Pulmonary Rehabilitation in Emphysema

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Pulmonary rehabilitation is an established treatment for patients with chronic lung disease. Benefits include improvement in exercise tolerance, symptoms, and quality of life, with a reduction in the use of health care resources. As an adjunct to surgical programs, such as lung volume reduction surgery, pulmonary rehabilitation plays an important role not just in preparing patients for surgery and facilitating recovery but also in selecting patients and ensuring informed choices about treatment options after optimal medical care. In the National Emphysema Treatment Trial (NETT), subjects completed 6–10 weeks of comprehensive pulmonary rehabilitation before randomization and continued rehabilitation throughout the trial, both at home and with intermittent supervision at either an NETT center or an NETT-certified satellite center. Sessions included a combination of upper and lower extremity exercise, education, and psychosocial support. Before randomization, pulmonary rehabilitation resulted in highly significant changes in exercise capacity, dyspnea, and quality of life. As expected, improvements were significantly greater in those without prior rehabilitation experience. Results for patients completing rehabilitation at satellites were similar to those at NETT centers. Prerandomization pulmonary rehabilitation had a significant effect on outcome after lung volume reduction surgery. NETT identified subgroups with differential outcome by treatment (surgical vs. nonsurgical), defined in part by postrehabilitation maximum exercise capacity. Overall, NETT demonstrated the effectiveness of pulmonary rehabilitation in improving function, symptoms, and health status in a large cohort of patients with advanced emphysema treated in a cross-section of programs in the United States.

Keywords: emphysema; rehabilitation; chronic obstructive pulmonary disease

DESCRIPTION OF PULMONARY REHABILITATION

Pulmonary rehabilitation enhances standard therapy for patients with emphysema by helping to control and alleviate symptoms, optimize functional capacity, and reduce the medical and economic burdens of disabling lung disease (1–5). The primary goal is to restore the patient to the highest possible level of independent function. This goal is accomplished by helping patients become more physically active and learn more about their disease, treatment options, and how to cope. Patients are encouraged to become actively involved in providing their own health care, more independent in daily activities, and less dependent on health professionals and medical resources.

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Many rehabilitation strategies have been developed for patients with disabling chronic obstructive pulmonary disease (COPD). Programs typically include components such as patient assessment, exercise training, education, nutritional intervention, and psychosocial support. Pulmonary rehabilitation has also been applied successfully to patients with other chronic lung conditions such as interstitial diseases, cystic fibrosis, bronchiectasis, and thoracic-cage abnormalities (6).

The American Thoracic Society and the European Respiratory Society have recently adopted the following definition of pulmonary rehabilitation: “Pulmonary rehabilitation is an evidence-based, multidisciplinary, and comprehensive intervention for patients with chronic respiratory diseases who are symptomatic and often have decreased daily life activities. Integrated into the individualized treatment of the patient, pulmonary rehabilitation is designed to reduce symptoms, optimize functional status, increase participation, and reduce health care costs through stabilizing or reversing systemic manifestations of the disease” (3).

This definition focuses on three important features of successful rehabilitation:

1. *Multidisciplinary:* Pulmonary rehabilitation programs utilize expertise from various health care disciplines, which is integrated into a comprehensive, cohesive program tailored to the needs of each patient.
2. *Individual:* Patients with disabling lung disease require individual assessment of needs, individual attention, and a program designed to meet realistic individual goals.
3. *Attention to physical and social function:* To be successful, pulmonary rehabilitation pays attention to psychological, emotional, and social problems, as well as helping to optimize medical therapy to improve lung function and exercise tolerance.

The interdisciplinary team of health care professionals in pulmonary rehabilitation may include physicians, nurses, respiratory and physical therapists, psychologists, exercise specialists, and/or others with appropriate expertise. Specific team makeup depends on the resources and expertise available, but usually includes at least one full-time staff member dedicated to pulmonary rehabilitation (7).

