

Smith Seminars
Online Course
AARC-Approved for 2 CRCE

Pulmonary Rehabilitation

Objectives

1. Consequences of respiratory diseases
2. Definition, goals, and benefits of pulmonary rehabilitation
3. Patient selection, assessment, and setting for pulmonary rehabilitation
4. Treatment and optimizing medical care for pulmonary rehabilitation

Pulmonary rehabilitation is an integral part of the clinical management and health maintenance of patients with chronic respiratory disease who remain symptomatic or continue to have decreased function despite standard medical treatment.

Consequences of Respiratory Diseases

Peripheral muscle dysfunction

- Respiratory muscle dysfunction
- Nutritional abnormalities
- Cardiac impairment
- Skeletal disease
- Sensory deficits
- Psychosocial dysfunction

Mechanisms for these morbidities

- Deconditioning
- Malnutrition
- Effects of hypoxemia
- Steroid myopathy or ICU neuropathy
- Hyperinflation
- Diaphragmatic fatigue
- Frequent hospitalizations
- Effects of various medications
- Psychosocial dysfunction results from anxiety, depression, guilt, dependency, and sleep disturbance.

Definition of Pulmonary Rehabilitation

Pulmonary rehabilitation has been defined in the following terms:

A multidimensional continuum of services directed to persons with pulmonary disease and their families, usually by an interdisciplinary team of specialists, with the goal of achieving and maintaining the individual's maximum level of independence and functioning in the community.

Principal Goals of Pulmonary Rehabilitation

Pulmonary rehabilitation aims to reduce symptoms, decrease disability, increase participation in physical and social activities, and improve the overall quality of life for patients with chronic respiratory disease.

These goals are achieved through patient and family education, exercise training, psychosocial and behavioral intervention, and outcome assessment.

The rehabilitation intervention is geared toward the unique problems and needs of each patient and is implemented by a multidisciplinary team of healthcare professionals.

Benefits of Pulmonary Rehabilitation

The benefits of pulmonary rehabilitation are seen even in irreversible pulmonary disorders, since much of the disability and handicap results not from the respiratory disorder, but from secondary morbidities that often are treatable if recognized. Although the degree of airway obstruction or hyperinflation of chronic obstructive pulmonary disease (COPD) does not change appreciably with pulmonary rehabilitation, reversal of muscle deconditioning and better pacing enables patients to walk farther with less dyspnea.

Rehabilitation programs include prevention; early recognition and treatment of morbidities; and inpatient, outpatient, and extended care of patients with chronic respiratory illness. The anticipated patient outcomes of a comprehensive rehabilitation program include increased independence, fewer hospitalizations or shortened length of stays, and improved quality of life.

Disease, Impairment, Disability, and Handicap

According to the international classification of impairments, disabilities, and handicaps developed by the World Health Organization, a patient's specific outcomes are described as follows:

Disease is a pathologic condition of the body with a unique set of symptoms and signs, often resulting in impairment. The impairment may lead to functional deficit.

Impairment is any loss or abnormality of psychological, physical, or anatomic structure or function.

Disability is any restriction or lack of ability (resulting from an impairment) to perform an activity in the manner or within the range considered normal for a human being.

Impairment of activities of daily living (ADL) has an impact on the capacity of the individual to live independently.

A handicap is a disadvantage for a given individual, resulting from an impairment or a disability that limits or prevents the fulfillment of a role that is normal for that individual.

For patients with pulmonary impairment, disability can be due to muscle dysfunction, primary skeletal or cardiopulmonary pathology, poor endurance, or some combination of impairments. The patient can be handicapped further by inadequate finances, inadequate family support or education, and various public policies.

Benefits

A successful rehabilitation program identifies and differentiates the disease process (e.g., impairments, disabilities, handicaps), so that remedial strategies can be determined. The functional consequences of these impairments are addressed so that the person with

chronic respiratory impairment is returned to the fullest possible physical, mental, social, and economic independence. The effectiveness of a comprehensive pulmonary rehabilitation program has been established by controlled clinical trials.

Several impairments such as weakness, dysfunction of peripheral and respiratory muscles, anxiety and depression, and abnormalities of nutrition have responded to treatment. Improvements in overall and exertional dyspnea, as well as health-related quality of living, have been documented. Significant increases in maximal exercise capacity, as measured during exercise testing, have been observed.

In the only randomized study that has been conducted, survival benefit was not demonstrated, possibly because of the inability to detect the difference. Controlled trials have shown a decrease in health care resource use after rehabilitation, indicated by reduction in the number of hospitalizations and emergency department or physician office visits.

Patient Selection and Assessment

Pulmonary rehabilitation is indicated for patients with chronic respiratory impairment who, despite optimal medical management, have dyspnea, have reduced exercise tolerance, or experience a restriction in activities. Indication for pulmonary rehabilitation is not based on the severity of physiologic impairment of the lungs, but on the persistence of symptoms, disability, and handicap.

Although COPD remains the major disease involved in referral for rehabilitation services, patients with other conditions may be appropriate candidates for pulmonary rehabilitation because the same principles of ameliorating secondary morbidity apply. Examples include asthma, chest wall disease, cystic fibrosis, bronchiectasis, interstitial lung disease, lung cancer, selected neuromuscular diseases, postpolio syndrome, and perioperative conditions (thoracic or abdominal surgery, lung transplantation, lung volume reduction surgery).

Exclusion criteria include conditions interfering with rehabilitative processes or involving risk of exercise training (eg, cognitive dysfunction, severe pulmonary hypertension, unstable angina, recent myocardial infarction).

