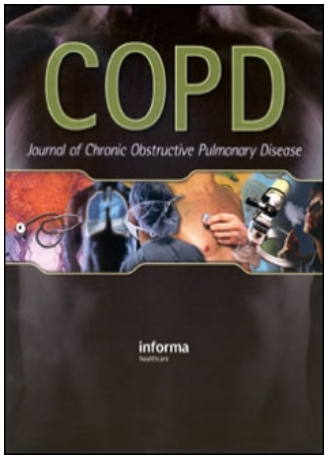

COPD: Journal of Chronic Obstructive Pulmonary Disease
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713597242

Costs of Pulmonary Rehabilitation and Predictors of Adherence in the National Emphysema Treatment Trial

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Online Publication Date: 01 April 2008
To cite this Article: Fan, Vincent S., Giardino, Nicholas D., Blough, David K., Kaplan, Robert M., Ramsey, Scott D. and Group, the NETT Research (2008) 'Costs of Pulmonary Rehabilitation and Predictors of Adherence in the National Emphysema Treatment Trial', COPD: Journal of Chronic Obstructive Pulmonary Disease, 5:2, 105 - 116
To link to this article: DOI: 10.1080/15412550801941190
URL: http://dx.doi.org/10.1080/15412550801941190

COPD: Journal of Chronic Obstructive Pulmonary Disease, 5:105–116
ISSN: 1541-2555 print / 1541-2563 online

DOI: 10.1080/15412550801941190

informa
healthcare

ORIGINAL RESEARCH

Costs of Pulmonary Rehabilitation and Predictors of Adherence in the National Emphysema Treatment Trial

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ABSTRACT

This study reports the costs associated with rehabilitation among participants in the National Emphysema Treatment Trial (NETT), and evaluates factors associated with adherence to rehabilitation. Pulmonary rehabilitation is recommended for moderate-to-severe COPD and required by the Centers for Medicare and Medicaid Services (CMS) prior to lung volume reduction surgery (LVRS). Between January 1998 and July 2002, 1,218 subjects with emphysema and severe airflow limitation ($FEV_1 \leq 45\%$ predicted) were randomized. Primary outcome measures were designated as mortality and maximal exercise capacity 2 years after randomization. Pre-randomization, estimated mean total cost per patient of rehabilitation was $2,218 (SD $314; 2006 dollars) for the medical group and $2,187 (SD $304) for the surgical group. Post-randomization, mean cost per patient in the medical and surgical groups was $766 and $962 respectively. Among patients who attended ≥ 1 post-randomization rehabilitation session, LVRS patients, patients with an $FEV_1 \geq 20\%$ predicted, and higher education were significantly more likely to complete rehabilitation. Patients with depressive and anxiety symptoms, and those who live $>$ 36 miles compared to $<$ 6 miles away were less likely to be adherent. Patients who underwent LVRS completed more exercise sessions than those in the medical group and were more likely to be adherent with post-randomization rehabilitation. A better understanding of patient factors such as socioeconomic status, depression, anxiety and transportation issues may improve adherence to pulmonary rehabilitation.

Keywords: Rehabilitation, Chronic Obstructive Pulmonary Disease, Depression
The research reported here was supported by the Department of Veteran Affairs, Health Services Research and Development Service Grants RCD 02-170-2 and by the NETT Coordinating Center. The National Emphysema Treatment Trial (NETT) is supported by contracts with the National Heart, Lung, and Blood Institute (N01HR76101, N01HR76102, N01HR76103, N01HR76104, N01HR76105, N01HR76106, N01HR76107, N01HR76108, N01HR76109, N01HR76110, N01HR76111, N01HR76112, N01HR76113, N01HR76114, N01HR76115, N01HR76116, N01HR76118, and N01HR76119), the Centers for Medicare and Medicaid Services (CMS; formerly the Health Care Financing Administration); and the Agency for Healthcare Research and Quality (AHRQ).
Note: The views expressed in this article are those of the authors and do not necessarily represent the views of the department of Veterans Affairs. The authors would like to acknowledge the contribution of Janne Abullarade to the preparation of the data set for analysis.
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INTRODUCTION

More than 20 million Americans currently have chronic obstructive pulmonary disease (COPD), and 1.4% of the U.S. population suffer from airflow obstruction of at least moderate severity with an $FEV_1 < 50\%$ predicted (1). Pulmonary rehabilitation improves patient symptoms such as dyspnea and fatigue, and improves their health-related quality of life (QOL) (2). International guidelines recommend pulmonary rehabilitation for patients with moderate to severe COPD (3, 4).

Pulmonary rehabilitation was an integral component of the National Emphysema Treatment Trial (NETT), a multicenter randomized, controlled study evaluating lung volume reduction surgery (LVRS) versus maximal medical therapy for patients with severe COPD (5). All patients participating in this trial underwent 6 to 10 weeks of standardized pulmonary rehabilitation prior to randomization, and an additional 8 to 9 weeks of rehabilitation after randomization. As with prior evaluations of pulmonary rehabilitation, NETT participants showed significant improvement in exercise tolerance, dyspnea and QOL at the end of the pre-randomization rehabilitation program (6). The greatest improvements were observed for patients who had not previously participated in a rehabilitation program.