BACKGROUND AND RATIONALE FOR PULMONARY REHABILITATION IN LUNG VOLUME REDUCTION SURGERY

Pulmonary rehabilitation has been recommended for patients with significant underlying lung disease as an important modality in the evaluation and preparation for and recovery from thoracic surgery procedures, such as lung volume reduction surgery (LVRS), lung transplantation, and lung resection for cancer or other conditions (8–13). Patients with disabling emphysema who are considering LVRS are excellent candidates for pulmonary rehabilitation. Many of these patients are severely dyspneic, depressed, dysfunctional, and desperate. Enrolling patients in rehabilitation before surgery has the advantage of optimizing

their functional status, improving physical and psychological symptoms, helping them learn more about their disease and alternative treatment options, and improving skills for coping and actively managing their disease.

In addition to optimizing preoperative physical and emotional function, an important function of pulmonary rehabilitation is to help select appropriate patients for surgery and to ensure that patients make a truly informed choice about treatment options. Some patients may improve sufficiently after rehabilitation and choose to defer or delay the decision to pursue surgical options. Although it cannot be quantified precisely, the experience in the National Emphysema Treatment Trial (NETT) was that many patients (perhaps 10%) who came to the study eager for surgery experienced such positive effects from pulmonary rehabilitation that they were subsequently unwilling to proceed to randomization and accept the surgical risks (14). Other patients, who initially seemed appropriate for surgery, were subsequently found during pulmonary rehabilitation to be too ill or fragile for surgery.

The preoperative pulmonary rehabilitation program helps give patients the preparation, self-reliance, independence, and confidence to continue their long-term daily care program after surgery. Rehabilitation after surgery helps patients to adapt to new levels of function and to reassess symptoms and oxygenation needs. Such patients typically need several months to recover from the effects of surgery and to recondition themselves to optimal levels. Supervised rehabilitation sessions during this period help to guide patient's recovery, physical reconditioning, and readaptation to life.

DESCRIPTION OF PULMONARY REHABILITATION PROGRAM IN NETT

The NETT provides an excellent example of the integration of pulmonary rehabilitation into a surgical treatment program (LVRS) for patients with advanced emphysema. In this multicenter clinical trial, after the initial evaluation to establish preliminary eligibility and before randomization, all subjects were required to complete a comprehensive program of pulmonary rehabilitation (6–10 wk, 12–16 sessions) regardless of whether they had undergone pulmonary rehabilitation at any time previously (14, 15). Although it was recognized that prior pulmonary rehabilitation might reduce the response to pulmonary rehabilitation in patients who had already experienced benefits from previous rehabilitation treatment, it was important for all patients in NETT to undergo a standard rehabilitation program to ensure optimal medical care and function before committing to the randomized portion of the study and possible surgery. The NETT rehabilitation program was designed to optimize physical and psychosocial function and improve each patient's understanding of lung disease and his/her ability to manage it. Secondary goals included provision of detailed information to the patient about the complex NETT protocol to ensure the following: (1) truly informed consent about the randomized study and potential benefits and risks of LVRS; (2) bonding with the NETT center to optimize continued participation in this difficult, long-term trial; and (3) adherence to recommendations for optimal medical management. The basic principle of the rehabilitation program in NETT was a daily self-care program with specified center-based supervised sessions to ensure that all patients received standardized educational and psychosocial treatment and appropriate oversight of their exercise training regimen. All patients were expected to continue their rehabilitation care plans daily at home throughout the study. The program was divided into three phases: prerandomization, postrandomization, and long-term maintenance.

The prerandomization phase included a total of 16 to 20 supervised sessions completed over a 6- to 10-week period. The

comprehensive program included components of exercise training (lower extremity, upper extremity, flexibility, and strength), education, psychosocial assessment and treatment, and nutritional assessment and treatment. An initial rehabilitation evaluation was performed during screening for the trial to determine each patient's level of physical, emotional, and social function. On the basis of this evaluation, specific individual rehabilitation goals were identified in each area (e.g., physical activities of daily living such as self-care, household chores, and exercise; coping with depression, fear or anxiety; social activities, such as meeting with friends, hobbies, and travel). The first four rehabilitation sessions were provided at an NETT center. The remaining 12 to 16 sessions were provided at either the same NETT center or a satellite facility nearer to the patient's home that was certified by the NETT center that remained responsible for patient management. The certifying NETT center was responsible for ensuring that satellite center staff members were trained in NETT procedures and for overseeing the patient's rehabilitation program through regular communication including weekly progress reports and exercise session logs. Each NETT center was responsible for developing a specific program consistent with the NETT protocol and ensuring compliance in its certified satellite centers.

