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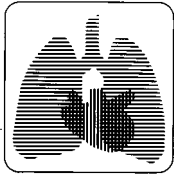
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A M E R I C A N C O L L E G E O F





reviews

Disease Management of COPD With Pulmonary Rehabilitation*

Brian L. Tiep, MD

Pulmonary rehabilitation is a set of tools and disciplines that attends to the multiple needs of the COPD patient. It extends beyond standard care by addressing the disabling features of chronic and progressive lung disease. It centers on self-management, exercise, functional training, psychosocial skills, and contributes to the optimization of medical management. Exercise enables other components by building strength, endurance, confidence, and reducing dyspnea. Patients who have undergone rehabilitation often enjoy a reduced need for health-care utilization. On the downside, rehabilitation is a one-time intervention, the benefits of which dissolve over time. The patient's physician is rarely a participant in the program; thus, the physician is at a disadvantage in being able to support a long-term response. Rehabilitation is available to a small percentage of a large patient population who could benefit. Optimal disease management would entail redesigning standard medical care to integrate rehabilitative elements into a system of patient self-management and regular exercise. It should emphasize physician involvement in self-management, which is essential in developing and maintaining an effective exacerbation protocol. Pulmonary rehabilitation should take its place in the mainstream of disease management through its integrative and reconciliative role in the multidisciplinary continuum of services, as defined by the National Institutes of Health, Pulmonary Rehabilitation Research, Workshop of 1994.

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Key words: COPD; disease management; exercise; psychosocial; pulmonary rehabilitation; self-management

Abbreviations: ADL=activities of daily living; LTOT=long-term oxygen therapy; MDI=metered-dose inhaler; NOD=nocturnal oxygen desaturation; PLB=pursed lips breathing; PRN=as needed; SaO₂=arterial oxygen saturation; SIP=Sickness Impact Profile; VMT=ventilatory muscle training; VO₂=oxygen uptake; VO₂max=maximal oxygen uptake

Pulmonary rehabilitation is a multifaceted systematic approach to treating patients with chronic lung diseases such as COPD. Designed to be comprehensive in its scope, rehabilitation encompasses the multiple systems victimized by the pathophysiology as well as the psychosocial impact created by a predictable avoidance of dyspnea. It enlarges on standard care by addressing the disabling features of the disease. This review will present chronic lung disease as exemplified by COPD, look at how the disease makes its impact on the patient, family, and health-care system, and examine pulmonary rehabilitation as a therapeutic solution. Regarding pulmo-

nary rehabilitation as the integrative sum of multiple components, each component will be presented as referenced to its scientific basis and its contribution to the full program. The benefits of the overall program will be described along with the supporting studies. Finally, recommendations for future directions will be offered.

The historical roots of pulmonary rehabilitation extend beyond 30 years. It started as a program that seemingly did the impossible—it injected life and hope into chronically and progressively ill patients unable to function owing to breathlessness. In its inception, the concept of pulmonary rehabilitation ran counter to the intuition of the day, which was to advise breathless patients to avert ventilatory discomfort by rest and inactivity. Instead, pulmonary rehabilitation taught and nurtured patients into an active lifestyle, where they reassumed control in the face of dyspnea. Clinically it seemed to work. But,

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for years pulmonary rehabilitation was regarded as unproven, while awaiting a definitive study that would elevate it to the status of accepted standard management. Recently, randomized studies have addressed some of the critical issues and have lent credence to its nonsubtle, clinically observed benefits. To fully evaluate pulmonary rehabilitation is scientifically challenging, because both program composition and program presentation vary widely. However, common elements shared by most programs will serve as a basis for comparison.

The National Institutes of Health 1994 Workshop on Pulmonary Rehabilitation Research defined it as a "multidisciplinary 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."¹ The term *multidisciplinary* suggests more numerous and disparate skills than are ordinarily trained in one therapist; the term *continuum* implies a smooth and longitudinal melding of skills and disciplines to enable patients to become functional over the long term. Also described is the ideal availability of an *interdisciplinary team*, whose skills are synthesized into a unity of presentation. In a newer application, pulmonary rehabilitation has become an essential part of standard preparation as well as postoperative management for patients undergoing lung transplantation and lung volume reduction surgery.

Several excellent reviews have discussed the scientific merits and benefits of pulmonary rehabilitation for both the patient and the health-care system.²⁻⁶ It is fascinating to note that most studies cited have demonstrated increased functional ability and decreased need for health-care utilization, apparently uninfluenced by the enormous diversity in program content and presentation. One could speculate that any program might be effective as long as basic elements are included.^{7,8} Consistently, pulmonary rehabilitation would then be regarded as an integrating strategy for the *multidisciplinary continuum of services* in the disease management of COPD. Pulmonary rehabilitation has been implemented with clinical gratification in the treatment of several other chronic conditions, including cystic fibrosis, restrictive lung diseases, and chronic heart failure. However, this review will specifically address COPD, examine its long-term course, and evaluate the role of pulmonary rehabilitation in its management. If rehabilitation is effective, it should become a consistent part of any long-term disease management strategy.

COPD is a montage of chronic bronchitis, emphysema, and associated partially reversible asthmatic components that limit bronchial airflow. As these conditions are grouped together, the clinician, having identified one of these abnormalities, is obligated to address the probability that the others are also present. The proportional inclusion of each of these components may well determine the clinical presentation, the specific impact of the disease, and consequently the best intervention. The longitudinal course of COPD has been described in several ways. Some authors characterize COPD as accelerated lung aging, whereby the patient is losing lung capacity at a faster than normal rate. The natural course of the disease is progressive pathophysiologic deterioration but the rate will vary as determined by modifiers. As the disease evolves, its impact on the patient and family becomes part of the disease itself. Hence, the clinician must consider not only the pathophysiology and multiple exacerbations but psychosocial factors as well. Over the course of disease progression, all systems become, in some manner, affected. Contributing to the recruitment of other systems would be the compromise in oxygen transport due to the lung disease itself, pharmacologic intervention, or physical deconditioning. Accordingly, exercise, in its capacity to promote oxygen transport, takes its logical place in the management strategy of COPD.

Epidemiology of COPD

Estimates of the prevalence of COPD range from 14 million to 20 million persons in the United States and is steadily increasing.⁵ COPD now ranks as the fourth leading cause of death, second only to coronary heart disease in the number of patients receiving Social Security disability payments for chronic disease. It is also a major contributor to job absenteeism. The overall cost of caring for COPD patients has been estimated as high as \$40 billion annually with \$1.6 billion for long-term oxygen alone.⁹ The largest portion of health-care cost is borne in the last year of the patient's life.^{2,5}

Etiology and Clinical Features of COPD

The overwhelming cause of COPD is exposure to tobacco smoke. As cigarette smoking gives rise to an accelerated decline in FEV₁, 15% of smokers will progress to COPD. Most patients who develop COPD have been smoking more than 20 pack-years (packs per day times number of years smoked). Age of starting, total pack-years, and current smoking status are all predictive of COPD mortality. Passive

smoking also increases the symptoms of COPD. The other well-known risk factor is α_1 -antitrypsin deficiency, which accounts for about 1% of patients with COPD. Curiously, patients with COPD have a higher risk of developing several forms of lung cancer—a risk greater than predicted by their common smoking etiology.¹⁰ As COPD is overwhelmingly a disease of smokers, smoking and its associated addiction should be regarded as part of the disease process rather than strictly a risk factor. Accordingly, smoking cessation would assume a high priority and all smoking patients should be screened for disease progression via spirometry.¹¹

Clinical Features of COPD and Implications for Disease Management

Most of the time course of COPD progresses asymptotically, followed by a period of time when the symptoms, although present, can be ignored or misinterpreted as a natural process of aging.¹² At this point, symptoms may be experienced only when the patient engages in a physical challenge, such as stair climbing. Over the course of disease progression, lower levels of exertion are sufficient to inflict similar respiratory discomfort. In the last few years of life, dyspnea becomes unbearable, and life becomes restricted to the home. Often, a mortal fear of breathlessness drives the behavioral response as the patient retreats from an active lifestyle to a sedentary existence. Avoidance of activity gives way to physical deconditioning, which further incapacitates the patient in a vicious downward spiral. Further progression of the disease may subject the patient to chest tightness, wheezing, cough with episodic purulent secretions, claustrophobia, depression, anxiety, and insomnia. Eventually, dyspnea at rest leaves no further room for retreat. Patients seek medical intervention during exacerbations or when their dyspnea becomes undeniable and intolerable. Ultimately, other organ systems decompensate from tissue hypoxia, cor pulmonale, undesirable responses to medications, and other associated maladies and additional factors as yet to be identified. Toward end stage, the patient is beset by exacerbations of accelerating frequency and intensity.