Assessment

Comprehensive assessment of the candidate for pulmonary rehabilitation is necessary for developing an appropriate individualized plan of care. The clinical history, physical examination, and review of pertinent investigations (e.g., pulmonary function tests) are necessary to determine the severity of respiratory impairment. The determination of baseline exercise capacity is essential in formulating the exercise training prescription and evaluating for hypoxemia during exercise. The assessment of exercise capacity may be performed using either incremental exercise testing or a timed 6-minute walk test. Other assessments that may be performed include measurements of respiratory muscle strength (e.g., maximum inspiratory and expiratory pressures), measurement of peripheral muscle strength, assessment of performance of activities of daily living (ADL), health status, cognitive function, emotional and mood state, and nutritional status, as well as body composition.

Questionnaires may be used to screen for anxiety and depression. Nutritional assessment is important, since changes in body weight, body composition, or eating habits are common in patients with advanced respiratory diseases. Body composition can be

evaluated using anthropometry, bioelectrical impedance analysis, or dual-energy x-ray absorptiometry (DEXA), which estimates lean body mass.

Setting for Pulmonary Rehabilitation

Despite a substantial variability in program structure, efficacy of pulmonary rehabilitation performed in inpatient, outpatient, or home settings has been documented. The structure and components of the program, rather than the setting itself, determine the effectiveness of pulmonary rehabilitation.

The choice of setting often depends on the physical, functional, and psychosocial status of the patient; the variability and distance to the program; insurance payer coverage; and patient preference. Inpatient rehabilitation generally is recommended for patients affected to the greatest degree because of intensive rehabilitative services and specialized training for the patient and/or family. Outpatient rehabilitation, which can be hospital-based or community-based, requires a certain level of functional ability and has the potential to benefit most patients. Although outcomes have not been studied well, home-based pulmonary rehabilitation is convenient for the patient and family members and may provide sustained motivation for continued exercise training.

Rehabilitation Team

Because rehabilitation is a holistic and comprehensive approach to medical care, the combined expertise of an interdisciplinary team is necessary. The rehabilitation team is led by a physician specialist skilled in evaluating the neuromuscular, musculoskeletal, cognitive, and cardiopulmonary systems. The physician should be trained in cardiopulmonary and exercise fitness, ventilator management, and treatment of functional deficits. The physician should be skilled in working with a team of professionals, as he or she is responsible for the medical treatment and rehabilitation program.

The other members of the rehabilitation team include a physical therapist, occupational therapist, rehabilitation nurse, social worker, respiratory therapist, vocational counselor, and psychologist. A successful team maintains coordination, cooperation, and open communication. Each member also needs to have knowledge of the general principles of other members' approaches.

Optimizing Medical Care

The goal of treatment is to improve function in daily living and quality of living by preventing symptoms and recurrence of exacerbations by preserving optimal lung function. Once the diagnosis of COPD has been established, educate the patient about the disease. Encourage the patient to participate actively in therapy.

Smoking cessation continues to be the most important therapeutic intervention. Many patients with COPD have a history of smoking, and many currently smoke. A smoking cessation plan is an essential part of a comprehensive management plan. The success rates are low because of the addictive potential of nicotine, the conditioned response to smoking-associated stimuli, and psychological problems, including depression, poor education, and forceful promotional campaigns by the tobacco industry. Any smoking cessation program must involve multiple interventions.

Oral and inhaled medications are used for patients with stable disease to reduce dyspnea and improve exercise tolerance. Most of the medications employed are directed at 4

potentially reversible causes of airflow limitation in a disease state with largely fixed obstruction. The following factors may be present:

1. Bronchial smooth muscle contraction
2. Bronchial mucosal congestion and edema
3. Airway inflammation
4. Increased airway secretion

Smoking Cessation and Physical Intervention

The transition from smoking to not smoking occurs in the following 5 stages:

1. Precontemplation
2. Contemplation
3. Preparation
4. Action
5. Maintenance

Smoking intervention programs include self-help, group, physician-delivered, workplace, and community programs. Setting a quit date may be helpful. Physicians and other healthcare providers should participate in setting the target date and follow up with respect to maintenance.

Successful cessation programs usually employ tools such as patient education, establishment of a quit date, follow-up support, relapse prevention, advice for healthy lifestyle changes, social support systems, and adjuncts to treatment (e.g., pharmacological agents).

Smoking Cessation and Pharmacologic Intervention

Nicotine replacement therapy

Supervised use of pharmacologic agents is an important adjunct to self-help and group smoking cessation programs.

Nicotine is the ingredient in cigarettes primarily responsible for the addiction.

Withdrawal from nicotine may cause unpleasant side effects, including anxiety, irritability, difficulty concentrating, anger, fatigue, drowsiness, depression, and sleep disruption. These effects usually occur during the first several weeks of any attempt at smoking cessation.

Nicotine replacement therapies after smoking cessation reduce withdrawal symptoms. A smoker who requires his or her first cigarette within 30 minutes of waking up is most likely to be highly addicted and could benefit from nicotine replacement therapy.

Several nicotine replacement therapies are available. Nicotine polacrilex is a chewing gum with better quit rates than counseling alone. Transdermal nicotine patches are available readily for replacement therapy. Long-term success rates range from 22-42%, compared to 2-25% with a placebo. These agents are well tolerated, and the side effects are limited to localized skin reaction.

Nicotine replacement therapy patches are sold under the trade names Nicoderm, Nicotrol, and Habitrol. The usual drug-dosing schedule is the same for all 3 brands. Individuals who smoke more than 1 pack per day initially need a 21-mg patch, followed by 14-mg and 7-mg patches.