Based on the results of the NETT, the Centers for Medicare and Medicaid Services (CMS) now pays for LVRS (7, 8). Furthermore, the CMS stipulates that pulmonary rehabilitation must be included before and after surgery as a condition for reimbursement. Pulmonary rehabilitation therefore adds to the total cost of LVRS. Unlike the surgery itself, adherence to pulmonary rehabilitation can be affected by patient factors such as social support, socioeconomic factors and other health behaviors (9). The purpose of this report is to describe the costs associated with pulmonary rehabilitation among participants in the NETT, and to determine the factors associated with adherence after randomization.

METHODS

Setting and data collection

The patients for this study were enrolled in the NETT. The design of the NETT and its results have been reported previously (5, 10, 11). Between January 1998 and July 2002, 1,218 subjects with emphysema and severe airflow limitation ($FEV_1 \leq 45\%$ predicted) were randomized, with primary outcome measures designated as mortality and maximal exercise capacity 2 years after randomization.

After a baseline evaluation, eligible patients were required to complete a comprehensive pulmonary rehabilitation program prior to randomization. The NETT rehabilitation program consisted of three phases: 1) pre-randomization, 2) post-randomization, and 3) long-term maintenance (6). During the pre-randomization phase, subjects were required to attend 16–20 supervised sessions that were completed over a 6–10 week period. The components of the comprehensive pulmonary rehabilitation program included exercise training, COPD education and skill sessions, psychosocial counseling, and a nutritional assessment. The first 4 rehabilitation sessions ("core") were provided at the participating NETT center, whereas the remaining 12–16 sessions ("continuation") were given either at the same NETT center or at a satellite facility nearer to the patient's home (Figure 1).

During the post-randomization phase, subjects participated in an additional 8 to 9 weeks of pulmonary rehabilitation. As