Each session included supervised exercise training and either an education or psychosocial session. All rehabilitation program activities were administered and supervised by multidisciplinary rehabilitation team members directed by a physician medical director experienced in pulmonary rehabilitation. Depending on the individual rehabilitation treatment goals, the 16- to 20-session rehabilitation program included approximately 12 to 16 education and 4 to 8 psychosocial counseling sessions. The exercise training program incorporated lower extremity endurance exercise either by walking or on a bicycle (five times per week), supported or unsupported upper extremity exercise (three times per week), flexibility exercises (five times per week), and strength training with therabands, free weights, or circuit training (three times per week). The education program was tailored to the individual patient and covered both disease-specific and study-related topics such as overview of COPD, medications, oxygen therapy, breathing training, secretion clearance, stress management, nutrition, travel, sexuality, energy conservation, advanced directives, and understanding LVRS and NETT. Psychosocial assessment was performed by rehabilitation staff during the initial evaluation and was supplemented by the Beck Depression Inventory (16, 17), the Self-Evaluation Questionnaire of state and trait anxiety (18), and the Trail Making Test to assess divided attention and psychomotor functioning (19). Psychosocial counseling was provided by an appropriate mental health professional. Patients with serious psychological problems were referred to a psychologist or psychiatrist.

The postrandomization phase included an additional 8 to 9 weeks of supervised rehabilitation. Surgical group patients resumed rehabilitation activities in the hospital as soon as practical after surgery. Patients were encouraged to get out of bed and begin walking again in the early postoperative period. Rehabilitation staff were available to assist with reassessing exercise and oxygen prescriptions and reinforcing strategies taught during the preoperative rehabilitation program (e.g., breathing control techniques, such as pursed lip breathing, coughing and secretion management, stress reduction, and relaxation techniques). At the time of hospital discharge, surgical patients received a minimum of two rehabilitation sessions at the NETT center, followed by supervised sessions at least once weekly over 8 weeks at either the NETT or satellite center. Similar to the prerandomization phase, supervised sessions included exercise, reinforcement education, and psychosocial and nutrition components. For nonsurgical