Acute exacerbations of bronchitis require special attention and emphasis. More common in the latter stages of COPD, these episodes may wreak endobronchial havoc. They are characterized by airway inflammation, morphologic damage, infection, purulent mucous blockage, and airway remodeling. Exacerbation episodes call for immediate intervention of increasing intensity. This increase is paralleled by an escalating cost of care. Chronic bronchitic patients are frequently colonized by *Haemophilus influenzae*,

Streptococcus pneumoniae, and *Moraxella catarrhalis*, which together may account for about 70% of all exacerbations.¹³ Inflammatory cells and mediators have been discovered in the airways of these patients, which supports the presence of inflammation. Exacerbations represent a dynamic process of destruction and blockage.

A vicious cycle hypothesis has been advanced that explains many of the observations made in chronic bronchitic patients with multiple exacerbations.¹⁴ The cycle is triggered by either an infection (viral or bacterial) or a destructive agent like an airborne pollutant. This chain of events is entered at bronchial inflammation, which, in turn, damages the mucosal lining, impairing mucosal defenses, thereby setting the stage for bacterial infection. Infection then intensifies the inflammation and further destruction of the mucosal wall, ultimately creating a larger surface area for bacterial growth and wall destruction. Inflammation causes bronchial wall edema, bronchospasm, and mucous plugging. The vicious cycle is a dynamically destructive process as it evolves into chronic inflammation with thickening and fibrosing bronchial walls less able to withstand further infectious insults. Due to weakened bronchial defenses, each exacerbation sets the stage for the next to appear.

Conceptually, COPD can be considered as a disease of layers. The inner layer represents impaired lung mechanics and inadequate gas exchange due to chronic inflammatory changes and airway remodeling.¹⁵ The outer layer represents the more rapid and dramatic changes that inflict acute flare-ups of dyspnea from bronchospasm, cor pulmonale, acute inflammation, infection, fear, and panic—exacerbations. Disease management of the inner layer centers on prevention, long-term maintenance, and suppression of inflammation, whereas management of the outer layer calls for rescue measures and intervening in the dynamic process of exacerbating bronchitis, in order to prevent or reverse acute respiratory failure.

MEDICAL MANAGEMENT OF COPD

Comprehensive medical management starts with prevention, but over time adds bronchodilators, anti-inflammatories, oxygen, adequate nutrition, exercise, control of anxiety and depression, and exacerbation management^{7,8} (Table 1). Primary prevention, preventing the occurrence of the disease, is the first step in any disease management. COPD is basically a self-inflicted disease. The first important intervention is to halt the self-destruction through smoking cessation. Secondary prevention, averting the progression of the disease, also emphasizes smoking

Table 1—Medical Management of COPD

Management
Prevention (primary and secondary prevention)
1. Smoking cessation
2. Avoidance of triggers
3. Immunization
4. Prevent infection transmission
Exacerbation management
1. Prevent exacerbation (tertiary prevention)
2. Outpatient
3. Inpatient
Baseline pharmaceuticals
1. Anti-inflammatories
2. Bronchodilators
3. Diuretics
4. Antielastase replacement: homozygous deficit
Rescue pharmaceuticals
1. Anti-inflammatories
2. Bronchodilators
3. Antibiotics
4. Diuretics
Bronchial hygiene measures
1. Cough
2. Bronchodilators
3. Secretion mobilization
Oxygen
1. Rest
2. Sleep
3. Exercise
Exercise
1. Walking
2. Arm exercises
Control of anxiety and depression
1. Sedatives/tranquilizers (not advised)
2. Antidepressants
Surgery
1. Lung transplants
2. Lung volume reduction surgery (investigational)

cessation, but additionally includes immunization against influenza virus and pneumonia bacteria, as well as the general avoidance of exposure to organisms and bronchial irritants. Symptomatic relief is afforded by carrying out bronchial hygiene, alleviation of airway obstruction, and control of anxiety and depression. Tertiary prevention is directed toward reducing complications that accompany the disease.¹⁶ Accordingly, the prevention of exacerbations assumes a high priority, while those in progress are rapidly detected and dealt with. A regular exercise program promotes oxygen transport and facilitates general mobilization. Oxygen therapy, to prevent tissue hypoxia, is prescribed for patients with oxygen saturations below 90%. Oxygen during exercise protects the patient from exercise hypoxemia and its consequences. Some patients tolerate and live with

chronic hypercapnia. Owing to acid-base compensation via bicarbonate buffering, they are able to function comfortably with lower ventilatory effort. However, these patients must avoid sedative medications, so as not to further aggravate CO₂ retention and respiratory acidemia. The clinician should be aware of the possibility that a patient in respiratory depression may have taken a sedative earlier in the day to calm his or her dyspnea.

Although most COPD patients demonstrate little or no bronchodilator response on spirometry, most of these patients will derive some symptomatic relief from bronchodilators—particularly inhaled ones. The patient may begin with albuterol, or other short-acting β -agonists, on an as needed (PRN) basis, but eventually add ipratropium per a regular schedule. As bronchodilator response becomes less gratifying, corticosteroids are commonly added. The value of steroids for asthmatics is well defined and fundamental, but in COPD, they are much less delineated despite their common usage. Their best application is during an acute exacerbation.⁷

Management of cor pulmonale requires adequate oxygenation and the use of diuretics to prevent or reduce the edema of right heart failure. Digitalis is generally reserved for patients with left heart failure or to suppress rapid supraventricular cardiac rate. Patients with homozygous α_1 -antitrypsin deficiency may benefit from replacement therapy. Some of the younger patient population with minimal complication may be considered for a lung transplant. In a more controversial approach, lung volume reduction surgery has some reported benefits in patients with heterogeneous emphysema.¹⁷ In both of these surgical approaches, pulmonary rehabilitation is advised both in preparing the patient for the operation and aiding in the recovery.

Prevention

Smoking Cessation and Environmental Triggers: The physician has a strong and guiding role in steering the patient onto the path of successful withdrawal. Showing interest and concern, the physician should be very direct in informing patients that smoking is causing them great harm and possibly premature death.^{16,18} Physician counseling must be strong, directive, and ongoing. The five stages of smoking cessation are precontemplation, contemplation, preparation, action, and maintenance. The physician should help the patient to move through each stage in coordination with the strong support and guidance of the pulmonary rehabilitation team. Setting a quit date and attempting “cold turkey” will be more likely to meet with success than gradual withdrawal. Group sessions are offered in most hospitals,

some cosponsored by the American Lung Association. Nicotine replacement via a patch or gum can be adjunctive to a diligent withdrawal effort, particularly by alleviating some of the withdrawal symptoms such as irritability, anxiety, anger, fatigue, depression, and sleep disturbance.

Second-hand smoke is associated with many of the same consequences as active smoking.¹⁸ It promotes progression of the disease, is a respiratory irritant, and it thwarts attempts at smoking cessation. Avoidance of second-hand, as well as personal smoking, is essential to improving and maintaining lung health. Patients and their families must maintain a smoke-free environment at home and insist on a smoke-free environment in public places.

Other environmental irritants are found in the workplace and in the home. Dusts, molds, particulate matter, and allergens are a few examples. Avoidance of exposure to respiratory irritants such as house paint and solvents may save the patient a brush with exacerbation. As the disease progresses, patients become intolerant of many odors that were previously pleasant such as perfumes, the smell of barbeque, or a wood-burning fire.

Vaccines and Amantadine: Patients with chronic lung disease are at increased risk of suffering serious complications from influenza. Prevention of exacerbation, many of which may be triggered by viral infections, assumes a high priority in COPD disease management. Whereas vaccines are not available against most respiratory viruses, yearly seasonal exposure to influenza A and B can be countered by vaccines formulated to immunize against prevalent strains of that season. Moreover, health-care workers, who administer to populations at risk from the flu, should also be vaccinated to prevent transmission to their patients. Amantadine, an oral antiviral agent, is effective in prophylaxis against influenza A. Treatment with it should be started within 48 h of the first flu symptoms and is effective only during the time it is administered. If taken for 2 to 3 weeks, it may suppress the severity and shorten the length of the illness, while the patient mounts an immune defense to continue the fight.