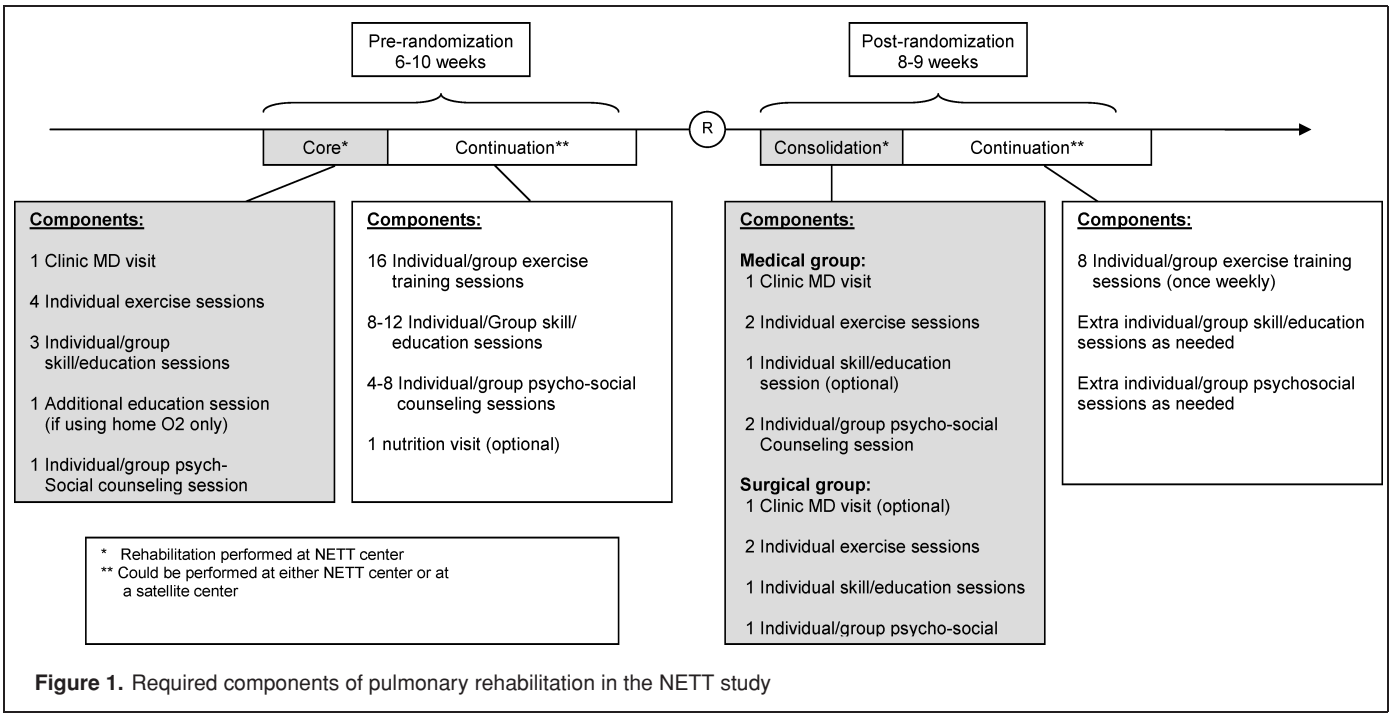

Figure 1. Required components of pulmonary rehabilitation in the NETT study

with the pre-randomization rehabilitation period, patients were to have 2 initial rehabilitation ("consolidation") sessions at a NETT study center with the remaining 8 sessions ("continuation") provided at either the NETT center or the participating satellite. Patients in the maximal medical therapy group began rehabilitation immediately after randomization, whereas subjects in the surgery group began rehabilitation after hospital discharge. The medical group had a minimum of two psychosocial counseling sessions after randomization to help patients cope with any disappointment regarding the assigned treatment arm. After the post-randomization rehabilitation, all patients were to continue their exercise regimen at home, and could receive additional supervised rehabilitation sessions if recommended by the study physician.

Calculation of rehabilitation costs

Costs for pulmonary rehabilitation were estimated based on reimbursements by CMS for bills submitted for individual services, and the number of services received by each patient in the pre randomization phase and the initial 8–9 weeks of the post randomization phase of the NETT rehabilitation program. The analysis was complicated by the fact that Current Procedural Terminology (CPT) billing codes for the specific LVRS-related rehabilitation sessions (e.g., exercise vs. education) had not been established prior to the NETT study; new CPT codes were introduced shortly after the trial had started. As a result, bills for NETT patient rehabilitation sessions were occasionally submitted as nonspecific "pulmonary rehabilitation" CPT codes, particularly during the early years of the trial. In addition, using NETT trial case report forms as the reference standard record for the total number of rehabilitation visits over the course of the trial, it became clear that both facilities and physicians had not consistently billed CMS for rehabilitation sessions or physician visits that patients attended. The methods used to account for these issues are described next.

Study research coordinators at each site recorded the total number of rehabilitation exercise sessions completed by subjects during pre-randomization and post-randomization periods. In addition, research coordinators recorded whether patients saw a NETT physician during rehabilitation. The education, counseling and nutrition sessions were not recorded separately; rather, these three types of sessions were summarized. We refer to these visits as the total number of "education-related sessions" for each phase of the rehabilitation for this analysis.

To estimate the cost of an education-related session, we calculated a weighted average reimbursement based on the proportions of CPT codes submitted to Medicare for NETT patients that were for education, nutrition, and counseling by providers in 2002 (the final year of the study) multiplied by the reimbursement rate for each individual code. Educational sessions could be conducted as either group or individual sessions; separate reimbursement rates were applied for each type of session.

Exercise sessions could also be billed as group or individual sessions; reimbursement levels differed for each type of session. Individual exercise sessions were billed as 15-minute units, known as Revenue Units. The total cost of an individual exercise session was determined by the number of Revenue Units completed on that day. Group sessions were billed using a different CPT code. To calculate the cost of an average exercise session, we calculated a weighted average that was based on the proportions of individual and group sessions and the associated reimbursements for each type of session. The average number of Revenue Units per individual exercise session was used to determine the reimbursement for individual exercise sessions.

Different reimbursement rates were used to calculate costs for subjects based on the CMS region where the rehabilitation facility was located. In addition, payments differed according to whether the care was delivered at a NETT facility or a satellite rehabilitation center. Facility-related reimbursements were used for rehabilitation NETT sites; non-facility reimbursements were used for sessions at satellite centers.

We estimated the costs of physician services by examining records of physician visits in the clinic case report forms. All patients were evaluated by a physician prior to initiating rehabilitation and in the post-randomization period. Medical patients and surgical patients could also be seen by a physician at the beginning of rehabilitation. Physician visits recorded on case report forms were assigned a CPT code of 99205 (highest level initial visit—level 5) for pre-randomization visits and were assigned 99213 (follow-up—level 3) during the post-randomization period.

The total rehabilitation costs for an individual patient were then determined by multiplying the total number of rehabilitation sessions by the corresponding weighted average cost per session and adding the physician costs. Costs are reported in 2006 dollars.

Adherence to pulmonary rehabilitation

All patients were required to complete the pre-randomization rehabilitation to be eligible for randomization, and adherence by definition was 100% for this phase of the study. In the post-randomization period, however, a significant proportion of patients did not attend all of the 10 required exercise sessions and were defined as non-adherent. To identify factors associated with adherence once rehabilitation has started, we included patients who attended at least one session in this analysis.