Nicotine replacement therapy chewing pieces are marketed in 2 strengths (2 mg, 4 mg). An individual who smokes 1 pack per day should use 4mg pieces. The 2mg pieces are to

be used by individuals who smoke less than 1 pack per day. Instruct patients to chew hourly, as well as at the time of their initial cravings for 2 weeks. Gradually reduce the amount chewed over the next 3 months.

The use of an antidepressant medication also is effective for smoking cessation. The antidepressant, bupropion, is a non-nicotine aid to smoking cessation that enhances central nervous nonadrenergic function. A recent study demonstrated 23% sustained cessation at 1 year, compared to a 12% sustained cessation with the placebo. Bupropion also is effective in patients who have not succeeded with nicotine replacement therapy.

Anti-inflammatory Agents (Inhaled Steroids)

The minority of patients who respond to oral corticosteroids could be maintained on long-term inhaled steroids. Despite a lack of conclusive evidence to support the role of inhaled corticosteroids in management of COPD, the use of these agents is widespread. Researchers have completed 3 large placebo-controlled trials investigating the use of these agents in severe, mild, and very mild disease. Based on the rate of decline in the forced expiratory volume in 1 second (FEV₁), results from these 3 trials suggest that inhaled corticosteroids did not slow the decline in lung function but did decrease the frequency of exacerbations and improve disease-specific and health-related quality of living.

Inhaled corticosteroids have fewer side effects than oral agents. Although effective, these agents improve expiratory flows less than oral preparations, even at high doses. These agents may be beneficial in slowing the rate of progression in a subset of COPD patients who demonstrate rapid decline in pulmonary function.

Bronchodilators

Inhaled beta₂-agonist bronchodilators activate specific B₂-adrenergic receptors on the surface of smooth muscle cells, which increases intracellular cyclic adenosine monophosphate (AMP) and smooth muscle relaxation. Patients, even those who have no measurable increase in expiratory flow, benefit from treatment using beta₂-agonists. Methylxanthines have decreased in popularity over the last decade because of the narrow therapeutic range and frequent toxicity. The mechanism of actions may involve increased intracellular calcium transport, adenosine antagonism, and inhibition of prostaglandin E₂. Additionally, methylxanthines may improve diaphragm muscle contractility.

Beta₂-agonists

In patients with COPD, beta₂-agonists produce less bronchodilation compared with use in patients with asthma. Furthermore, spirometric changes may be insignificant, despite symptomatic benefit. Patients primarily use beta₂-agonists for relief of symptoms of COPD. Inhaled beta₂-agonists are the initial treatment of choice for acute exacerbations of COPD.

In stable patients, beta₂-agonists have an additive effect when used with an anticholinergic agent (e.g., ipratropium bromide). Although oral preparations of beta₂-agonists are available, the preferred route of administration is inhalation. Use a spacer, if indicated, to improve aerosol delivery and reduce side effects.

Long-acting Bronchodilators

Two long-acting beta2-agonists (formoterol and salmeterol) are available. They improve symptoms and morning peak flows and may be useful where bronchodilators are used frequently. More studies should establish the best role for these agents.

Anticholinergic Agents

Treatment with aerosolized anticholinergic agents (ipratropium bromide) may be more effective than a beta2-agonist in patients with COPD. Ipratropium bromide has bronchodilatory activity with minimum side effects and is administered by a metered dose inhaler. Studies in patients with stable COPD have shown that ipratropium bromide has equivalent or superior activity when compared with a beta2-agonist. In combination with a beta2-agonist, there is an additional 20-40% bronchodilation. This medication has slower onset and a longer duration than a beta2-agonist and is less suitable for use as needed. Inhaled anticholinergic bronchodilators do not influence the long-term decline of FEV1. Initiate regular therapy with an ipratropium at 2-4 puffs 4 times a day and add a beta2-agonist as needed.

Anticholinergic drugs compete with acetylcholine for postganglionic muscarinic receptors, thereby inhibiting cholinergically mediated bronchomotor tone, resulting in bronchodilatation. They block vagally mediated reflex arcs that cause bronchoconstriction. The onset of action is slower (30-60 min).

Theophylline improves respiratory muscle function, stimulates the respiratory center, and promotes bronchodilation, in addition to demonstrating anti-inflammatory effects.

Adding theophylline to the combination of bronchodilators can result in further benefit in patients with stable COPD. The response to theophylline therapy also may vary among patients with severe COPD. Patients metabolize theophylline primarily by the hepatic enzyme system, a process affected by age and heart and liver abnormalities. Monitor serum levels of theophylline during therapy because of the drug's potential for toxicity. Side effects include anxiety, tremors, insomnia, nausea, cardiac arrhythmia, and seizures.

Oral Steroids

The use of corticosteroids requires a careful evaluation for individual patients on adequate bronchodilator therapy who fail to improve sufficiently or who develop an exacerbation. Most studies suggest that 20-30% of patients with COPD improve if given chronic oral steroid therapy. Carefully document the effectiveness of such therapy (>20% improvement in FEV1) before giving a patient prolonged daily or alternate day treatment.

Researchers found a positive correlation between bronchial eosinophilia and bronchodilator response in patients who had mild-to-moderate air flow obstruction. Outpatients have used oral steroids with success to treat acute exacerbations; however, after stabilization, gradually wean the patient off oral corticosteroids because of their potential side effects.

In a recent meta-analysis of 16 controlled trials in patients with stable COPD, researchers found that approximately 10% respond to these drugs. Carefully identify recipients. An increase in FEV1 by more than 20% has been used as surrogate marker for steroid

response. In acute exacerbation of COPD, use steroids routinely to improve symptoms and lung function.

