Development of a shuttle walking test of disability in patients with chronic airways obstruction. *Thorax*. 1992;47:1019-1024.
21. McGavin CR, Artvinli M, Naoe H, McHardy G. Dyspnoea, disability and distance walked: comparison of estimates of exercise performance in respiratory disease. *Br Med J*. 1978;2:241-243.
22. Lareau SC, Carrieri-Kohlman V, Janson-Bjerklie S, Roos PJ. Development and testing of the Pulmonary Functional Status and Dyspnea Questionnaire (PFSDQ). *Heart Lung*. 1994;23:242-250.
23. Eakin EG, Resnikoff PM, Prewitt LM, Ries AL, Kaplan RM. Validation of a new dyspnea measure: the UCSD Shortness of Breath questionnaire. *Chest*. 1998;113:619-624.
24. American Thoracic Society. Dyspnea: mechanisms, assessment, and management: a consensus statement. *Am J Respir Crit Care Med*. 1999;159:321-340.
25. Benditt JO, Wood DE, McCool FD, Lewis S, Albert RK. Changes in breathing and ventilatory muscle recruitment patterns induced by lung volume reduction surgery. *Am J Respir Crit Care Med*. 1997;155:279-284.
26. Laghi F, Jurban A, Topeli A, et al. Effect of lung volume reduction surgery on neuromechanical coupling of the diaphragm. *Am J Respir Crit Care Med*. 1998;157:475-483.
27. Anderson KL. Change in quality of life after lung volume reduction surgery. *Am J Crit Care Med*. 1999;8:389-396.
28. Benditt JO, Lewis S, Wood DE, Klima L, Albert RK. Lung volume reduction surgery improves maximal O₂ consumption, maximal minute ventilation, O₂ pulse, and dead space-to-tidal volume ratio during leg cycle ergometry. *Am J Respir Crit Care Med*. 1997;156:561-566.
29. Goto Y, Kohzoki M, Megoro M, Kurosawa H. Long-term beneficial effects of lung volume reduction surgery on quality of life in patients with COPD. *Tohoku J Exp Med*. 2007;213:157-166.
30. van der Molen B. Dyspnoea: a study of measurement instruments for the assessment of dyspnoea and their application for patients with advanced cancer. *Adv Nurs*. 1995;22:948-956.
31. Moser KM. Results of a comprehensive rehabilitation program. *Arch Intern Med*. 1980;140:1596-1601.
32. Nosedá A, Carpiáx JP, Schmerber J, Yernault JC. Dyspnoea assessed by visual analogue scale in patients with chronic obstructive lung disease during progressive and high intensity exercise. *Thorax*. 1992;47:363-368.
33. Barr RG, Celli BR, Martinez FJ, et al. Physician and patient perceptions in COPD: the COPD resource network needs assessment survey. *Am J Med*. 2005;118:1415.
34. Muza SR, Sileverman MT, Gilmore GC, Hellerstein HK, Kelsen SG. Comparison of scales used to quantitate the sense of effort to breathe in patients with chronic obstructive pulmonary disease. *Am Rev Respir Dis*. 1990;131:909-913.
35. Gift AG. Validation of a vertical analogue scale as a measure of clinical dyspnea. *Rehab Nursing*. 1989;14:323-325.
36. Ainsworth BE, Haskell WL, Whitt MC, et al. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Ex*. 2000;32(9 Suppl):S498-504.
37. Horowitz MB, Littenberg B, Mahler DA. Dyspnea ratings for prescribing exercise intensity in patients with COPD. *Chest*. 1996;109:1169-1175.