We created a multivariate model to address socio-demographic, clinical, and facility-related factors that might predict adherence. We considered several factors including socio-demographic variables such as age, gender, race, marital status, education, income, and self-reported alcohol use. Clinical factors included COPD severity, depression, and anxiety recorded at the start of the study. Measures of COPD disease severity included post-bronchodilator forced expiratory volume in 1 second (FEV_1), arterial hypoxemia (partial pressure of oxygen $\leq$55), distance walked in 6 minutes (6-MW), exercise capacity, and dyspnea measured with the University of California at San Diego (UCSD) shortness of breath questionnaire (SOBQ). Because the Medical Research Council (MRC) dyspnea scale was not measured for the NETT study, a modified BODE (Body

mass index, airflow Obstruction, Dyspnea, Exercise capacity) score was calculated as a summary measure of disease severity using SOBQ score instead of MRC score (12, 13). COPD-related health care utilization was also measured using Medicare claims data from the year prior to randomization. All hospitalizations were identified, and COPD-specific emergency department (ED) visits and hospitalizations identified with a primary ICD-9 CM discharge diagnosis code of 490, 491, 492, or 496.

Baseline non-COPD comorbidity was determined using the Deyo adaptation (14) of the Charlson comorbidity index (15). Co-morbid conditions were identified from ICD-9 CM diagnosis codes from both inpatient and outpatient visits in the 12 months preceding randomization.

Depression (not a part of the comorbidity index) was measured with the Beck Depression Inventory (BDI) questionnaire (16, 17), a self-reported 21-item measure of depressive symptoms that ranges from 0 and 63 with higher scores indicating more symptoms. General anxiety at baseline was measured with the State-Trait Anxiety Inventory (STAI) (18), which consists of a 20-item State scale that asks subjects to describe how they feel at one point in time, and a 20-item Trait scale to describe how they feel in general. Each scale has a range from 20 to 80, with higher scores indicating higher levels of anxiety.

Other potential factors that were considered included prior participation in pulmonary rehabilitation and use of a satellite rehabilitation center. To evaluate whether distance was associated with adherence, we calculated the distance (19) between the subject's zip code of residence and the rehabilitation center using zip codes to determine longitude and latitude (20). The distance to the satellite rehabilitation center was calculated, and if a satellite was not used, the distance to the NETT clinic was used instead.

Statistical analysis

Patients in the medical and surgical groups were compared using the χ^2 statistic for categorical variables and Student's *t*-test for continuous variables in bi-variate analysis. Distance was found to have a non-normal distribution and was compared using the Wilcoxon Rank-Sum test statistic.

Multivariable logistic regression was used to predict adherence to at least 10 post-randomization exercise sessions. The index date was defined as the date of randomization for the clinical trial, and all baseline variables were collected prior to randomization. All 8 variables associated with adherence at the $p < 0.1$ level in univariate logistic regression model were included in the final multivariate logistic regression model (randomization group, age, alcohol use, education, FEV_1, BDI, STAI, and distance). Five variables not associated with adherence in univariate regression were included in the final model to increase precision of the model: gender, BMI, SOBQ, 6-MWT, and co-morbidity. Education was used as a marker of socioeconomic status instead of income since the two variables were highly correlated ($p < 0.0001$). Age was found to be approximately linear and modeled as a continuous variable. FEV_1, distance, BDI score, and STAI score were found to have a non-linear relationship and modeled as categorical variables. We assessed model fit using the Hosmer-Lemeshow goodness-of-fit test statistic (21).

RESULTS

Patients randomized to the medical and surgical arms had a similar mean age, marital status, income, measures of COPD disease severity, co-morbidity, and prior COPD-related utilization (Table 1). There were slightly more women in the surgical group (42 vs. 36%, $p = 0.04$) and higher education level in the medical group ($p = 0.02$). The median estimated distance from subjects' home residence to the NETT clinical center was 70 miles in the medical group and 66 miles in the surgical group ($p = 0.8$).

All patients completed the required pre-randomization exercise and education rehabilitation sessions in order to be randomized, but some completed more sessions than the minimum required. During this period, rehabilitation patients spent a mean of 55.1 ($\pm$10.8) days in pulmonary rehabilitation, and on average attended 20.6 ($\pm$3.3) exercise sessions and 19.6 ($\pm$2.5) education sessions. 62.6% of patients completed a portion of their rehabilitation at a satellite rehabilitation center. The median distance to the center where the subject attended the continuation rehabilitation sessions was 14.8 [IQR 6.1–37.0] miles. There were no significant differences during pre-randomization rehabilitation between the medical and surgical groups (Table 2).

During the post-randomization period, 33 patients in the medical group did not complete at least one rehabilitation session (20 refused for travel inconvenience, 3 for medical reasons, 1 went to a non-NETT rehabilitation facility, and 9 for unknown reasons). In the surgery group, 86 patients did not complete any rehabilitation sessions following surgery (24 died, 5 refused for travel inconvenience, 29 for medical reasons, 2 attended non-NETT rehabilitation facilities, and 26 for unknown reasons). Among the 119 patients who did not participate in post-randomization rehabilitation, there was no difference in mean age (67.7 vs. 67.1, $p = 0.7$) or percent predicted FEV_1 (25.2 vs. 24.8, $p = 0.8$) between medical and surgical patients with 0 sessions.