Antibiotics

In patients with COPD, chronic infection or colonization of the lower airways is common from *Streptococcus pneumoniae*, *Haemophilus influenzae*, and *Moraxella catarrhalis*. Empiric antimicrobial therapy must be comprehensive and should cover all likely pathogens in the context of the clinical setting. The goal of antibiotic therapy in COPD is not to eliminate the organisms, but to treat acute exacerbations.

Exacerbations are indicated by increased sputum purulence and volume and the development of dyspnea along with other features, including fever, leukocytosis, or infiltrate on a chest radiograph.

The first-line treatment choices include amoxicillin, cefaclor, or trimethoprim/sulfamethoxazole. Second-line antibiotic regimens are the more expensive antibiotics, including azithromycin, clarithromycin, and fluoroquinolones.

The use of antibiotics in patients with COPD is supported by the results of a meta-analysis showing that patients who receive oral antibiotic therapy have a small, but clinically significant, improvement in peak expiratory flow rate and a rapid resolution of symptoms.

Patients who benefit most are those whose exacerbations are characterized by increases in at least 2 of the Winnipeg criteria (dyspnea, sputum production, sputum purulence).

Mucolytic Agents

Mucolytic agents reduce sputum viscosity and improve secretion clearance. Viscous lung secretions in patients with COPD consist of mucous-derived glycoproteins and leukocyte-derived DNA. The oral agent N-acetylcysteine has antioxidant and mucokinetic properties and is used to treat patients with COPD.

Oxygen Therapy

COPD commonly is associated with progressive hypoxemia. Oxygen reduces mortality rates in patients with advanced COPD because of the favorable effects on pulmonary hemodynamics.

Two landmark trials (The British Medical Research Council [MRC study] and National Heart, Lung, Blood Institutes Nocturnal Oxygen Therapy Trial [NOTT]) showed that long-term oxygen therapy improves survival 2-fold or more in hypoxemic patients with COPD. Hypoxemia is defined as PaO₂ of less than 55 mm Hg or oxygen saturation of less than 90%. Oxygen was used from 15-19 hours per day.

Specialists recommend long-term oxygen therapy, therefore, for patients with a PaO₂ of less than 55 mm Hg and a PaO₂ of less than 59 mm Hg with evidence of polycythemia or cor pulmonale. Reevaluate these patients 1-3 months after initiating therapy, since some patients may not require long-term oxygen.

The condition of many patients with COPD who are not hypoxemic at rest worsens during exertion. Even though studies designed to determine the long-term benefit of oxygen solely for exercise have not been conducted yet, home supplemental oxygen commonly is prescribed for these patients.

Oxygen supplementation during exercise can prevent increases in pulmonary artery pressure, reduce dyspnea, and improve exercise tolerance.

Oxygen therapy generally is safe. Oxygen toxicity from high-inspired concentrations (more than 60%) is well recognized. Little is known about the long-term effects of low-flow oxygen.

The increased survival and quality of living benefits of long-term oxygen therapy outweigh the possible risks. PaCO₂ retention from depression of hypoxic drive has been overemphasized. PaCO₂ retention is more likely a consequence of ventilation/perfusion mismatching, rather than respiratory center depression. While this complication is not common, it is best avoided by titration of oxygen delivery to maintain PaO₂ at 60-65 mm Hg.

The major physical hazards of oxygen therapy are fires or explosions. Patients, family members, and other caregivers must be warned not to smoke. Overall, major accidents are rare and can be avoided by good patient and family training.

Oxygen Systems

The continuous flow nasal cannula is the standard means of oxygen delivery for the stable hypoxemic patient. This means of oxygen delivery is simple, reliable, and generally well tolerated. Each liter of oxygen flow adds 3-4% to the fractional inspired oxygen (FIO₂). Nasal oxygen delivery also is beneficial for most mouth-breathing patients.

Oxygen-conserving devices function by delivering all of the oxygen during early inhalation. These devices improve the portability of oxygen therapy and reduce overall costs. Three distinct oxygen-conserving devices exist (reservoir cannulas, demand pulse delivery devices, transtracheal oxygen delivery systems).

Transtracheal oxygen delivery involves the insertion of a catheter percutaneously between the second and third tracheal interspaces. Transtracheal oxygen delivery is invasive and requires special training by the physician, the patient, and the caregiver. The procedure has risks as well as medical benefits, but it also has limited application. Humidification generally is not beneficial when the patient receives oxygen by nasal cannula at flows less than 5 L/min.

Preventative Therapy

Influenza vaccine

Influenza is an acute respiratory illness caused by influenza A or B viruses that occur in outbreaks and in epidemics worldwide almost every year. Influenza viruses that affect humans are classified into 2 antigenic subtypes, hemagglutinin (H) and neuraminidase (N). Three subtypes of hemagglutinin (H1, H2, H3) and 2 subtypes of neuraminidase (N1, N2) are recognized. The influenza vaccines are inactivated preparations of the virus or the split products. Several studies have examined the efficacy of influenza vaccine in different populations. A meta-analysis of 20 cohort studies in elderly persons had a pooled estimate of vaccine efficacy at 56%. These studies have found that in patients with chronic lung disease, administration of influenza vaccine substantially decreases mortality, hospitalization for influenza and pneumonia, exacerbation of chronic lung disease, and physician visits for respiratory complaints.

Present recommendations for administration of influenza vaccines include the following populations: Persons aged 65 years or older, residents of nursing homes and chronic care facilities, adults and children who have chronic disorders of the pulmonary or

cardiovascular systems, and adult and children who required regular medical follow-up or hospitalization during the previous year because of chronic diseases such as diabetes mellitus, renal dysfunction, or immune suppression.

Side effects of influenza vaccine are seen in fewer than 5% of cases and include low-grade fever and mild systemic symptoms. Vaccine is not recommended for people who have allergy to egg products. A rare risk of Guillain-Barré syndrome may exist, approximately one case per million vaccine recipients.