S pneumoniae is a common agent causing bacterial infection in COPD patients. Pneumococcal vaccine has been formulated to immunize patients against pneumococci and is recommended for the same population of patients.¹⁶

Medications

Multiple drugs are prescribed for airway patency. Some have proven benefit, some are controversial, and others are brought on board at a moment of clinical desperation. Often desirable is a long-term

plan for each patient, recognizing likely benchmarks of disease progression. A stepwise and systematic approach has been recommended for the addition and deletion of specific medications. The prevailing view in the etiology of exacerbations is that infection and inflammation play a central role; accordingly, anti-inflammatories and antibiotics have become standard inclusions in exacerbation rescue protocol.^{5,7,8,13} Medication strategy must be viewed over the long term with adequate planning for eventual disease progression. Dosing and scheduling for optimal chronotherapy require rehabilitative support. Since most patients experience some of their most oppressive symptoms at night, medication schedules should be adjusted to optimize nocturnal availability.

Anticholinergics: Ipratropium bromide suppresses vagally mediated airway smooth muscle contraction and reduces mucus secretion. It is at least as effective as β -agonists, but is slower in onset and maintains activity longer. Ipratropium also diminishes sputum production without altering viscosity.¹⁹ It is well tolerated when taken regularly with no demonstrated attenuation.²⁰ Ipratropium is not ideal as a single rescue agent for patients in respiratory distress. Thus, it is commonly recommended as first-line therapy prescribed on a regular schedule—relegating β -agonists as a PRN rescue drug for immediate symptom relief. Often, ipratropium bromide is used as a companion agent to the β -agonist during rescue to affect longer-lasting relief of airways obstruction.

β_2 -Agonists: Short-acting β -agonists such as albuterol and terbutaline are bronchodilators utilized in the intermittent relief of symptomatic bronchospasm and bronchial edema. The increasingly common practice of designating these drugs only for PRN rescue, rather than regularly scheduled dosing, is derived from concerns raised in asthmatics²¹ and recent studies in COPD demonstrating tolerance from regular use.²² The data from these studies are suggestive, but not conclusive in this population. A typical plan is for ipratropium to be used on a regular schedule plus PRN with inhaled β -agonists used PRN only. Oral β -agonists are useful for suppressing nocturnal respiratory symptoms, although long-acting inhaled salmeterol is now available for this purpose.

β -Agonists are specifically helpful when administered prior to an exercise session.²³ In an additional application, spirometry testing before and after β -agonists is used to determine bronchodilator reversibility. In most cases, these tests are only confirmatory since, regardless of the result, bronchodilator agents are usually prescribed on a clinical basis. A potential exists for cardiac side effects and hypokalemia with high doses of β -agonists, particularly from

oral agents as they result in higher blood levels. Because of the higher potential of side effects from oral agents, inhaled administration is generally preferred.

Aerosols via Machine-Driven Nebulizer and Metered-Dose Inhalers: Nebulized medications, particularly bronchodilators, are quite effective in the treatment of both acute and chronic phases of COPD. Machine-driven nebulizers had been the mainstay of aerosol delivery over the past couple of decades, having been shown to be as effective as intermittent positive pressure breathing.²⁴ More recently, a number of studies have demonstrated that the metered-dose inhaler (MDI), when administered optimally, can be equally as effective as the nebulizers.^{25,26} For the patient in stable condition and even in some exacerbations, MDIs with spacers are replacing the machine-driven nebulizer as a rapid and effective delivery of aerosol medications.

Spacers: The self-administration of the MDI requires dexterity, aiming, and timing. Also, the pressurized aerosol shoots a fast-moving jet of droplets that tend to crash and deposit at the back of the throat, instead of along the airways, as intended. The addition of a spacer improves the timing, direction, and speed of aerosol jet, and protects the throat from bearing the high impact and deposition of droplets. Spacers are holding chambers into which the patients discharge their MDI; they then inhale slowly. A slow inhalation, which creates a more laminar airflow, allows the droplets to turn the corner at the throat and redirect into the trachea and bronchial passages. Holding the breath at deep inspiration for about 10 s allows a wider distribution and deposition of droplets into the airways. Since most patients are able to benefit from spacers, most programs include them as standard equipment.

Theophylline: Theophylline is a weak bronchodilator that modestly increases the strength of contraction of respiratory and other muscles. It promotes collateral ventilation, mucociliary clearance, and may have an anti-inflammatory effect.^{27,28} However, these actions do not fully describe the ability of these drugs to relieve dyspnea. Theophylline has been shown to reduce nocturnal declines in FEV₁ and prevent morning dyspnea.²⁹ Once a first-line drug for both asthma and COPD, theophylline's role in the management of both diseases is continually being subjected to reassessment largely because its toxicity range overlaps its therapeutic range. Accordingly, patients using theophylline should have their theophylline blood levels monitored regularly.

Theophylline adds to the symptomatic benefits of β -agonists and ipratropium, but it is rarely utilized as a single agent. However, it should be considered for the patient unable to adhere to a regimen of inhaled

agents. Many factors influence the theophylline blood level in either direction. Both the clinician and patient should be cognizant of toxic signs such as tremors, palpitations, and GI symptoms.

Anti-inflammatory Agents: In asthma, the anti-inflammatory agents, corticosteroids, cromolyn, and nedocromil perform a central role. In COPD, the place for corticosteroids is less defined, and except for the coexistence of allergic components, cromolyn and nedocromil are not a part of standard regimen. Corticosteroids have been commonly utilized in two venues: short-term exacerbation rescue and long-term therapy. Short-term administration for an acute exacerbation of bronchitis has accepted value.^{7,30} Some patients may benefit from low-dose long-term steroids therapy.^{8,31} Unfortunately, the side effect profile list is long and treacherous, and lengthens over time. It includes osteoporosis, myopathy, diabetes, ulcers, and opportunistic infection.^{32,33} Regular use of corticosteroids in end-stage COPD is common, but with the pernicious nature of side effects, often rivaling the disease itself, the clinician is strongly advised to reconsider this practice. In an all-too-common scenario, high-dose IV or oral steroid is ordered for the treatment of an acute exacerbation with the intention of tapering the dose to zero. Unfortunately, during the slow taper, the patient with severe COPD often suffers another exacerbation, which is then treated by increasing the steroid dose. This sawtooth pattern of high dosing and slow tapering leaves the patient receiving some level of steroids continuously, hence the patient is termed, "steroid dependent."

Actually, the short-term use of high-dose steroids for acute exacerbations can bring dramatic relief of symptoms at minimal risk of side effects. However, over time of long-term use, the side-effect profile gathers. Hence, the rescue use should be short term, perhaps 5 to 7 days and then discontinued. Tapering the dose over that period carries little advantage. Rather, a short intense pulse at peak level will give maximal benefit during the exacerbation. For patients receiving long-term steroid therapy who seem to be steroid dependent, it is advisable to taper their daily dose to the lowest level. Over time, inhaled steroids may replace oral steroids or support reduction to a lower minimal dose.^{34,35}

Antibiotics: Exacerbations may either be caused by a bacterial infection, or alternatively, an infection will develop in the course of exacerbation. The early signs of infectious bronchitis or pneumonia may be a worsening dyspnea and increasing sputum purulence. Sputum cultures are typically unhelpful as they may not accurately identify the infecting organism.³⁶ Chest radiograph changes may not appear soon enough to confirm pneumonia.³⁷ Fever is often

not present as chronic bronchitic patients tend to be colonized by the infecting organisms. The decision to utilize antibiotics is clinical in response to early signs, and the choice of antibiotic is partly based on the patient's history. COPD patients are generally colonized by *H influenzae*, *S pneumoniae*, or *M catarrhalis*. Initially, patients may respond to older antibiotics such as amoxicillin, doxycycline, trimethoprim-sulfa, or erythromycin. After several exacerbations, newer agents will be required to achieve the same level of rescue. Because of the involvement of bacterial infection at some stage of exacerbation, antibiotics should generally be included in the exacerbation rescue strategy.

Mucolytic Agents: Mucolytic agents may be adjunctive to facilitate the clearance of thick and tenacious secretions. Whereas coughing is the definitive secretion clearance mechanism, liquefying inspissated mucosal secretions enables movement to the upper airways. Hydration adds moisture at the throat and, for dehydrated patients, increasing fluid intake will probably add local moisture to the airways. Overhydration is of no proven benefit. Mucolytic agents may liquefy secretions by breaking chemical bonds that maintain tenacity and viscosity. Hence, these agents are adjunctive to adequate hydration, bronchodilators, steroids, mobilization techniques, and antibiotics; mucolytics are not stand-alone medicines. Studies on iodinated glycerol have demonstrated improvement in secretion clearance but no significant improvement in lung function.³⁸ More common drugs such as saturated solution of potassium iodide and guaifenesin have been less impressive. Standard cough syrups have proven disappointing. Acetylcysteine is used in some centers, particularly for cystic fibrosis and bronchiectasis, and is believed to have an antioxidant effect.³¹ Patients without significant secretions are not likely to benefit from any of these drugs.