Using an intent-to-treat analysis, during the post-randomization period patients randomized to LVRS spent a similar number of days in rehabilitation compared to maximal medical therapy patients (52.6 vs. 53.9, $p = 0.5$); however, LVRS patients attended more exercise sessions (mean 11.3 vs. 9.6, $p < 0.0001$) than those in the medical therapy group (Table 2). This was in spite of the fact that surgical patients were more likely to be hospitalized during the rehabilitation period (9.4% vs. 5.1%, $p = 0.004$). More patients in the medical group used a satellite rehabilitation center, reflecting the fact that more patients participated in rehabilitation in the medical group than the surgical group.

Among subjects who attended at least 1 post-randomization rehabilitation session (Table 2), the duration in days between initiation and completion of rehabilitation was longer for the surgical group compared to the medical group (mean 62.0 vs. 58.6, $p = 0.04$). In addition, surgical patients attended more exercise sessions (mean 13.1 vs. 10.1, $p < 0.00001$) compared

Table 1. Baseline characteristics

Variables	NETT group: Medical N = 610	NETT group: Surgical N = 608	*p*-value
Mean Age (SD)	66.7 (5.9)	66.5 (6.3)	0.6
Female, %	35.9	41.6	0.04
Non-Caucasian, %	5.7	4.4	0.3
Married, %	64.9	64.6	0.9
Education, %			
< High school	21.2	19.4	0.02
High school	27.7	35.5	
Some College	34.3	31.9	
≥ College	16.9	13.2	
Income, %			
< $15,000	18.4	19.3	0.8
$15-$29,999	33.5	35.5	
$30-$49,999	29.2	27.3	
≥$50,000	18.9	17.9	
Body mass index	24.9 (3.7)	24.6 (4.0)	0.2
FEV_1 (L), Mean (SD)	0.8 (0.2)	0.8 (0.2)	0.3
FEV_1 (% pred), Mean (SD)	26.7 (7.0)	26.8 (7.4)	0.7
$PaO_2 \leq 55$, %	21.8	21.6	0.9
Low exercise capacity*	42.5	45.2	0.3
Modified BODE**, mean (SD)	5.0 (1.7)	5.0 (1.7)	0.4
Distance walked in 6 min (feet), mean (SD)	1210 (316)	1207 (311)	0.9
Total UCSD SOBQ score, mean (SD)	63.4 (18.5)	61.6 (18.1)	0.08
BDI total score, mean (SD)	9.3 (5.9)	9.4 (6.3)	0.9
STAI trait anxiety score, mean (SD) (Y2)	34.5	34.4	0.9
Health care utilization in previous 12 months			
≥ 1 COPD ED Visit, %	8.9	8.6	0.9
≥ 1 COPD Hospitalization,%	19.2	20.1	0.7
Charlson co-morbidity score ≥ 1, %	38.7	40.6	0.5
Rehab prior to NETT, %	65.1	62.5	0.3
Distance NETT Clinical center†, median [IQR]	70.4 [21.9–207.5]	66.4 [21.2–92.3]	0.8

SD = Standard Deviation, FEV_1 = Forced expiratory volume in 1 second, L = liter, COPD = Chronic Obstructive Pulmonary Disease, SOBQ = Shortness of Breath Questionnaire, BDI = Beck Depression Inventory score, STAI = State-Trait Anxiety Index, ED = Emergency Department, IQR = Inter-quartile range.
*Based on NETT criteria; values presented obtained prior to the pre-randomization rehabilitation program.
**BODE score calculated using the SOBQ instead of the MRC dyspnea scale. †For patients who participated in at least 1 post-randomization rehabilitation session (N = 1,099).

to the medical group. Among those who attended rehabilitation, there were no differences in the proportion who used a satellite center, or in the distance to the rehabilitation center.

The majority of claims for exercise sessions during the pre-randomization period were for group sessions (57.2%) (Table 3). The mean Revenue Units, corresponding to a 15 minute increment, for an individual session was 3.8 (± 2.4) suggesting that an average individual session was 57 minutes in length. Post-randomization, there were a similar proportion of claims for group and individual sessions.

During the pre-randomization period, 43% of education/skills sessions were individual and 41% were group sessions. Post-randomization, however, the majority (61.7%) of education sessions were individual as opposed to group (23.2%). There were fewer claims for nutritional guidance sessions, psychological testing, and psychosocial counseling than for education/skills sessions during either the pre- or post-randomization periods.

The estimated mean total cost per patient of rehabilitation during the pre-randomization period was $2,218 (SD $314) in the medical group and $2,187 (SD $304) in the surgical group. During the post-randomization period, the total mean cost per patient of rehabilitation was higher in the surgical group $962 (± $481) than in the medical group $766 (± $315), likely reflecting a higher cost associated with exercise sessions ($802 vs. $619).