Recent pharmacological agents such as zanamivir, an inhaled compound, and oseltamivir, an orally ingested compound, have been demonstrated to be effective in the prophylaxis and therapy of influenza A and B infections. Both of these medications, if taken within 36 hours of the infection, have shown to decrease duration and severity of influenza symptoms.

Pneumococcal vaccine

Ninety different capsular types of pneumococci are known, making it impossible to manufacture a comprehensive vaccine. Thus, vaccines representing a subgroup of highly prevalent types have been formulated. The currently available pneumococcal vaccines include 23 purified capsular polysaccharide antigens, representing 85-90% of the types that cause invasive disease in the US.

The Centers for Disease Control has demonstrated a 57% overall protective effectiveness of this vaccine against invasive disease; however, many trials have shown no efficacy against pneumonia or other invasive diseases in vaccinated populations. The vaccine presently is recommended for patients at risk of pneumococcal infection. These at-risk patients include the following groups:

- Elderly individuals (aged 65 years or more) who have chronic cardiovascular conditions

- Patients with chronic pulmonary disease or diabetes mellitus

- Persons with alcoholism

- Patients with chronic liver disease or who are living in chronic care facilities

- Immunocompromised patients receiving immunosuppressive therapy or chemotherapy

- Patients who have asplenia or who recently have undergone organ transplantation

Vaccine is administered intramuscularly as one 0.5 mL dose. A second dose may be administered, rarely, 5 years later. Mild local side effects may develop; rare systemic reactions such as fever and myalgias also have been seen.

Surgical Care

Over the past 50-75 years, researchers have described a variety of surgical approaches for improving symptoms and restoring function in patients who suffer from emphysema.

Only giant bullectomy and, possibly, lung volume reduction surgery are useful.

Bullectomy

Removal of giant bullae has been a standard approach in selected patients for many years.

The bullae in patients with emphysema generally range in size from 1-4 cm in diameter; however, on occasion, giant bullae can occupy more than 33% of the hemithorax.

Giant bullae may compress adjacent lung tissue, thereby reducing the blood flow and ventilation to the normal tissue. Removal of these bullae may result in the expansion of compressed lungs and improved function.

Patients who are symptomatic and have an FEV1 of less than 50% predicted have a better outcome after bullectomy, which is performed either through midline sternotomy or a lateral incision with or without video-assisted thoracoscopy. Postoperative leaks are the major potential complications.

Giant bullectomy can produce subjective and objective improvement in selected patients who have bullae that occupy at least 30% and, preferably, 50% of the hemithorax that compresses the adjacent lung, an FEV1 of less than 50% predicted, and otherwise relatively preserved lung function.

Lung-volume reduction surgery

Nearly 40 years ago, Brantigan et al first reported resectioning surgery for diffuse emphysema in 33 patients. They resected the 20-30% of each lung that appeared the most diseased. Brantigan hypothesized that removal of a portion of the emphysematous lung increased the radial traction on the airways in the remaining lung, improving expiratory airflow and mechanical function of the respiratory system, thereby reducing symptoms.

Recently, lung volume reduction surgery (LVRS) has gained considerable momentum, after researchers documented a marked improvement in the FEV1 (+82%), the forced vital capacity (FVC) (+27%), the 6-minute walk distance, and quality of living indices. Currently, large prospective clinical trials are underway in the US and Canada to evaluate the effectiveness of LVRS.

The indications and patient selection criteria for LVRS have not been defined rigorously. Generally, the candidates for LVRS have symptoms secondary to severe emphysema, marked hyperinflation (elevated residual volume/total lung capacity ratio), and CT scan evidence of heterogeneous emphysema. The study excluded patients who are hypercapnic or have pulmonary hypertension or other cardiac risk factors.

Surgical approach uses a midline sternotomy with stapling of the lung margins. Surgeons generally resect 20-30% of each lung from the upper zones. The LVRS procedure has a mortality of 0-18%. Several complications, including pneumonia and prolonged air leaks, have been observed.

Lung transplantation

Lung transplantation continues to gain acceptance for the treatment of end-stage lung disease, particularly emphysema and idiopathic pulmonary fibrosis. Lung transplantation also is used in patients with sarcoidosis, eosinophilic granuloma, extrinsic allergic alveolitis, lymphangioliomyomatosis, pulmonary hypertension, cystic fibrosis, and severe bronchiectasis.

Single lung transplantation is preferred, as bilateral lung transplantation does not alter patient survival significantly. The initial morbidity and mortality is slightly less following a single transplant, but the lungs from one donor can be used to benefit 2 patients. The double lung transplant is used for patients with cystic fibrosis, since a single transplanted lung would be susceptible to spread of infection from the native lung. Patients with severe pulmonary hypertension have received double lung transplantation in

the past to minimize hemodynamic instability. Patients treated with a double lung transplant tolerate bronchiolitis obliterans syndrome better than patients with a single transplant.

For donor selection, a 10-20% difference in size between the donor and the recipient lungs is acceptable. Only blood group typing is performed. The recipient must have no history of a recent malignancy and should be taking less than 20 mg of prednisone per day. Patients aged 65 years or less are candidates for single transplant, and patients aged 55 years or less for bilateral transplant. Patients with multisystem diseases are considered to be poor candidates for lung transplant. Patients with cystic fibrosis and pulmonary infection with pan antibiotic-resistant organisms (especially *Pseudomonas cepacia*) have high rates of reinfection after transplant and increased mortality. All patients being evaluated for lung transplant undergo CT imaging of the chest and all noncalcified nodules need to be evaluated to exclude malignancy.