Other Medications: Cor pulmonale is a common complication of COPD. Accordingly, oxygen and diuretics are an integral part of the overall disease management in the advancing stages. As COPD progresses, so do comorbid conditions that may or may not be causally related. Common comorbid conditions include diabetes, atherosclerotic cardiovascular disease, hypertension, arthritis, myopathy, and osteoporosis, the two latter conditions being a consequence of long-term steroid therapy. Thus, the medication list may reflect the addition of diuretics, digoxin, calcium channel blockers, angiotensin-converting enzyme inhibitors, and psychoactive drugs. Additional pharmacologic side effects may include dehydration, electrolyte imbalance, arrhythmia, GI upset, hypotension, and renal failure.

GOALS OF PULMONARY REHABILITATION

Pulmonary rehabilitation is ideally a comprehensive management strategy that addresses all components of the chronic and progressive lung disease. It neither is curative nor will it completely halt pathophysiologic deterioration; however, it should relieve much of the disability—the complex interaction between pathophysiology and individual adaptation. In a functional definition, pulmonary rehabilitation applies the art, skill, physiology, and multiple clinical disciplines to prevent or reverse the disability associated with chronic lung disease.³⁹ Specifically, the goals are to relieve symptoms, train patients to successfully manage their disease process, maintain an active and independent lifestyle, and maximize functional skills.

ADMISSION CRITERIA

Evaluating candidates for pulmonary rehabilitation need not be a complicated process. The two basic questions are as follows: (1) Does the patient have a diagnosis that qualifies for pulmonary rehabilitation? (2) Is the program likely to help the patient? The diagnosis should arrive with the patient referral, along with the pulmonary function tests. The team must then determine whether the program will meet the patient's goals effectively and safely. Essential information will include the diagnosis, stage of the disease, comorbidity, ability to learn and adapt, and motivation to put forth the effort. Also considered are complicating problems that might impede the program or pose a danger to the patient undergoing exercise training. Patients at an early stage of their disease must understand that their disease is progressive and their goal is to slow that progression. At the end stage, the question is more focused on the patient's ability to tolerate rehabilitative intervention. Most can, if they are motivated.³⁹

Spirometry helps to confirm the diagnosis. A simple flow/volume loop is adequate with the most important variables being FVC and FEV₁. Lung volumes and diffusion capacity are helpful in some instances, but it is uncommon that major clinical decisions are made based on those values. An FEV₁ <55% of predicted with an obstructive pattern on the flow/volume loop strongly suggests a diagnosis of COPD. An arterial blood gas sample provides the first and most accurate information about gas exchange and initially determines a need for supplemental oxygen. A pulse oximetry reading, performed at the same setting as the arterial blood gas, will serve as an accuracy anchor for future arterial oxygen saturation via pulse oximetry measurements. An exercise test will determine exercise tolerance, exer-

cise desaturation, cardiac arrhythmias, and will establish the safety of exercise training, which is at the heart of pulmonary rehabilitation. ECG and chest radiograph are always useful baseline studies in this population. Other tests, including a theophylline blood level, are performed as indicated.

A psychosocial assessment should be part of the evaluation of any patient with chronic lung disease. This is particularly true if the patient is a candidate for pulmonary rehabilitation. The patient should be motivated and cognitively capable of the task of education, training, and exercise program. Sometimes it is necessary to determine the family's capacity to be supportive to the patient over the long term.

METHODS OF PULMONARY REHABILITATION

Pulmonary rehabilitation programs seek to meet the goals of the patient, along with those directed by the therapeutic team (Table 2). Considering the wide variation of therapy and training within the fabric of pulmonary rehabilitation programs, some general areas of commonality prevail. Initially, the clinician must optimize medical management by assuring bronchial hygiene. Bronchodilators and anti-inflammatory medications open airways, reduce swelling, and dislodge blocking secretions. Prevention is a part of daily self-management. These programs basically train and equip patients to manage their disease process and how to live more comfortably. Dyspnea is managed by invoking several tools, disciplines, training, and medications. Exercise training, which not only builds endurance and strength, but effectively reduces dyspnea, while raising the patient's tolerance to it. Combined with breathing retraining, an exercise program adds confidence and minimizes anxiety, depression, fear, and apprehension, allowing the patient to tolerate more activities of daily living (ADL) for a richer quality of life. Oxygen transport can be optimized through adequate bronchial hygiene, supplemental oxygen (if required), and an exercise program to maximize transport, uptake, and utilization of oxygen.

Self-management is the cornerstone to a successful rehabilitative effort. The patient is responsible for the control of the disease process and disease progression. The medical care team must support and enable the patient to assume this role successfully. This concept spans the entire activity of care, including exacerbation management. Advance directives are continually updated reflecting the patient's changing needs.

Table 2—Methods of Pulmonary Rehabilitation

Methods
Prevention
1. Smoking cessation
2. Assure immunizations
3. Prevent exacerbation
Optimize medical management: See Table 1
Self-management
1. Medication training: oral, nebulized
2. Bronchial hygiene
3. Breathing retraining
4. Oxygen therapy
5. Adequate nutrition
6. Family training
7. Reporting to physician
8. Exacerbation protocol
a. Self-assessment
b. Self-intervention
c. Access physician
Dyspnea relief
1. Exercise
2. Breathing retraining
3. Medication: reduce airway obstruction
4. Bronchial hygiene
5. Reduce anxiety, depression
6. Reduce fear, apprehension
7. Improve confidence
Oxygen transport
1. Oxygen therapy
2. Bronchial hygiene
3. Exercise program
Exercise training
1. Ambulation training
2. Upper extremity training
3. VMT
Functional training (ADL)
1. Self-care
2. Care of the home
3. Leisure pursuits
4. Work (as appropriate)
5. Active lifestyle
6. Shopping
7. Sexual counseling
Team support
1. Acceptance of disease
2. Coping skills
3. Encouragement
4. Positive thinking
5. Self-esteem
6. Quality of life focus
Advance directives
1. Advance
2. Continuing

COMPONENTS OF PULMONARY REHABILITATION

Smoking Cessation

Patients entering a pulmonary rehabilitation program generally have quit smoking prior to their referral. Those who continue to smoke have two options: (1) complete smoking cessation prior to entering, or (2) undergoing a parallel smoking ces-

sation program while proceeding with pulmonary rehabilitation. The rehabilitation team may have one of several roles: (1) to help the patient initiate and proceed with smoking cessation; (2) to support continued cessation for patients who had a previous intervention; (3) to coordinate with the parallel program of smoking cessation; and (4) to help both patient and family understand the importance of maintaining a smoke-free environment.⁴⁰

Education and Training

Education and training help patients to develop living patterns that incorporate self-management. The aim is to teach methods that can be unintrusively integrated into the patient's lifestyle. Education is informative—teaching patients about their lungs, disease, medications, limitations, and necessary interventions.⁴¹ Patients learn how to exercise safely and how to use their oxygen. They learn what to focus on and what to ignore. Such critical knowledge builds the understanding and acceptance that can alleviate fear. Training develops functional skills and habit patterns, to enable self-management to take its place in the normal process of living. The training is accomplished through clear, concise, and repetitive messages, in a milieu that provides ample opportunity to practice the techniques under the guidance of the team. In the present example, patients are educated about their exacerbation protocol and then trained how to do it.

Self-management

Self-management training is the central task of pulmonary rehabilitation. Along with the enablement provided by a progressive exercise program, self-management training integrates all of the skills and disciplines for the patients to control their disease and live functional lives.⁴² Patients are trained in daily habit patterns so as to maximize the maintenance of self-care and minimize decision making. They are taught a set of daily rituals to provide them with the fundamental basics of self-care, including prevention, medications, oxygen, bronchial hygiene, breathing retraining, and self-assessment. Patients receiving functional training will incorporate their new skills into their ADL as part of their daily routine. Patients develop the mastery of being in charge. Self-care includes a daily self-assessment to determine whether to invoke their exacerbation protocol—described in the next section.

To improve the prospect that patients will incorporate self-care techniques into their lives, the number of tasks should be limited and practiced regularly. A few of the disciplines presented in

pulmonary rehabilitation are intuitive, but the rest require careful attention and practice. Ideally the patient will develop habit patterns, rather than relying on clinical judgment and decision making. This process includes introduction, education, training, monitored practice, and reinforcement for life.