TABLE 1. RESPONSE TO REHABILITATION IN NETT*

Characteristic	All Patients (n = 1,218)	Changes (Post/Pre)			
		Prior Rehabilitation		Rehabilitation at	
		Yes (n = 777)	No (n = 441)	Satellite (n = 786)	NETT Center (n = 432)
FEV ₁ after BD, % predicted	-0.13 ± 3.67	-0.13 ± 3.57	-0.12 ± 3.85	-0.18 ± 3.64	-0.02 ± 3.73
FEV ₁ after BD, L	-0.01 ± 0.11	-0.01 ± 0.11	0.00 ± 0.11	-0.01 ± 0.12	0.00 ± 0.10
RV/TLC after BD, %	-0.6 ± 5.1 [†]	-0.5 ± 5.1	-0.7 ± 5.1	-0.5 ± 5.1	-0.8 ± 4.9
IC after BD use, L	-0.00 ± 0.36	-0.02 ± 0.34	0.03 ± 0.39	-0.02 ± 0.36	0.03 ± 0.35
Maximum work rate, W	3.1 ± 11.1 [†]	2.4 ± 10.4	4.3 ± 12.0 [‡]	2.7 ± 11.1	3.9 ± 11.0
Borg muscle fatigue [§]	-0.9 ± 2.3 [†]	-0.8 ± 2.3	-1.0 ± 2.3	-0.8 ± 2.3	-1.0 ± 2.4
Borg breathlessness	-0.8 ± 2.2 [†]	-0.7 ± 2.1	-1.0 ± 2.4	-0.8 ± 2.3	-0.8 ± 2.2
Six-minute-walk distance, ft	75.5 ± 176.3 [†]	60.7 ± 184.6	101.7 ± 157.3 [‡]	70.7 ± 180.4	84.2 ± 168.4
Borg muscle fatigue [§]	-0.3 ± 2.1 [†]	-0.2 ± 2.0	-0.5 ± 2.2	-0.3 ± 2.0	-0.5 ± 2.2
Borg breathlessness	-0.5 ± 1.9 [†]	-0.4 ± 1.9	-0.6 ± 2.0	-0.5 ± 1.9	-0.5 ± 2.0
SGRQ					
Total score	-3.5 ± 9.8 [†]	-2.6 ± 9.6	-5.1 ± 10.1 [‡]	-3.6 ± 9.7	-3.2 ± 10.0
Activity score	-2.4 ± 10.7 [†]	-1.3 ± 10.2	-4.4 ± 11.4 [‡]	-2.3 ± 10.6	-2.8 ± 11.0
Impacts score	-4.4 ± 13.3 [†]	-3.5 ± 13.2	-6.1 ± 13.5 [‡]	-4.7 ± 13.2	-3.8 ± 13.6
Symptoms score	-2.4 ± 16.1 [†]	-2.0 ± 16.1	-3.0 ± 16.3	-2.6 ± 16.2	-1.9 ± 16.1
UCSD Shortness-of-Breath Questionnaire [¶]	-3.2 ± 13.4 [†]	-2.3 ± 13.5	-4.8 ± 13.0 [‡]	-3.1 ± 13.5	-3.4 ± 13.1
QWB average daily score ^{**}	0.035 ± 0.117 [†]	0.034 ± 0.113	0.036 ± 0.125	0.032 ± 0.114	0.040 ± 0.122
SF-36					
Physical Health Summary score ^{††}	1.3 ± 7.1 [†]	0.9 ± 7.2	2.2 ± 6.8 [‡]	1.4 ± 6.9	1.3 ± 7.4
Mental Health Summary score	2.0 ± 9.6 [†]	1.8 ± 9.8	2.3 ± 9.2	1.9 ± 9.5	2.2 ± 9.9
Physical functioning score ^{††}	3.6 ± 14.9 [†]	2.6 ± 14.9	5.5 ± 14.8 [‡]	3.4 ± 14.3	4.1 ± 16.0
Role limit (physical health problems) score	7.9 ± 37.9 [†]	6.7 ± 38.2	10.1 ± 37.5	8.7 ± 37.6	6.4 ± 38.5
Role limit (personal/emotional problems) score	6.1 ± 46.0 [†]	6.0 ± 47.2	6.2 ± 44.0	4.6 ± 45.0	8.8 ± 47.7
Energy/fatigue score	4.9 ± 17.4 [†]	4.3 ± 17.3	6.0 ± 17.5	5.1 ± 17.1	4.6 ± 18.0
Emotional well-being score	3.2 ± 14.3 [†]	2.3 ± 14.1	4.7 ± 14.7 [‡]	3.0 ± 14.1	3.6 ± 14.8
Social functioning score	4.9 ± 25.3 [†]	4.2 ± 25.0	6.0 ± 26.0	5.9 ± 25.2	3.1 ± 25.4
Bodily pain score	1.2 ± 22.9	0.3 ± 22.9	2.7 ± 22.9	0.4 ± 22.3	2.6 ± 24.0
General health perceptions	2.9 ± 16.6 [†]	1.8 ± 16.4	4.7 ± 17.0 [‡]	2.6 ± 16.1	3.4 ± 17.6

Definition of abbreviations: BD = bronchodilator, DL_{CO} = diffusing capacity of carbon monoxide; IC = inspiratory capacity; QWB = Quality of Well-Being scale; SF-36 = Short Form-36; SGRQ = St. George's Respiratory Questionnaire; RV = residual volume.

Results are expressed as mean ± SD.

* Changes from pre- to postrehabilitation for all patients and by prior rehabilitation experience.

[†] $P < 0.001$ from the paired t test or signed rank test when nonnormal.