Among the 577 medical subjects who attended at least one post-randomization rehabilitation session, 423 (73.3%) attended all 10 sessions. In the surgical group, 446 (85.4%) out of 522 patients completed all 10 recommended exercise sessions ($p < 0.0001$ compared to the medical group). Variables associated with adherence at the $p < 0.1$ level in univariate regression were randomization group, age, education level, daily alcohol use, FEV1, depressive symptoms, anxiety, and distance. In a multivariable logistic regression model, subjects randomized to LVRS were more likely to be adherent (OR 2.43, 95% CI 1.77–3.35), as were patients with higher socioeconomic status, and

Table 2. Pulmonary rehabilitation sessions completed

Pulmonary Rehabilitation Phase Pre-randomization	NETT Study Group: Medical N = 610	NETT Study Group: Surgical N = 608	*p*-value
Physician clinic visit, %	100%	100%	
Duration of rehabilitation in days**, mean (SD)	54.9(9.6)	55.3(11.9)	0.5
Exercise sessions, mean (SD)	20.8 (3.2)	20.5 (3.3)	0.2
Education sessions***, mean (SD)	19.7 (2.6)	19.5(2.4)	0.06
Any hospitalization during rehab*,%	4.9%	4.3%	0.6
Satellite rehabilitation center used	62.8%	62.3%	0.9
Distance to rehabilitation center† (in miles), median [IQR]	14.4 [6.0–34.5]	15.4 [6.2–41.7]	0.4
Post-randomization, intent-to-treat	N = 610	N = 6 08	
Physician clinic visit, %	61.8%	60.2%	0.3
Duration of rehabilitation in days**, mean (SD)	53.9 (30.1)	52.6 (33.8)	0.5
Exercise sessions, mean (SD)	9.6 (4.5)	11.3 (7.7)	<0.0001
Education sessions***, mean (SD)	2.8 (2.7)	2.8 (3.4)	0.6
Any hospitalization during rehab*,%	5.1%	9.4%	0.004
Satellite rehabilitation center used	60.3%	54.1%	0.03
Distance to rehabilitation center† (in miles), median [IQR]	14.8 [6.5–36.6]	18.0 [6.7–56.2]	0.05
Post-randomization, per protocol*	N = 577	N = 522	
Physician clinic visit, %	65.3%	70.1%	0.09
Duration of rehabilitation in days**, mean (SD)	58.6 (26.6)	62.0 (27.7)	0.04
Exercise sessions, mean (SD)	10.1 (4.0)	13.1 (6.6)	<0.00001
Education sessions, mean (SD)	3.0 (2.7)	3.2 (3.5)	0.3
Any hospitalization during rehab*,%	5.4%	10.9%	0.001
Satellite rehabilitation center used	63.6%	63.0%	0.8
Distance to rehabilitation center† (in miles), median [IQR]	14.0 [6.3–33.2]	15.2 [6.0–43.0]	0.4

*Completed at least one postrandomization rehabilitation exercise or education session.
**Number of days between initiation and completion of pulmonary rehabilitation program.
***Combined education, counseling and nutrition sessions.
†If the patient did not use a satellite center, the distance to the NETT center was used.

those with better lung function indicated by an $FEV_1 \geq 20\%$ (OR 1.67, 95% CI 1.09–2.55) (Table 5). Other measures of disease severity such as BMI, dyspnea (SOBQ score), 6-MWT and comorbidity were not associated with adherence. Patients with depressive or anxiety symptoms were less likely to complete rehabilitation, as were patients who lived furthest away from the rehabilitation center.

DISCUSSION

We found that the costs associated with pulmonary rehabilitation in the NETT trial for surgical patients were estimated to be $2,187 during the pre-randomization rehabilitation period and $962 after LVRS. In the medical group, the costs were estimated at $2,218 prior to randomization and $766 afterwards. The largest proportion of rehabilitation costs were related to exercise sessions attended. Subjects who underwent LVRS had a higher mean number of exercise sessions compared to the medical group in both intent-to-treat and per-protocol analyses. After controlling for randomization group, factors associated with improved adherence to rehabilitation included higher FEV_1 and socioeconomic status, whereas depressive or anxiety symptoms as well as living further away from the rehabilitation center were associated with decreased adherence.

The results of this study have several implications for pulmonary rehabilitation in patients with severe COPD, both those who choose LVRS and those who remain with medical therapy. Pulmonary rehabilitation can be costly, particularly in the initial period leading up to surgery. Our previous analysis of the cost-effectiveness of LVRS did not include costs of rehabilitation incurred prior to randomization. Although pulmonary rehabilitation increases costs, it is associated with improved outcomes such as quality of life and exercise tolerance both in the NETT(6) and other populations (2).