Exacerbation Protocol

Patients experiencing the first signs of exacerbation may be on a short and rapid road to respiratory failure. The cause of an exacerbation in individual cases may be unknown; however, respiratory infection and inflammation are generally considered to play prominent roles.⁴³ Actually, several possible contributing factors, that vary chronologically in their appearance, can include infection, inflammation, bronchospasm, environmental irritants, gastroesophageal reflux, hypersedation, cor pulmonale, and right heart failure. Many of these factors conspire to promote mucous stasis, airway damage, and remodeling. At first recognition of exacerbation, action must be taken by the patient. As time progresses, the course of inflammation and infection causes progressive airway destruction and remodeling; thus, any sign of exacerbation should signal urgency to act.^{7,8,13,14} Fortunately, some patients are able to develop experience with their disease and know when an exacerbation is occurring in its early stages. They can often describe how they recognize their exacerbation, and what subtle signs they look for. In pulmonary rehabilitation, patients are taught a heightened awareness of those signals. They can have a protocol to follow with actions and medications that can be immediately initiated on awareness of an impending exacerbation. Sometimes, a family member will be required to help in the processes of recognition and intervention.

Self-Assessment: The patient is trained to do a self-assessment to observe for signs of exacerbation, which are *changes* in their usual state of being. These signs include increasing dyspnea, decreasing exercise tolerance, changing sputum character and consistency (darker, thicker, more copious, harder to expectorate), and dependent edema. Fever is not an invariable finding since many exacerbations coupled with sputum purulence are not accompanied by fever.

Self-intervention: There may be individual differences in protocols, but the basics will likely include calling the physician, intensive use of bronchodilators every 30 to 60 min, a pulse of oral steroids, starting an antibiotic course, coughing techniques, fluids, and pursed lips breathing.

While the first step may be to call the physician, some time may pass before physician contact is

actually established. To avoid delay, the patient can proceed with the rest of the protocol while awaiting the return call. When physician contact is achieved, the patient can then be advised on the next steps. Meanwhile, definitive intervention is set in place with no time wasted. The patient's physician will determine the cause of the exacerbation and adjust the intervention accordingly. The exacerbation protocol is one example of the importance of coordination between the patient, physician, and the program. The physician will need to write a prescription for the pulse of steroids and antibiotics so that the patient will have the medication on hand.

As with any management approach, the skillful clinician will determine if the individual patient is qualified to carry out a given protocol. Some patients may take their medications inappropriately and forget to call the physician, thus they may not be good candidates for such a protocol. In those cases, a modified protocol such as a call to the physician or team member may be an attainable goal.

Medications

The pulmonary rehabilitation team has a significant role in training and nurturing patient adherence to dosing schedules. Following a medication schedule geometrically increases in difficulty with the addition of each new medication; noncompliance likewise rises. Responsibility for medication administration is in the hands of the patient, as guided by the physician.⁴² The team should regularly assess the patient for adherence to dosages and schedules. Dosing schedules may be chronotherapeutically timed to target peak blood levels to control nocturnal symptoms. To vary from that timing would sabotage the treatment plan. PRN medications require a different kind of patient understanding.

Patients must learn to monitor themselves for signs and symptoms that will signal when to use a specific medication. For example, patients are trained in the use of corticosteroids, as proper self-administration not only improves their effectiveness but minimizes side effects. Patients may be taught the difference between short-term rescue and long-term taper dosing. Ideally, a basic plan is shared with the patient and the team for both long- and short-term steroid therapy. Exacerbation management requires the patient to have

creases oxygen uptake ($\dot{V}O_2$), utilization, and improves cardiac output. Thus, at equivalent workloads, the heart rate is slower and the minute ventilation is decreased. Volumetric increases in capillary blood flow have been measured, along with changes in the muscle oxidative enzymes and mitochondrial density. For many years, COPD patients have been known to make significant clinical gains from a submaximal exercise program. In recent years, these patients have been demonstrated to be able to endure relatively high intensity training⁵⁰ and to be able to raise their lactic acid threshold and maximal $\dot{V}O_2$ ($\dot{V}O_{2max}$).⁴⁸ As they tolerate higher workloads, their dyspnea sensation becomes blunted or better tolerated.

STRENGTH: Muscle weakness both in skeletal and ventilatory muscles is common in COPD patients. Curiously, COPD patients seem to be weak beyond a level solely explainable by inactivity and deconditioning. They may have decreased testosterone and related hormone levels.⁵¹ Patients receiving long-term corticosteroids can be exceptionally weak from steroid myopathy.⁵² Regardless of the mechanisms involved, strength training in specific muscle groups has enabled patients to more comfortably and confidently perform their ADL. Hence, strength training may be adjunctive to endurance training.⁵³

OXYGEN TRANSPORT: COPD patients can be compromised by inadequate gas exchange, cor pulmonale, and other limitations to oxygen transport and utilization. Oxygen demand of ventilatory and other muscle groups often outstrips the oxygen supply, although a corresponding rise in CO_2 presence at the tissue level actually facilitates oxygen release from hemoglobin and enhances oxygen availability to the cells. Exercise training challenges the full oxygen transport system to deliver and utilize oxygen in exercising muscle. The end result is an improvement in oxygen transport, uptake, and utilization.⁴⁸

DYSYPNEA: Training of both upper and lower extremity muscle groups reduces dyspnea for similar workloads, particularly in ADL.⁵⁴⁻⁵⁶ The mechanisms for this effect coincide with several of the previously described physiologic benefits of exercise, since dyspnea is the most common reason for patients stopping exercise. It is also difficult to separate the psychosocial factors involved.^{57,58} Exercise affords the patient an opportunity to tolerate the sensation of dyspnea and to modify his or her prevailing interpretation that dyspnea means impending death. Exercise, therefore, removes fear of dyspnea as a roadblock to being more active.

Exercise Testing: Exercise testing is commonly performed to assess the safety of an exercise program—specifically to identify if cardiac dysrhyth-

mias are provoked by typical exercise levels. Testing is also important to determine the patient's oxygen requirement during exertional conditions.^{2,3} The exercise test may provide the basis of the exercise prescription, although the typical prescription is to instruct the patient to walk to tolerance. The test format may vary from an incremental bicycle ergometry, a treadmill test, a 6- or 12-min walk distance test, or a typical walk in the hallway. Generally monitored are heart rate, BP, ECG, and arterial oxygen saturation via pulse oximetry. Arrhythmias aggravated by exercise, abnormal vital sign response, and oxygen desaturation are signs that further evaluation of cardiorespiratory status is required prior to proceeding with an exercise program.

Exercise Protocol:

HIGH-INTENSITY VS SUBMAXIMAL EXERCISE TRAINING: It is now known that severely impaired patients may be so deconditioned that they already function close to their anaerobic threshold. Hence, a low level of exercise in these patients may result in a training effect. Moreover, severely impaired patients subjected to higher intensity training have been able to raise their anaerobic threshold and $\dot{V}O_{2max}$.⁴⁷

Patients, therefore, have a choice between submaximal exercise, well below their anaerobic threshold, vs a high-intensity protocol at 60% of $\dot{V}O_{2max}$. This poses the question as to whether most COPD patients should be trained at their highest workload, or should training be performed at submaximal levels. On the one hand, high-intensity exercise confers all of the advantages of a training effect, but requires the patient to exercise at a relative level that even healthy individuals have difficulty maintaining over the long haul. On the other hand, submaximal exercise for longer periods achieves many of the benefits of a high-intensity training program and may be a more enjoyable experience. The tradeoff is between a training effect vs a possible enjoyable experience. This question should be addressed both for the individual patient and in a study that compares the two protocols over several years as pathophysiologic deterioration and aging take their toll. Whatever the protocol, patients need support, reassurance, and reaffirmation to maintain their exercise program over time.