Survival for patients undergoing single lung transplantation is approximately 70-90% at 1 year and 50% at 3 years. Prognosis for survival is best in patients who require transplant for obstructive pulmonary disease. The proper timing of transplant is difficult to assess; the patients selected to receive a transplant should have a life expectancy of 2 years or less. With lung transplantation, the profound dyspnea and limited lifestyle is substituted with improved quality of living at the risk of worsening survival.

Components of Comprehensive Pulmonary Rehabilitation

Comprehensive pulmonary rehabilitation programs generally have 4 major components: exercise training, education, psychosocial/behavioral intervention, and outcome assessment. These interventions are provided by a multidisciplinary team that often includes physicians, nurses, respiratory therapists, physical therapists, occupational therapists, psychologists, and social workers.

Exercise training is the foundation of pulmonary rehabilitation. Exercise does not alter underlying respiratory impairment but ameliorates dyspnea and improves other outcome measures. Exercise prescription emphasizes endurance training targeted at 60% of maximal workload for about 20-30 minutes, repeated 2-5 times a week. Generally, this training is well tolerated. An interval training regimen consisting of 2-3 minutes of high-intensity training (60-80% maximal exercise capacity) alternating with equal periods of rest might be a substitute for patients who cannot tolerate sustained activity. Dyspnea ratings during maximal graded exercise testing may offer reliable predictions of exercise intensity during training, so symptom-guided exercise training is a possible alternative to heart rate-guided training.

The training specificity refers to the benefit gained only in those activities involving the specific muscle groups that are trained. Since the performance of many ADL involves use of the arms, endurance training of the upper extremities to improve arm functions is important. Supported arm exercises are prescribed with ergometry or unsupported arm exercises by lifting free weights or stretching armbands.

Because peripheral muscle weakness contributes to exercise limitation in patients with lung disease, strength training is a rational component of exercise training during pulmonary rehabilitation. Even low-intensity leg and arm muscle conditioning has led to reduced ventilatory equivalent for oxygen and carbon dioxide.

The reversibility of training effects is well known. The effects of training are maintained only as long as exercise is continued. Therefore, efforts at improving long-term adherence with exercise training at home are necessary for the long-term effectiveness of pulmonary rehabilitation.

Respiratory muscle training using adequate loads improves the strength of the inspiratory muscles in patients with COPD; however, it remains unclear whether this improvement results in decreases in symptoms, disability, or handicap. Although improvement in inspiratory muscle strength is accompanied by decreased breathlessness and increased respiratory muscle endurance, the benefits have not been well established.

Education is an integral part of comprehensive pulmonary rehabilitation programs, encouraging active participation in health care, which leads to a better understanding of the physical and psychological changes that occur with chronic illness. With education, patients can become more skilled at collaborative self-management and have improved compliance.

In small groups or on an individual basis, the following topics generally are covered:

Energy conservation and work simplification

These principles assist patients in maintaining ADL and performing job-related tasks. The methods include paced breathing, optimizing body mechanics, advanced planning, prioritization of activities, and use of assisted devices.

Medications and other therapies

Education about types of medication, action, side effects, dose, and proper use of all oral and inhaled medication is an important part of a comprehensive pulmonary rehabilitation program. Instructions in metered-dose inhaler technique and spacer devices, as well as appropriate use of oxygen, are particularly important.

End-of-life education

Because of the progressive nature of COPD, risk of respiratory failure increases over time. Unfortunately, clinical factors assessable at the onset of respiratory failure caused by COPD are poor predictors of outcome from mechanical ventilation. The decision to initiate life support, therefore, requires patients to determine the acceptability of life-sustaining care by combining their own personal values and life goals with their physician's uncertain estimates of a meaningful recovery. Education during pulmonary rehabilitation provides patients with an understanding of life-sustaining interventions and the importance of advanced planning.

Psychosocial and behavioral intervention

Anxiety, depression, difficulties in coping with chronic lung disease, and the inability to cope with illness contribute to the handicap of advanced respiratory disease. Psychosocial and behavioral interventions in the form of regular patient education sessions or support groups focusing on specific problems are very helpful. Instructions in progressive muscle relaxation, stress reduction, and panic control may help reduce dyspnea and anxiety. Because of the effects of chronic respiratory disease on the family,

participation of family members or friends in pulmonary rehabilitation support groups is encouraged.

Chest physical therapy and breathing techniques

Controlled breathing techniques and chest physical therapy are the 2 major components of the multidisciplinary approach to the rehabilitation of patients with COPD, bronchiectasis, and cystic fibrosis. Although only smoking cessation and long-term oxygen therapy prolong life in patients with COPD, it is likely that chest physical therapy does the same for persons with cystic fibrosis and diffuse bronchiectasis.

The 3 major breathing techniques include the following:

Pursed-lip breathing

Patients exhale slowly for 4-6 seconds through pursed lips held in a whistling position. This technique relieves dyspnea by increasing expiratory airway pressure, thereby inhibiting dynamic expiratory airway collapse. Patients also shift their breathing pattern from a rapid respiratory rate, which is under involuntary respiratory center control, to a slower more controlled pattern governed by voluntary cortical function. The overall work of breathing does not change and, in fact, may increase slightly. The pursed-lip breathing shifts a major portion of inspiratory work of breathing from the diaphragm to the ribcage muscles, resting the diaphragm and reducing dyspnea.

Posture techniques

Leaning forward postures frequently relieve dyspnea in COPD patients by reducing respiratory effort. The shifting of abdominal contents elevates the depressed diaphragm cranially, resulting in improved performance. The most benefit occurs in patients with severe hyperinflation, who have paradoxical inward movement of the upper abdomen.