38. Portney LG, Watkins MP. *Foundations of Clinical Research: Applications to Practice*. Upper Saddle River, NJ: Prentice Hall Health; 2000.
39. Walter SD, Eliasziw M, Donner A. Sample size and optimal designs for reliability studies. *Stat Med*. 1998;17:101-110.
40. Cronbach LJ. *Essentials of Psychological Testing*. 4th ed. New York, NY: Harper & Row; 1984.
41. Nunnally JC. *Psychometric Theory*. New York, NY: McGraw-Hill; 1978.
42. Haley SM, Fragala-Pinkham MA. Interpreting change scores of tests and measures used in physical therapy. *Phys Ther*. 2006;86:735-743.
43. Richman J, Madrises L, Prince B. Research methodology and applied statistics, part 3: measurement procedures in research. *Physiother Canada*. 1980;32:253-257.
44. Mador MJ, Kufel TJ. Reproducibility of visual analog scale measurements of dyspnea in patients with chronic obstructive pulmonary disease. *Am Rev Respir Dis*. 1994;146:82-87.
45. Keller CA, Ruppel G, Hibbett A, Osterloh J, Naunheim KS. 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.
46. Ciccone AM, Meyers BF, Guthrie TJ, et al. Long-term outcome of bilateral lung volume reduction in 250 consecutive patients with emphysema. *J Thorac Cardiovasc Surg*. 2003;125:513-525.
47. Puham MA, Mador MJ, Held U, Goldstein R, Guyatt GH, Schunemann HJ. Interpretation of treatment changes in 6-minute walk distance in patients with COPD. *Eur Respir J*. 2008;32:637-643.
48. Gross NJ. Chronic obstructive pulmonary disease outcome measurements. *Proc Am Thorac Soc*. 2005;2:267-271.
49. Tweedale PN, Alexander F, McHardy GJR. Short-term variability of FEV₁ and bronchodilator responsiveness in patients with obstructive ventilatory defects. *Thorax*. 1997;42:487-490.
50. Martinez FJ, de Oca MM, Whyte RI, Stetz J, Gay SE, Celli BR. Lung-volume reduction improves dyspnea, dynamic hyperinflation, and respiratory muscle function. *Am J Respir Crit Care Med*. 1997;155:1984-1990.
51. O'Donnell DE, Webb KA, Bertley JC, Chau LKL, Conlan AA. Mechanisms of relief of exertional breathlessness following unilateral bullectomy and lung volume reduction surgery in emphysema. *Chest*. 1996;110:18-27.
52. Brenner M, Yusef R, McKenna RJ, Jr., et al. Lung volume reduction surgery for emphysema. *Chest*. 1996;110:205-218.
53. Mahler DA, Harver A. A factor analysis of dyspnoea ratings, respiratory muscle strength, and lung function in patients with chronic obstructive pulmonary disease. *Am Rev Respir Dis*. 1992;145:467-470.
54. Mannino DM, Gagnon RC, Petty TL, Lydick E. Obstructive lung disease and low lung function in adults in the United States: data from the National Health and Nutrition Examination Survey, 1988-1994. *Arch Intern Med*. 2000;160:1683-1689.
55. Lacasse Y, Goldstein R, Lasserson TJ, Martin S. Pulmonary rehabilitation for chronic obstructive pulmonary disease. *Cochrane Database of Syst Rev* 3: CD003793; 2002.
56. Cambach W, Wagenaar RC, Koelman TW, et al. The long-term effects of pulmonary rehabilitation in patients with asthma and chronic obstructive disease: a research synthesis. *Arch Phys Med Rehabil*. 1999;80:103-111.
57. Criner GJ, Sternberg AL. A clinician's guide to the use of lung volume reduction surgery. *Proc Am Thorac Soc*. 2008;5:461-467.

TODAY'S DATE: _____.

Perceived Shortness of Breath with ADL

Choose a point on the scale which best reflects your shortness of breath with the specified activity and mark that point with a slash mark. Rate only the shortness of breath and ignore other sensations such as cough, chest tightness, and nasal irritation or throat irritation. If oxygen is in use with the activity, write the amount in liters per minute in the space provided. If the activity does not apply to your normal routine or you are unable to perform the activity, please circle N/A. Please abstain from caffeine containing products for at least 12 hours prior to the testing.

1. Shortness of breath while at rest. N/A
| _____ |
Severe None
Amount of Oxygen used: _____ liters/minute
2. Shortness of breath while performing a 6-minute walk. N/A
| _____ |
Severe None
Amount of Oxygen used: _____ liters/minute
3. Shortness of breath while climbing one flight of stairs (10 steps). N/A
| _____ |
Severe None
Amount of Oxygen used: _____ liters/minute
4. Shortness of breath while getting into and out of bed. N/A
| _____ |
Severe None
Amount of Oxygen used: _____ liters/minute
5. Shortness of breath while getting into and out of a chair. N/A
| _____ |
Severe None
Amount of Oxygen used: _____ liters/minute
6. Shortness of breath while performing morning hygiene and grooming activity (brush hair, brush teeth, shave, etc) N/A
| _____ |
Severe None
Amount of Oxygen used: _____ liters/minute
7. Shortness of breath while bathing/showering (washing hair and body). N/A
| _____ |
Severe None
Amount of Oxygen used: _____ liters/minute
8. Shortness of breath while dressing. N/A
| _____ |
Severe None
Amount of Oxygen used: _____ liters/minute
9. Shortness of breath while eating. N/A
| _____ |
Severe None
Amount of Oxygen used: _____ liters/minute
10. Shortness of breath while speaking. N/A
| _____ |
Severe None
Amount of Oxygen used: _____ liters/minute