Weight Training: Most of the focus has been on endurance training, emphasizing high repetition and low workload. COPD patients tend to be weak, but they are capable of gaining strength through a weight-training program.⁵¹ Also, their level of conditioning is so low that exercises considered to be calisthenic may have some conditioning impact. Patients in weight-training regimens have gained not only greater strength in the muscle groups exercised but increased general endurance as well.⁵³

Upper Extremity Training: Patients become more dyspneic using their arms than their legs. This becomes particularly noticeable when patients attempt to raise their arms to shoulder level or higher.⁵⁹ This phenomenon is thought to be due to the fact that arm and shoulder muscles become recruited as accessory muscles of ventilation during exercise at higher workloads. Patients with flattened diaphragms tend to utilize their shoulders as a kind of auxiliary diaphragm. When those muscles are also required to perform upper extremity work, they may not be up to the additional task of ventilatory support.⁶⁰ The arms and shoulder muscles are required for most ADLs. Accordingly, upper extremity exercise training has become standard in most rehabilitation programs. As is typical of many exercise programs, some of the benefit observed from upper extremity training stems from improved mechanical efficiency of the muscle groups involved.⁶¹ Arm exercise may be accomplished by two methods: arm bicycle ergometry (arms are supported on the pedals) and gravity resistive exercises, which are arm exercises against the force of gravity (arms are unsupported). Both methods increase strength and endurance in the upper extremities, but the gravity resistive exercises, being unsupported, seem to be more effective.⁶² This is a convenient and practical finding because the patient does not have to be tied to expensive equipment and thus, can exercise anywhere. Because arm exercise training leads to a reduction in ventilatory requirement for arm elevation and exertion, COPD patients are able to perform ADL tasks with less dyspnea.⁶¹ Not all studies have shown a direct correlation between arm exercise training and improvement in ADLs.⁶³ Nevertheless, exercise programs for COPD patients should include upper extremity training.⁶⁴

Ventilatory Muscle Training: Ironically, in COPD, the inherent increase in ventilatory demand is serviced by a dysfunctional ventilatory apparatus. Hyperinflation, disadvantageous repositioning of the diaphragm, ventilatory muscle fatigability, and loss of ventilatory muscle strength are pathophysiologic contributors to progressive ventilatory ineffectiveness.^{65,66} Ventilatory muscle training (VMT) is exercise specifically designed to build endurance and strength in the muscles powering the ventilatory pump. VMT may prevent or delay the onset of ventilatory muscle fatigue and failure, and has been shown to decrease dyspnea over time.⁶⁷ Cofactors in the building and empowering of ventilatory muscles include enhancing nutritional status, assuring tissue oxygenation, and minimizing medications that contribute to muscle weakness. In addition, any therapeutic intervention that results in a structural nor-

malization of the ventilatory apparatus would both relieve demand and boost capacity to meet that demand.

The three forms of VMT are isocapnic hyperpnea, inspiratory resistance training, and inspiratory threshold training. Isocapnic hyperpnea training (not a common clinical tool) is directed toward increasing ventilatory muscle endurance by instructing patients to maximally hyperventilate over some period of time. To prevent hypocapnea and respiratory alkalosis, the patient breathes into a large tube with an adjustable opening to the atmosphere that returns a portion of the expiratory CO₂ to the patient. Inspiratory resistance training is focused on building strength in the inspiratory muscles by instructing the patient to inspire through small orifices. In inspiratory threshold training, the patients attempt to inspire through a sealed valve, which has an adjustable breaking pressure.⁶⁸ Once the breaking pressure is exceeded, the seal is defeated and inspiratory flow will ensue. Threshold training protocols can be adjusted to favor strength, endurance, or both. Some studies suggest that VMT may contribute to general body fitness, but this finding is inconsistent.^{69,70} The reverse may be true that exercising skeletal muscles with sufficient intensity could also challenge and strengthen the ventilatory muscles.⁷¹

VMT increases strength and endurance in the ventilatory muscles and can reduce dyspnea.⁶⁷ However, it is not clear whether VMT adds any benefit to the upper and lower extremity exercises of a comprehensive pulmonary rehabilitation program. There is no evidence that VMT can replace walking or arm exercises. Some studies indicate that VMT may be useful for quadriplegic and muscular dystrophy patients who are unable to exercise extremity muscles. Finally, VMT has been studied as a method to augment and facilitate ventilator weaning, with variable results.⁷²

Exercise Prescription: Patients with respiratory limitations gain the greatest benefit from an exercise program that emphasizes endurance. Strength training is also functionally enabling and supportive to the benefits of endurance training. Due to the unique limitations of patients with severe COPD, they may be able to exercise to as much as 95% of $\dot{V}O_{2max}$, because they may be functioning near that level.⁴⁵ In the design of an exercise protocol, the clinician may specify the intensity, repetitiveness, frequency, and duration of training. An exercise program centered on walking to tolerance will not directly specify these factors. The protocol may show preference to either building strength, endurance, or a combination of both. Consequently, an exercise protocol may simi-

larly vary from high workload/low repetition (for strength building), to low workload/high repetition (for endurance building).

Concomitant use of pursed lips breathing (PLB) techniques designed to reduce dyspnea and increase oxygen saturation should be a part of the exercise prescription.⁷³ Also, preexercise bronchodilators can be assistive modifiers in improving exercise performance. Oxygen is prescribed to maintain exercise saturation above 90% and can increase exercise tolerance. One cannot overstate the importance of psychosocial reinforcement in embarking on an exercise program for dyspneic patients. The challenge is to set a lifetime agenda of exercise that builds and maintains the patient's functional status that withstands aging and pathophysiologic deterioration.

Breathing Retraining

Patients with obstructive lung disease suffer from several inefficiencies of the ventilatory pump due to changes in their chest wall structure, deteriorating strength, lung hyperexpansion and crowding, reduced elastic recoil, poor gas exchange, and diaphragmatic malpositioning. The symptomatic end result is dyspnea. Breathing retraining may be one method of temporarily countering some of these changes. If successful, breathing retraining should both relieve dyspnea and improve gas exchange. The techniques most commonly taught are diaphragmatic breathing and PLB or a combination of both.

Diaphragmatic Breathing: In diaphragmatic breathing, patients are taught to synchronize inspiration with abdominal expansion as they breathe more slowly and deeply. On exhalation, the diaphragm is pushed upward by the abdominal muscles to create a more curved posture and better length-tension relationship. This increases the effective force of the diaphragm as an inspiratory muscle. It also slows breathing and deemphasizes the chest and accessory muscles. Diaphragmatic breathing is often used in combination with PLB and relaxation techniques. In a patient who is dyspneic to the point of panic, a dysphasic pattern may be brought back into synchrony, and thereby, eliminate the inefficiency of simultaneous contraction of opposing muscle groups. This self-intervention should lower the ventilatory cost and work of breathing. In general, diaphragmatic breathing can bring symptomatic relief and engender a feeling of control. Studies evaluating diaphragmatic breathing have been confounded by the differences in approach to the technique creating an unknown impact on ventilatory mechanics. Some studies have demonstrated this technique to improve gas exchange, while others have come to the opposite conclusion.^{74,75}

Pursed Lips Breathing: PLB is unique because patients often learn it spontaneously, discovering that it relieves their breathlessness.⁷⁶ This pattern of breathing has become the hallmark of emphysema. Methods of PLB training vary widely, but in general, patients are taught to inhale slowly through their nose and exhale more slowly through pursed lips. Pursing the lips retards exhalation and slows respiratory rate. In so doing, patients take deeper breaths to maintain their minute ventilation, and tend to spend a greater portion of the ventilatory cycle at higher lung volume and correspondingly greater elastic recoil.⁷⁷ Slowing exhalation probably reduces airways resistance by retarding airflow and turbulence. This breathing pattern may improve ventilation/perfusion matching by expanding lung volume, minimizing the dead space to tidal volume ratio and recruiting more alveolar units at the lung base. As a result, PLB temporarily raises oxygen saturation for the period of time the maneuver is being performed. With the biofeedback guidance of pulse oximetry, PLB is useful in training patients to increase their oxygen saturation.⁷⁸ Because many patients are reassured by PLB, it is useful in self-recovery when panic begins to set in. Also, PLB training during an exercise session is an effective way to learn control over dyspnea under controlled adverse conditions.

Some patients may discover alternative ventilatory patterns that bring them relief, while others will settle on dysfunctional patterns. It is not prudent to simply instruct patients to change their breathing pattern without evaluating the possible reasons for the existence of that pattern. It is helpful to measure dyspnea and arterial oxygenation to determine the effectiveness of a breathing retraining technique.

Secretion Clearance

In chronic bronchitis, chronic inflammatory changes become superimposed by acute inflammation and mucus hypersecretion. Bacterial infections alter viscoelastic properties of mucus rendering it thick, viscous, and difficult to expectorate. With additional impairment of mucociliary mechanisms, airways become clogged with secretions to the point of becoming life threatening. Coughing is the most immediately effective means of upwardly mobilizing lung secretions. Adjunctive to coughing, fluids moisten the throat and hydrate the dehydrated patient. Bronchodilators open the airways, while activity mobilizes secretions. Steroids reduce inflammation and relieve bronchospasm. The patient should be adequately oxygenated while undergoing secretion clearance techniques.