[‡] $P < 0.01$ from the two-sample t test comparing patients with prior rehabilitation and those without prior rehabilitation. No differences were observed comparing rehabilitation at NETT centers only versus NETT plus satellite centers.

[§] The Borg scale is a 10-point categorical perceived symptom scale where the patient rates symptoms of breathlessness and muscle fatigue at the end of the exercise tests; higher scores indicate worse symptoms.

^{||} The SGRQ is a 51-item respiratory disease-specific, health-related quality-of-life questionnaire completed by the patient; the total score ranges from 0 to 100 with lower scores indicating better health-related quality of life.

[¶] The UCSD Shortness-of-Breath Questionnaire is a 24-item questionnaire about dyspnea with activities of daily living that is completed by the patient; the total score ranges from 0 to 120, with lower scores indicating less shortness of breath.

^{**} The QWB is a 77-item questionnaire completed by the patient with regard to general quality of life. The average daily total score ranges from 0 to 1, where higher scores indicate better quality of life.

^{††} Medical Outcomes Study SF-36 is a 36-item questionnaire completed by the patient with regard to general quality of life; scores on the eight subscales range from 0 to 100 where higher scores indicate better quality of life; scores on the physical and mental health summary scores are standardized to the normal U.S. population with a mean of 50 and SD of 10 where higher scores indicate better quality of life.

group patients, the postrandomization phase began immediately after randomization. A minimum of two psychosocial sessions was required to assist the patient in overcoming any disappointment concerning the assigned treatment arm.

The long-term maintenance phase continued for the duration of follow-up in NETT. Each NETT center maintained contact through scheduled in-person visits supplemented with regular telephone contacts to assess adherence to the rehabilitation treatment plan. When necessary, additional supervised rehabilitation sessions could be prescribed.

NETT RESULTS: EFFECT OF PRERANDOMIZATION PULMONARY REHABILITATION ON EXERCISE, DYSPNEA, AND QUALITY OF LIFE

Results of the prerandomization pulmonary rehabilitation program in NETT have been published previously (14). Of the 3,777

patients who were evaluated, 1,796 met preliminary eligibility criteria and began the prerandomization pulmonary rehabilitation program. Over the next 10 weeks, 578 of these patients did not proceed to randomization for a variety of reasons including the following: not completing the rehabilitation program or post-program assessment, doing well in rehabilitation and becoming unwilling to risk surgery, decline in function during rehabilitation and being declared ineligible either by choice or by study investigators, making an informed choice not to continue after further discussions during rehabilitation, illness or other complication rendering patients ineligible for surgery, or exclusion by the pulmonologist or surgeon. Additional data were not collected on these patients who were not randomized.

Characteristics of the 1,218 patients who entered the randomized portion of the trial after pulmonary rehabilitation have been summarized in previous publications (14, 20) and elsewhere in this review. As expected, these patients had severe

airflow obstruction (mean FEV₁, 26.9% predicted) and marked impairment in exercise capacity (maximum cycle work rate, 5.9 W; six-minute-walk distance, 1,142 ft), symptoms of dyspnea, and reduction in health-related quality of life. On the oxygen titration test, 58% required supplemental oxygen to maintain saturation levels above 90% by cutaneous oximetry. In general, patients enrolled in NETT had more severe obstructive lung disease than that typically found in most pulmonary rehabilitation programs (1, 2). This is likely due to the fact that these patients were dissatisfied with their symptoms and health status on optimal medical therapy and interested and willing to undertake the risk of surgery to gain improvement. Of note, 777 (64%) had prior pulmonary rehabilitation and 786 (65%) used one of the satellite rehabilitation centers.