Diaphragmatic breathing

Some patients may benefit from this technique. The patient is taught to employ only the diaphragm during inspiration and to maximize abdominal protrusion. During expiration, the patient may contract the abdominal wall muscles to displace the diaphragm more cephalad. Not all COPD patients benefit from this technique; therefore, close clinical monitoring to ascertain efficacy is required.

Chest physical therapy along with postural drainage enhances mucous clearance from central and peripheral lung airways. The value of this therapy in stable COPD patients and in acute COPD exacerbation is uncertain. Nonetheless, for patients who have more than 30 mL sputum production every 24 hours or have difficulty with sputum expectoration, chest physical therapy combined with postural drainage and effective coughing techniques enhances sputum expectoration; the actual benefit, however, has not been determined.

Chest physical therapy remains an essential component in the therapy of bronchiectasis and cystic fibrosis. The frequency of treatments must be individualized, based on the severity of disease and the quantity of airway secretions that must be cleared. Standard chest physical therapy with postural drainage, cough, and the forced expiratory technique is the cornerstone of such treatment regimen. Newer modalities, such as mechanical

chest percussion and mask positive airway pressure, warrant further clinical trials before they can be used routinely. Chest physiotherapy is essential for the management of atelectasis in postoperative or seriously ill COPD patients who are hospitalized.

Nutritional Assessment

The onset of weight loss in a patient with chronic respiratory disease is a poor prognostic indicator. Approximately 50% of hospitalized COPD patients are reported to suffer from protein and calorie malnutrition. Progressive weight loss occurs from inadequate dietary intake, diet-induced thermogenesis, increased resting energy expenditure, and failure of normal adaptive response to undernutrition. These mechanisms lead to energy imbalance and weight loss.

Maintenance of adequate nutritional status by timely screening and appropriate management is essential. Provide patient education in weight maintenance techniques and emphasize the importance of preserving muscle mass and tissue stores.

Optimal nutritional status in pulmonary rehabilitation should help maximize the patient's state of health, respiratory muscle function, and overall sense of well-being; it also may improve disease outcome. Obesity, which is defined as a body weight 20% greater than the ideal body weight, may be detrimental to respiratory function. The increased fat mass increases the work of the compromised respiratory system, particularly during weight-bearing activities. Encourage reduction of the body fat mass in this patient population.

Patient Evaluation

A diet history includes an assessment of nutritional, medical, socioeconomic factors, as well as other pertinent details that affect adequate nutrition intake.

The calculation of percentage of ideal body weight by comparing measured body weight to a standard or group norm has been performed traditionally. This assessment does not take account of lean body mass, although serial follow-up measurements are useful.

Other approaches to estimating body composition are useful. Anthropometry can be used for assessment of lean body mass. The bioelectrical impedance analysis is easy to use, noninvasive, and relatively inexpensive.

Biochemical tests have been advocated as a marker of nutritional status and include albumin, prealbumin, transferrin, and retinol-binding protein; however, these indicators generally are not reliable in identifying inadequate nutrition. They should not be used alone in assessing nutritional status.

Nutritional Intervention

The usual intervention for a malnourished patient with chronic respiratory disorder results in weight gain with an adequate provision of calories. A calorie intake of 1.7 times the resting energy expenditure is recommended. Provision of adequate nitrogen to maintain body stores, replete tissue mass, and spare calories is required. Based on trials, it appears that protein supplementation of at least 1.7 g/kg of body weight per day is associated with nitrogen retention and physiologic improvement. Nutrition counseling to address the planning and preparation of a nutritionally adequate meal plan, the adequacy of food supply, the use of nutritional supplements, and other details is essential to the success of any intervention program.

Outcome Assessment

Outcome assessment is an important component of a comprehensive pulmonary rehabilitation for determining individual patient responses and for evaluating the overall effectiveness of the program.

Measurement of outcomes should be incorporated into every comprehensive pulmonary rehabilitation program.

Minimal requirements include assessment of the following measures of the patient's recovery both before and after rehabilitation:

- Dyspnea
- Exercise ability
- Health status
- Activity levels

Consideration also should be given to follow-up measurements at longer periods of time such as 6 and/or 12 months.

Measures of Disability

Exercise testing

Progressive exercise testing on a stationary bicycle or treadmill is performed to a heart rate of 85% of predicted maximum. Dyspnea during exertion can be rated using a visual analogue scale. This test is reproducible and sensitive to improvements from pulmonary rehabilitation. Instead of incremental increase in work rate, endurance capacity can be measured at a constant fraction of maximal work rate. A longer exercise time indicates greater exercise endurance and leads to reduction in ventilatory requirements.

Walking tests

The 6-minute and 12-minute walking tests, as well as shuttle walking tests, correlate positively to peak exercise performance on graded exercise tests. The minimal increase that is clinically meaningful in 6-minute walking distance is about 54 m.

Exertion and overall dyspnea

Dyspnea is the most common symptom of individuals with chronic pulmonary disease and is frequently the major reason for seeking acute care. Dyspnea during exercise usually is measured with a category scale such as the Borg scale or visual analogue scale. The effect of dyspnea on daily activities can be measured with the Medical Research Council dyspnea questionnaire or the dyspnea component of the chronic respiratory disease questionnaire. The relief in dyspnea correlates with a fallen ventilatory demand during exercise, indicating a training effect.

Respiratory specific functional status

Functional capacity is what the patient is capable of doing, whereas functional performance is what the patient actually does on a day-to-day basis. Functional reserve is the difference between the two. Pulmonary rehabilitation improves a patient's functional reserve. Functional status usually is measured by a questionnaire, which estimates the impact of program on various activities.