Coughing: Patients are trained and encouraged to cough and clear secretions effectively. Most patients

can follow a directed cough; however, some patients are unable to generate an explosive cough. As an alternative, the "huff cough," consisting of a slow inspiration to total lung capacity, followed by huffs with the glottis open, may be effective. The multiple huffs are thought to minimize collapse of small airways, bronchospasm, and fatigue common to fits of uncontrolled coughing.⁷⁹ These techniques have proven effective in bronchiectasis and cystic fibrosis, but their efficacy is less clear in chronic bronchitis.⁸⁰

Chest Physiotherapy: Postural drainage and percussion are clinically effective in patients with bronchiectasis, cystic fibrosis, and chronic bronchitis with copious secretions. However, there is sparse evidence to support its implementation in all bronchitis patients, even during an exacerbation.⁸⁰ Variables measured include spirometry, sputum volume and character, gas exchange, and symptom score. While the impact of chest physiotherapy on these variables has been unimpressive, clinicians strongly support continued usage, particularly when faced with mucus impaction. Similarly, chest wall and airway vibration have been studied without much change except for complicating bronchospasm. Positive expiratory pressure has shown some increase in secretion mobilization in cystic fibrosis patients, although these benefits are less clear for patients with chronic bronchitis.⁸¹

Nutrition

Improving nutritional status is an important component of pulmonary rehabilitation in order to reverse generalized weakness, improve ventilatory muscle strength and endurance, and maintain immunocompetence.⁸² Unfortunately, such support is neither as easy nor as successful as it would seem. Patients find it difficult to eat when their appetites are poor, and nutritional supplements, while effective over the short term, are difficult for the patient to maintain over time. Force feeding swells stomach volume, thereby contributing to dyspnea.

About 25% of COPD patients are unable to maintain their nutritional status, as evidenced by weight loss; this number expands to 50% in COPD patients hospitalized for exacerbations.^{83,84} Nutritional depletion is more common in patients with profound mechanical and gas exchange impairment. The cause of the weight loss is not always known, but may include poor appetite, high-energy cost of breathing, and desaturation during eating. A loss of protein and lean body mass leads to skeletal muscle and diaphragmatic weakness.

An optimal level of caloric supplementation has not been established. Multiple small feedings of food and supplements, and assuring adequate oxygen

saturation during eating, may heighten daily caloric intake. Skewing the diet toward fat in lieu of carbohydrate will increase the caloric intake per unit volume. Also, a fat concentrated diet metabolizes to less CO₂ than carbohydrate, which may reduce the ventilatory workload.⁸⁵ The practical impact of this principle is uncertain in the ambulatory patient. However, it is known that overfeeding will lead to diminishing returns by causing excessive lipogenesis, which increases the ventilatory workload.⁸⁶

It is important to correct protein malnutrition and electrolyte derangements, particularly potassium, magnesium, phosphate and calcium—all of which have an impact on ventilatory muscle strength and endurance. Excessive sodium intake increases cardiac workload and should be avoided. Obesity is also a significant problem as it imposes a greater metabolic workload and restricts ventilatory effort. Good nutritional counseling can be valuable for patients malnourished by nutritional depletion or obesity. Coercive diets, forced supplements, and fad diets should be avoided. Eating should be a pleasant and enjoyable experience; individual creativity in crafting a diet may improve chances of success.

Oxygen

Many patients have difficulty in accepting their need for oxygen. Patients first prescribed oxygen experience fear, anxiety, depression, and great uncertainty about their future. They often regard their need for oxygen as a major step toward their death. This is a most difficult crossroad; consequently, the pulmonary rehabilitation team should devote thoughtful time, energy, and skills in helping patients to understand and accept their need for oxygen. Patients should be involved in the choice of their oxygen systems and delivery method. They must understand that their oxygen is a supplementation that will enable them to function better and live longer. Accepting their oxygen, transfilling, learning to clean and care for their units at home, knowing when to call for service, all take the mystery out of oxygen supplementation for patients and their families.

Two multicentered studies have demonstrated that long-term oxygen therapy (LTOT) for hypoxemic patients increases survival, to a degree proportionate to the number of hours per day that the oxygen is taken.^{87,88} Hence, the correction and prevention of hypoxemia assume a high priority in the treatment of COPD patients. LTOT lowers pulmonary artery pressure and pulmonary vascular resistance, reverses secondary polycythemia, strengthens cardiac function, enhances psychomotor performance, boosts exercise capacity, and improves

ADL.⁸⁹ Mobilization is critical to successfully conducting an active lifestyle; therefore, oxygen systems should be chosen for their maximum portability.⁹⁰

Oxygen is prescribed and reimbursed based on arterial blood gas evidence of hypoxemia. Patients with a $\text{PaO}_2 \leq 55$ mm Hg at rest should receive LTOT.⁸ If the PaO_2 is between 56 and 59 mm Hg and there are signs of cor pulmonale, the patient should receive LTOT. Oxygen is generally not prescribed for patients whose $\text{PaO}_2 > 60$ mm Hg, unless desaturation occurs during sleep or exertion. Gray areas include oxygen therapy for relief of severe dyspnea or to improve exercise performance in patients without hypoxemia. Oxygen is prescribed with a goal of assuring $\text{PaO}_2 > 60$ mm Hg, which generally corresponds to an arterial oxygen saturation (SaO_2) $> 90\%$. To push the SaO_2 much higher probably accomplishes little, and may increase the risk of CO_2 retention in some patients. While this complication is infrequent in low-flow oxygen therapy, it is best avoided by maintaining the $\text{SaO}_2 < 93\%$ and monitoring for CO_2 retention. Chronic hypercapnea with compensated acid-base balance in end-stage COPD is adaptive by permitting a lower work of breathing. Acute hypercapnea is a sign of respiratory failure requiring acute intervention.

Prescribing Oxygen: In prescribing LTOT, an arterial blood gas sample, rather than pulse oximetry, is used for the initial determination of hypoxemia. Arterial gases are more accurate and include other important gas-exchange variables: PCO_2 , pH, and SaO_2 via co-oximetry. However, when a blood gas sample is drawn, a simultaneous pulse oximetry measurement can be compared to the SaO_2 via co-oximetry, so that future adjustments in oxygen flow can be more confidently based on pulse oximetry.

Patients who are hypoxemic during wakeful rest are often more hypoxemic during sleep. If the patient does not have sleep apnea, oxygen administered during sleep will generally correct sleep desaturation. For a sleep oxygen setting, it is commonly recommended that 1 L/min be added to the resting setting. This flow increase may either underestimate or overestimate the nocturnal oxygen requirement. If indicated by signs of cor pulmonale, in an otherwise adequately oxygenated patient, an 8-h sleep saturation study will reliably determine the patient's nocturnal oxygen requirement.

Patients who are hypoxemic at rest, and some who are adequately oxygenated, may desaturate during exertion. The exertion may be as minimal as eating or as demanding as walking upstairs. Patients in pulmonary rehabilitation, being trained and encouraged to maintain an active lifestyle, must be adequately oxygenated during exercise. Short-term studies have

demonstrated that oxygen during exercise improves exercise tolerance, reduces dyspnea, and prevents rises in pulmonary artery pressure.^{91,92} The long-term benefit of oxygen with exercise is not known, but suspected to be similarly protective. Exertional oxygen should be prescribed based on the flow setting required to maintain $\text{SaO}_2 > 90\%$ during an exercise challenge slightly greater than normally experienced during daily living. A pulse oximeter is commonly used in this clinical testing, but may not be highly accurate, particularly in a patient with poor tissue perfusion.⁹³ An arterial blood gas sample drawn at the end of exercise would be more accurate and, in addition, confirms the oximetry readings.⁸

Oxygen Systems: Oxygen comes packaged as a compressed gas, liquid oxygen, or as an oxygen concentrator. Compressed gas oxygen is stored in metal containers at 2,000 to 3,000 psi. An 18-lb aluminum E cylinder supplies about 4.5 h of oxygen at 2 L/m continuous flow. Liquid oxygen is stored at nearly absolute zero with 1 liquid liter producing nearly 1,000 gaseous liters. A 9.5-lb liquid flask provides nearly 7 h of oxygen at 2 L/min. The oxygen concentrator is an ideal stationary source of oxygen, but to date and to our knowledge, no practical portable oxygen concentrator is available. The smallest liquid system with an oxygen-conserving device weighs 5.5 lb, lasts 8 h, and can be refilled by the patient. The smallest gas system with an oxygen-conserving device weighs 4.5 lb, lasts 10.5 h, but cannot be refilled by the patient. The pulmonary rehabilitation team must teach, assist, and facilitate to determine which system would best meet the needs of the individual patient.