Changes from before to after the prerandomization phase of the NETT pulmonary rehabilitation program are presented in Table 1 for (1) all patients (n = 1,218), (2) patients with (n = 777) and without (n = 441) prior pulmonary rehabilitation, and (3) patients who completed pulmonary rehabilitation using a satellite (n = 786) or solely an NETT (n = 432) center. Overall, there were highly statistically significant changes in all measures of exercise capacity, dyspnea, and quality of life, except for the Short Form (SF)-36 pain score. With the exception of slightly less hyperinflation (decrease in RV/TLC ratio of 0.6%), there were no significant changes in lung function. This was expected because previous studies of pulmonary rehabilitation have found that benefits are not associated with improvement in measures of pulmonary function (2, 3). Improvements were significantly greater in patients without prior rehabilitation experience than for those with prior rehabilitation for measures of maximum work rate; six-minute-walk distance; St. George's total, activity, and impacts scores; the University of California, San Diego (UCSD), Shortness of Breath score; and SF-36 scores of physical health summary, and components of physical functioning, emotional well-being, and general health perceptions. There were no significant differences in changes for patients who completed the prerandomization rehabilitation program at satellite versus NETT centers.

Box plots for changes in maximum cycle work rate, St. George's total score, and UCSD Shortness-of-Breath Questionnaire score from before to after the prerandomization phase are shown in

Figure 1 for all patients, as well as those with and without prior pulmonary rehabilitation experience. These demonstrate greater improvements in patients without prior rehabilitation. Approximately half of the NETT patients demonstrated clinically important improvements for each of these measures based on investigator estimates of minimal clinically important differences: 5 W for cycle work rate, 4 units for St. George's total score (21), and 5 units for UCSD Shortness-of-Breath Questionnaire score (22).

Changes in the eight subscales of the SF-36 health profile are presented in Figure 2. After pulmonary rehabilitation, seven of the eight subscales showed significant improvement. Only the bodily pain score, which was near normal at baseline, failed to improve.

IMPLICATIONS OF NETT RESULTS FOR PULMONARY REHABILITATION

Overall, the results from pulmonary rehabilitation in NETT confirm and extend those previously published from single, specialized pulmonary rehabilitation centers as well as other multicenter outcome studies (23–25), and provide strong evidence that the benefits from pulmonary rehabilitation as currently practiced are generalizable to community-based centers. In the analyses of all NETT patients, the magnitude of improvement in most variables was less than typically observed in single-center studies and less than accepted thresholds for clinically important differences. However, patients in NETT were recruited regardless of prior pulmonary rehabilitation experience, although all were required to complete the NETT pulmonary rehabilitation program before randomization. Because benefits from prior rehabilitation experience before NETT may have blunted the response to subsequent pulmonary rehabilitation treatment in NETT, the results in patients without prior rehabilitation (Table 2) may be a truer indication of the expected response in patients naive to pulmonary rehabilitation when evaluated for LVRS. In the rehabilitation-naïve patients, the average changes after rehabilitation did reach levels generally considered to represent clinically important differences for the measures of exercise capacity, dyspnea, and health-related quality of life.

Figure 1. Box plots of changes from pre-pulmonary rehabilitation to postrehabilitation in exercise capacity (maximum work rate), health-related quality of life (St. George's Respiratory Questionnaire total score), and dyspnea (UCSD Shortness-of-Breath Questionnaire) for all 1,218 patients (Total), as well as for subgroups with (Prior) and without prior (No Prior) pulmonary rehabilitation experience. Dashed lines represent estimated minimal clinically important differences: 5-W increase for maximum work rate, 4-unit decrease for St. George's Respiratory Questionnaire total score, and 5-unit decrease for UCSD Shortness-of-Breath Questionnaire. (Reprinted by permission from Reference 14.)

Figure 2. Changes in the subscales of the Short Form-36. EF = energy/fatigue; EW = emotional well-being (higher values indicate better quality of life); GH = general health perceptions; Pain = bodily pain; PF = physical functioning; RE = role limit (personal/emotional problems); RP = role limit (physical health problems); SF = social functioning. Solid circles and line represent prerehabilitation measures; open circles and dashed line represent postrehabilitation measures. (Reprinted by permission from Reference 14.)