Measures of Handicap and Quality of Life

A health-related quality of life instrument can assess overall benefit of improvements in symptoms, disability, and handicap. Quality of life has been described as a person's satisfaction or happiness with life in demands that the patient considers important. Quality of life may be considered a balance between what is desired in life and what is achieved (although these indicators are difficult to measure).

In rehabilitation, the following instruments have been used:

- General health questionnaires, such as sickness impact profile and short form
- Disease-specific scales, such as the chronic respiratory disease questionnaire
- The St George respiratory questionnaire

The disease-specific measures demonstrate greater sensitivity to change from baseline after rehabilitation intervention.

Future Directions of Pulmonary Rehabilitation

Despite the progress made in understanding pulmonary rehabilitation, more information is needed to ensure appropriate treatment for the increasing number of patients with chronic respiratory disease. Pulmonary rehabilitation remains an art of medical practice, but one that is built increasingly on a foundation of scientific research. The research embraces traditional outcome measures (mortality and physiologic indices of lung and exercise function), as well as psychosocial measures (symptoms, health-related quality of living, economic analysis of costs and benefits).

The following are several areas where further study or research is needed as the field of pulmonary rehabilitation continues to grow:

Few data have been published on the impact of pulmonary rehabilitation on health care costs and survival; controlled studies in both areas are needed.

Exercise training is an important component of pulmonary rehabilitation. Little is known about the additional benefit of education, breathing strategies, psychosocial support, and group therapy. Knowledge of the effectiveness of these components would be beneficial for other patients who cannot exercise.

More remains to be learned regarding the intensity, duration, and optimum form of exercise training. The benefits of strength training and the best exercises for upper extremity training are unknown.

The benefits of respiratory muscle rest with noninvasive positive pressure mechanical ventilation need to be explored further. Perhaps for selected patients with stable but advanced COPD, noninvasive positive pressure ventilation could be used to help patients exercise more.

Not much scientific information is available on the effectiveness of pulmonary rehabilitation in diseases other than COPD and asthma. As an established, effective, noninvasive, and low-cost preventive health care strategy for patients with chronic lung disease, pulmonary rehabilitation certainly is an ideal subject for logical scientific inquiry.

Resources

- Belman MJ: Exercise in patients with chronic obstructive pulmonary disease. *Thorax* 1993 Sep; 48(9): 936-46.
- Belman MJ: Exercise in chronic obstructive pulmonary disease. *Clin Chest Med* 1986 Dec; DA - 19870206(4): 585-97.
- Celli BR: Pulmonary rehabilitation in patients with COPD. *Am J Respir Crit Care Med* 1995 Sep; 152(3): 861-4.
- Epstein SK, Celli BR: Cardiopulmonary exercise testing in patients with chronic obstructive pulmonary disease. *Cleve Clin J Med* 1993 Mar-Apr; 60(2): 119-28.
- Goldstein RS, Gort EH, Stubbing D: Randomised controlled trial of respiratory rehabilitation. *Lancet* 1994 Nov 19; 344(8934): 1394-7.
- Gray-Donald K, Gibbons L, Shapiro SH: Nutritional status and mortality in chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 1996 Mar; 153(3): 961-6.
- Killian KJ, Jones NL: Respiratory muscles and dyspnea. *Clin Chest Med* 1988 Jun; 9(2): 237-48.
- Lacasse Y, Wong E, Guyatt GH: Meta-analysis of respiratory rehabilitation in chronic obstructive pulmonary disease. *Lancet* 1996 Oct 26; 348(9035): 1115-9.
- Lake FR, Henderson K, Briffa T: Upper-limb and lower-limb exercise training in patients with chronic airflow obstruction. *Chest* 1990 May; 97(5): 1077-82.
- Mahler DA, Faryniarz K, Lentine T: Measurement of breathlessness during exercise in asthmatics. Predictor variables, reliability, and responsiveness. *Am Rev Respir Dis* 1991 Jul; 144(1): 39-44.
- Mueller RE, Petty TL, Filley GF: Ventilation and arterial blood gas changes induced by pursed lips breathing. *J Appl Physiol* 1970 Jun; 28(6): 784-9.
- Rearson J, Awad E, Normandin E: The effect of comprehensive outpatient pulmonary rehabilitation on dyspnea. *Chest* 1994 Apr; 105(4): 1046-52.
- Ries AL, Kaplan RM, Limberg TM: Effects of pulmonary rehabilitation on physiologic and psychosocial outcomes in patients with chronic obstructive pulmonary disease. *Ann Intern Med* 1995 Jun 1; 122(11): 823-32.
- Schols AM, Mostert R, Soeters PB: Body composition and exercise performance in patients with chronic obstructive pulmonary disease. *Thorax* 1991 Oct; 46(10): 695-9.
- Smith K, Cook D, Guyatt GH: Respiratory muscle training in chronic airflow limitation: a meta-analysis. *ALYSIS* 1992 Mar; 145(3): 533-9.
- Strijbos JH, Postma DS, van Altena R: A comparison between an outpatient hospital-based pulmonary rehabilitation program and a home-care pulmonary rehabilitation program in patients with COPD. A follow-up of 18 months. *Chest* 1996 Feb; 109(2): 366-72.
- Wedzicha JA, Bestall JC, Garrod R: Randomized controlled trial of pulmonary rehabilitation in severe chronic obstructive pulmonary disease patients, stratified with the MRC dyspnoea scale. *Eur Respir J* 1998 Aug; 12(2): 363-9.
- Weiner P, Azgad Y, Ganam R: Inspiratory muscle training combined with general exercise reconditioning in patients with COPD. *Chest* 1992 Nov; 102(5): 1351-6.