Adherence will play a role in both the cost of treatment and for outcomes. For patients who elect LVRS today, our analysis is likely a reasonable approximation of pre- and post-surgery rehabilitation costs, since patients must complete these sessions as a

Table 3. Proportion of all claims with a CPT code for pulmonary rehabilitation for participants in the NETT in 2002

Name of session	CPT code	Pre-randomization Claims	Post-randomization Claims
Total number of claims		N = 1111 %	N = 860 %
Exercise sessions			
Rehabilitation exercise training—individual	97530	42.8	40.9
Mean revenue units (SD)*		3.8 (2.4)	3.7 (2.3)
Rehabilitation exercise training—group	97150	57.2	58.1
Education, counseling, and nutrition sessions			
Education/skills training, individual	G0110†	43.0	61.7
Education/skills training, group	G0111†	41.0	23.2
Nutritional guidance—initial	G0112†	2.5	0.1
Nutritional guidance—subsequent	G0113†	0.6	0.2
Psychosocial consultation	G0114†	1.5	1.1
Psychological testing	G0115†	0.3	0.1
Psychosocial counseling—individual	G0116†	3.3	9.1
Psychosocial counseling—group	90853	7.8	4.4

*One revenue unit corresponds to a 15 minute individual exercise period.
†CPT codes specifically used for NETT study.

prerequisite for the procedure. Adherence in the medical therapy arm is artificially high compared to what one is likely to observe for persons who choose rehabilitation without surgery, since trial participants in both arms had to complete required sessions prior to randomization. Indeed, post-randomization adherence in the medical therapy group might be a reasonable approximation of adherence to rehabilitation in general for patients who choose rehabilitation rather than surgery today.

We found "modifiable" factors that predict adherence after randomization: depression, anxiety and distance to the facility. Importantly, we found that even mild depressive symptoms measured with the Beck Depression Inventory score were associated with significantly decreased odds of completing rehabilitation. In addition, anxiety trait, measured with the State-Trait Anxiety Inventory, was also associated with adherence indicating that patients' emotional state contributes to their willingness to participate in rehabilitation. Screening for and aggressively treating depression and anxiety may be useful components to include at the start of pulmonary rehabilitation. We need more research to determine whether early intervention for depression improves outcomes of COPD rehabilitation. Expanding training and thus the number of available pulmonary rehabilitation facilities may reduce transportation distances for some patients, translating into better adherence.

A recent evidence-based review shows that pulmonary rehabilitation can improve functional status and quality of life in persons with COPD (25), but there have been few studies of the cost of pulmonary rehabilitation in COPD. An economic analysis of an intensive 6-month pulmonary rehabilitation program in Canada that included an initial 2 month inpatient phase followed by 4-month outpatient program showed a total cost of CDN $11,597 (1989 dollars) (22). Although that program differed from the NETT rehabilitation in that the majority of costs in that program were due to the inpatient rehabilitation, and the costs associated with the outpatient portion (3–4 home care visits and 4–5 outpatient visits) were significantly lower (CDN $741). More recently, a study of a Canadian rehabilitation program in 2001 showed that the total annual program costs were CDN $345,355 with an average cost of CDN $1,092 per patient.(23) During this program each patient completed 16–18 sessions combining education, exercising and breathing techniques lasting approximately 2½ hours. This before-after community-based study also suggests that a reduction in health

Table 4. Estimated per patient cost of pulmonary rehabilitation for all patients in an intent-to-treat analysis

	NETT Study Group							
Pulmonary Rehabilitation Phase	Medical N = 610				Surgical N = 608			
Pre-randomization	Mean (SD)	Median	Min	Max	Mean (SD)	Median	Min	Max
Exercise Sessions	$1332 (249)	$1261	$935	$2445	$1313 (240)	$1251	$954	$2679
Education Sessions**	$747 (124)	$727	$527	$1353	$735 (115)	$714	$527	$1463
Physician Visit	$139 (8)	$137	$129	$161	$139 (8)	$136	$129	$161
Total	$2218 (314)	$2149	$1640	$3722	$2187 (304)	$2125	$1680	$4290
Post-randomization*	Mean (SD)	Median	Min	Max	Mean (SD)	Median	Min	Max
Exercise Sessions	$619 (263)	$602	$0	$2057	$802 (418)	$635	$0	$3602
Education Sessions**	$125 (123)	$81	$0	$1132	$135 (161)	$81	$0	$1231
Physician Visit	$22 (16)	$33	$0	$40	$24 (16)	$33	$0	$40
Total	$766 (315)	$718	$0	$2576	$962 (481)	$776	$0	$3723

*In intent to treat analysis
**Combined education, counseling and nutrition sessions

Table 5. Multivariable logistic regression model to predict completion of 10 or more post-randomization pulmonary rehabilitation exercise sessions