EFFECT OF PULMONARY REHABILITATION ON OUTCOME AFTER LVRS

In the primary report of NETT results (20), maximum exercise capacity after pulmonary rehabilitation and radiographic distribution of emphysema proved to be important characteristics in defining four subgroups with differential outcome by treatment group. Cut-points for the high and low maximum exercise capacity groups were defined based on the sex-specific 40th percentile values for maximum cycle ergometry work rate after rehabilitation (25 W for females, 40 W for males) (20). Preran-

domization pulmonary rehabilitation had a significant effect on NETT subgroup assignment by effecting change in maximum exercise capacity (20, 26) (Table 2). Overall, 20% of all non-high-risk patients ($FEV_1 \leq 20\%$ predicted and either homogeneous emphysema on computed tomography scan or $DL_{CO} \leq 20\%$ predicted [26]) changed subgroup after rehabilitation, 13.5% from the low- to high-exercise subgroup and 6.5% from the high- to low-exercise subgroups. The effect of rehabilitation on subgroup assignment was greater for patients without prior rehabilitation: 16.5% changed from the low- to high-exercise subgroup and 6.2% from the high to low subgroup.

Therefore, on the basis of the NETT experience, pulmonary rehabilitation can have an important role in identifying appropriate patients for LVRS and in properly characterizing them according to the NETT subgroups based on postrehabilitation exercise tolerance. In some patients, increases in exercise tolerance after pulmonary rehabilitation may put them in a less favorable outcome subgroup because of reduced additional expected benefits from surgery and induce them to be less willing to accept the surgical risks. On the other hand, patients who are able to complete pulmonary rehabilitation but with reduced exercise tolerance could actually wind up in a more favorable NETT subgroup and, paradoxically, be considered better candidates for LVRS because of worsened prognosis without surgery. At the same time, patients who are unable to complete pulmonary rehabilitation may be considered, by themselves or by the medical/surgical staff, to be poor surgical candidates and not be subjected to the risks of LVRS.

TABLE 2. CLASSIFICATION OF PATIENTS INTO HIGH- AND LOW-EXERCISE NATIONAL EMPHYSEMA TREATMENT TRIAL SUBGROUPS BEFORE AND AFTER PULMONARY REHABILITATION

Postrehabilitation Subgroup	Prerehabilitation Subgroup		<i>P</i> *
	Low Exercise	High Exercise	
All non-high risk [‡] patients (n = 1,078)			
Low exercise	369	70	<0.001
High exercise	145	494	
All non-high-risk [‡] patients with prior rehabilitation (n = 672)			
Low exercise	233	45	0.003
High exercise	78	316	
All non-high-risk [‡] patients with no prior rehabilitation (n = 406)			
Low exercise	136	25	<0.001
High exercise	67	178	

* P value from McNemar's test.

†Low- and high-exercise groups defined by 40th percentile sex-specific value for maximum work rate on the cycle ergometer (25 W for females, 40 W for males).

‡High-risk patients had $FEV_1 \leq 20\%$ predicted and either homogeneous emphysema on computed tomography scan or $DL_{CO} \leq 20\%$ predicted.

CONCLUSIONS

The NETT study provides a remarkable demonstration of the effectiveness of pulmonary rehabilitation in a large cohort of patients with advanced emphysema treated in a cross-section of programs in the United States. Although the trial was not

designed specifically to evaluate pulmonary rehabilitation and there was no comparison group without rehabilitation, significant improvements in exercise capacity, dyspnea, and health-related quality of life were nevertheless observed consistently across many of the 17 NETT and 539 satellite centers. The only variable that consistently demonstrated an effect on rehabilitation outcomes was whether the patient had rehabilitation experience before enrolling in NETT. As expected, those patients without prior rehabilitation experience demonstrated the greatest gains.

As the field of pulmonary rehabilitation has continued to develop, a growing body of evidence supports the inclusion of rehabilitation as an accepted treatment option and standard of care for patients with advanced emphysema as well as a variety of other chronic lung diseases (2). Current treatment guidelines for COPD contain statements about the benefits of pulmonary rehabilitation and recommendations for including such programs in the management of patients with moderate to severe disease (4). The experience in NETT adds to the growing evidence that pulmonary rehabilitation may also be an important adjunct to surgical programs such as LVRS, both in improving outcomes from surgery but also in the selection of appropriate patients. The NETT highlights the important benefits that can be derived from including pulmonary rehabilitation as part of an interdisciplinary, collaborative and integrated approach in surgical programs such as LVRS and lung transplantation.

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