Variables	OR	95% CI
Intervention group		
Medical therapy	1.0	Ref
Lung volume reduction surgery	2.43	(1.77, 3.35)
Age (per 1 year change)	1.01	(0.99, 1.04)
Female gender	0.87	(0.62,1.21)
Daily alcohol use	1.33	(0.82, 2.17)
Education		
< High school	1.0	Ref
High school	1.58	(1.05, 2.38)
Some College	1.66	(1.10, 2.51)
≥College	2.21	(1.27, 3.85)
Body mass index*	1.00	(0.96, 1.04)
FEV_1, percent predicted		
< 20%	1.0	Ref
≥ 20%	1.67	(1.09, 2.55)
Total SOBQ score**	1.04	(0.99, 1.09)
Distance walked in 6 minutes†	1.01	(0.91, 1.12)
Charlson Comorbidity score		
0	1.0	Ref
≥ 1	1.13	(0.82, 1.56)
Beck Depression Inventory Score		
< 5	1.0	Ref
≥ 5	0.55	(0.34, 0.87)
STAI Anxiety Trait Score		
< 36	1.0	
≥ 36	0.65	(0.47, 0.91)
Distance to rehabilitation in miles (in quartiles)		
< 6	1.0	Ref
6-14.9	0.86	(0.55, 1.36)
15 - 35.9	0.91	(0.57, 1.44)
>36	0.49	(0.31, 0.75)
Goodness of Fit test‡,		
$\chi^2$and *p*-value	1126.7	0.16

OR = Odds Ratio; CI = Confidence Interval; FEV_1 = Forced expiratory volume in 1 second; SOBQ = Shortness of breath questionnaire; STAI = State-Trait Anxiety Inventory.
*OR for each 1-unit change.
**OR for 5 points change.
†OR for 180-foot change.
‡Hosmer-Lemeshow Goodness-of-fit statistic ($p > 0.05$ indicates adequate model fit).

care utilization results from pulmonary rehabilitation, and may reduce health care costs by CDN $344 per person per year.

The data from this study have limited usefulness for computing the cost-effectiveness of pulmonary rehabilitation + medical therapy versus medical therapy alone. The optimal way to estimate the incremental effectiveness of rehabilitation would have been to include a third arm in the NETT trial that included medical care only. Prior studies with less methodological rigor suggest that pulmonary rehabilitation may be cost-effective for patients with COPD. A cost-effectiveness study of pulmonary rehabilitation in the United Kingdom found that the costs associated with an 18 session program over 6 weeks were £725 per patient for 18 sessions and was cost-saving compared to usual care (Difference - £152 (95% CI, £ -880 to £ 577) (24). The costs that we calculated for rehabilitation in the NETT trial are consistent with these studies.

We found that patients who underwent LVRS attended a higher mean number of exercise sessions in spite of being less likely to be able to start rehabilitation due to death or medical illness and being more likely to be hospitalized during rehabilitation once started. This may reflect an improvement in exercise capacity associated with surgery allowing patients to fully participate in rehabilitation. This is supported by the fact that there was no difference in the number of education sessions attended in either the intent-to-treat or per-protocol analysis. However, we cannot exclude the possibility that the difference may be due to the fact that medical patients did not wish to continue to participate for other reasons.

Patients in the NETT trial were more likely to be adherent to the post-randomization rehabilitation program if they had a higher socioeconomic status as measured by level of education attained. This is consistent with a study of predictors of non-adherence to respiratory rehabilitation that found that patients owning their house were more likely to be adherent (9). Other factors in that study that were found to be associated with increased adherence were being married, a non-smoker, and having adequate COPD social support.

Although patients with better lung function were more likely to complete the post-randomization rehabilitation program, other markers of disease severity such as the BODE score, hypoxemia, exercise capacity, 6-MWT, or dyspnea measured with the SOBQ score were not associated with adherence. This suggests that disease severity plays a modest role in determining whether patients complete rehabilitation.

We note several limitations to the study. Coding for rehabilitation was uneven for patients in the study, and case report forms did not contain enough detail to determine reimbursement levels for individual services. This forced us to make several assumptions to estimate the cost of rehabilitation. Nevertheless, codes and coding patterns were selected from the final year of the study, a time when practice had become standardized for these patients. Thus our methods likely approximate practice since the time that LVRS has been approved for reimbursement by CMS. Adherence in clinical trials is usually higher than that seen in clinical practice. It is reasonable to assume high levels of adherence for pre-surgery patients today, thus enhancing the external validity of this portion of our analysis. We view observed adherence for patients in the medical arm post-randomization as an upper limit on likely adherence for patients today who choose to enter a pulmonary rehabilitation that is not connected with LVRS. Finally, we used Medicare reimbursements to estimate costs. Reimbursements do not necessarily represent and provider's true cost of delivering the good or service.

Despite these limitations, the data from this study may be useful to determine the budget impact of rehabilitation as a therapy for patients with severe emphysema, based on observed utilization of rehabilitation with and without LVRS. These data may also be helpful for modeling studies aimed at estimating the cost-effectiveness of pulmonary rehabilitation, in the absence of data from randomized trials. This study also suggests that adherence

to rehabilitation may be improved by reducing travel distance to rehabilitation facilities and by addressing baseline depressive and anxiety symptoms prior to entering the program.

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Other acknowledgments

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