Oxygen Delivery: Oxygen is most commonly delivered to the patient via a dual-pronged nasal cannula. Each increase in liter flow adds about 3 to 4% to the patient's fraction of inspired oxygen. The nasal cannula has relatively good patient acceptance, but it wastes about 84% of the oxygen flow due to the inefficiency of delivering throughout the respiratory cycle. Oxygen-conserving devices were developed to improve the efficiency of delivery and render oxygen therapy more portable and acceptable to the patient. These include the reservoir cannulas, transtracheal catheters, and demand pulsing devices. The reservoir cannulas (the Oxymizer⁹⁴ and Oxymizer Pendant; Chad Therapeutics; Chatsworth, Calif)⁹⁵ function by storing oxygen during exhalation thereby making the stored oxygen available for the next inhalation. They are simple, inexpensive, and improve the delivery efficiency by up to fourfold. On the downside, they are large on the face and somewhat bulky. Recently, they have been used for patients with high flow requirements and as a step

down device for mechanically ventilated patients recently weaned and extubated.⁹⁶

Transtracheal catheters are thin plastic tubes inserted through a small hole in the neck and into the trachea.^{97,98} Via this technique, delivery efficiency is improved by nearly threefold. Perhaps an even greater benefit is the fact that oxygen is completely removed from the face and can be hidden from view. In addition, high flows of oxygen via transtracheal catheters can reduce minute ventilation and the work of breathing.^{98,99} Also, transtracheal air insufflation may be considered an alternative to nasal continuous positive airway pressure in patients intolerant to that therapy.¹⁰⁰ Transtracheal requires considerable patient education—an ideal role for the pulmonary rehabilitation team.

Demand pulsing oxygen delivery devices function by sensing the onset of inhalation and delivering a short pulse of oxygen.^{101,102} Ideally, the oxygen pulse arrives close to the very beginning of inhalation, and stops delivering before the dead-space portion of inhalation. These devices vary in their configuration and design priorities. Considerations when prescribing them include efficacy, weight, portability, battery life, alarms, whether they are integrated into a liquid system or stand-alone, and product support. These are complex, high-technology devices. Also, they may not deliver if the patient is mouth breathing.

Most patients do not require their oxygen to be humidified at liter flows <4 L/m. The reservoir cannula (Oxymizer) actually humidifies oxygen via the patient's exhaled moisture at temperatures between room air and body temperature. Patients receiving transtracheal oxygen do require humidification to prevent the formation of mucus balls at the end of the catheter.¹⁰³

Activities of Daily Living

ADL training is the culmination of all components of rehabilitation coalesced into a lifestyle that optimizes the patient's ability to function. Included are self-care, management of the home environment, leisure activity, and work. In ADL training, patients learn work efficiency and motion economy, thereby minimizing the energy cost of grooming, hygiene, meal preparation, and maintaining their environment—all of this while leaving energy for activities that add quality to their lives.

The basic goal of ADL training is to maximize the patient's ability to function comfortably and enjoy more quality living. Patients often train by performing the tasks that challenge them while being monitored by the therapist. These tasks may include self-care, household chores, marketing, yard work, lifting, good body mechanics, and control of anxiety

and panic. Patients learn to pace their activities to their respiratory cycle while performing PLB. This is similar to weight-lifting training where the effort is coupled to the respiratory cycle. Patients learn to shop while carrying oxygen and pushing a cart. They are trained in showering and preparing a meal. Many self-care efforts and household chores can be performed while patients are seated, conserving energy for other endeavors.²⁻⁶

Claustrophobia, an anxiety provoking closed-in feeling associated with dyspnea, is common in COPD patients. Showering can be claustrophobic—especially aggravated by steam. This can be alleviated by having the patient turn the cold water on first, minimizing the steam. Similarly, in other areas, patients are taught mastery over their environment. Many patients are afraid to venture out of the home due to a fear of crowds and “catching an infection.” These fears can be allayed by practical solutions such as a hand fan for claustrophobia, avoiding hand contact, and functional mastery training. Relaxation techniques can also facilitate the ability to control the environment, while calming anxiety and panic.

Psychosocial Factors

Physiologic impairment is only part of the story in COPD. The real drama in rehabilitation takes place within the realm of the psychosocial.¹⁰⁴ As patients sink into progressive inactivity and dependence on others, maladaptive role reversals can have a demeaning effect on patient self-concept and how their families begin to view them as well. Patients become depressed, anxious, panicky, and insomniac. Inherent in pulmonary rehabilitation programs are methods for addressing the psychosocial component. The program trains patients and families to adapt and manage disease-related problems. Exercise, breathing-retraining techniques, self-management techniques, coping techniques, assertion training, insomnia recommendations, and better medical management all assist patients in learning to adapt. When crisis threatens, many programs maintain a cadre of psychologists, social workers, family counselors, and clergy for the times of need.

Family Training

The family plays an essential role in the life of the COPD patient with advancing disease. Family interaction requires that they have an understanding of the disease process and what to expect. Families are usually not ready for the extreme burden that this disease process imposes on them. Supportive family members easily find themselves in the role of assuming charge of the patient's life—an encumbrance handed to them by an increasingly dependent and demanding patient. They may be left to strike a fine

balance between being supportive and assuming complete responsibility, at a time when that level of control is counterproductive. Not all families are supportive; some family members may become disinterested or even hostile. Severe dyspnea in a loved one can be frightening, so it is important to train family members in helping their loved one and to avoid their own panic. Family members are encouraged to participate in the rehabilitative process. Appropriate family members should be trained in the exacerbation protocols and when to call for help. The family is also taught the importance of maintaining a smoke-free environment.

Insomnia

Insomnia, daytime sleepiness, and nightmares are common in COPD patient. They have all of the usual reasons for sleep disturbance as the general population, with the addition of dyspnea, orthopnea, sinusitis, anxiety, and depression.¹⁰⁵ Commonly prescribed medications have been considered culprits; however, most studies on sleep architecture in patients taking theophylline, β -agonists, and steroids have failed to demonstrate alteration of sleep staging or efficiency.¹⁰⁶ In fact, these medications may relieve respiratory causes of sleep deprivation. COPD and obstructive sleep apnea may present simultaneously as overlap syndrome.¹⁰⁷ Also, there appears to be a relationship among sleep architecture, nocturnal saturation, and ventilatory muscle function.^{108,109} Prescribing sedatives and tranquilizers for insomnia in COPD patients is ill advised, although some studies have found no blunting of chemosensitivity using low levels of these drugs.^{110,111} Patients suspected of having sleep apnea should be evaluated by a sleep screening protocol.

Nocturnal oxygen desaturation (NOD), common in patients with daytime hypoxemia, is not accurately predicted by exercise saturation or even resting hypoxemia.¹¹² Some patients with normal daytime saturations may have NOD due to reduced ventilation during sleep (particularly rapid eye movement), widening ventilation/perfusion mismatching, blunted chemosensitivity, hypercarbia, or dysfunctional lung mechanics. Since NOD is frequently associated with pulmonary hypertension, cor pulmonale may be a first indicator of nocturnal desaturation.

In pulmonary rehabilitation, the patient learns that sleep deprivation, although uncomfortable, is usually not harmful, unless the patient falls asleep while driving. Hence, patients learn not to lose sleep over the loss of sleep. Patients are warned not to take sleeping pills to get to sleep or stimulants to wake up. They are also advised not to exercise just before bedtime. If the cause of insomnia is dyspnea, the

dyspnea must be addressed. Patients are taught to accept middle-of-the-night awakenings as an opportunity to clear their secretions; they get up, use their inhaled β -agonists, drink some water, cough, and clear their secretions, before lying back down. For patients having difficulty in getting to sleep, they can be taught to do progressive relaxation or biofeedback. Some patients become somnolent while watching television; a television with an automatic shutoff becomes their electronic sleeping pill.

Sexuality

Sexuality is more than the sex act, it is a part of a person's self-concept.¹¹³ Some patients with severe disease are still sexually active, whereas others have relegated that part of their lives to be a remnant of the past. Pulmonary rehabilitation programs may address sexuality as a part of the program, or on an individual basis, being sensitive and responsive to the needs of individual patients. In some cases, chronic disease or medications may impair physicality. These problems can be successfully addressed. Understanding and communication are first steps toward physical and emotional expressions of love and affection. Patients should be nurtured to feel comfortable when discussing sexuality. Open and honest conversation between the patient and a trusted team member, along with insightful suggestions, may help the patient with the desire to maintain the physical aspect of a loving relationship through warmth and touching.

Physician Patient Collaboration

The physician-patient relationship holds a unique microspace in the world of human interaction. It may be advisory, paternalistic, confiding, trusting, directive, kind, nurturing, friendly, or embody other qualities that call on the physician's insight and wisdom. Rarely, does this relationship require patients to contribute their own insights. However, in chronic illness, particularly COPD, the advisory and reassuring qualities are maintained, but now this becomes a collaborative relationship. With the patient being trained in self-management, the information exchanged will involve the participation of a well-informed patient charged with specific responsibilities.⁴²

With a progressively disabling disease, these patients carry sizable emotional baggage, which can be expressed as dyspnea, frustration, or noncompliance. Hence, the physician must address these patients in a manner that is nonrushed and nurturing. The patient and physician must communicate on level ground, because they are both involved in the care of "the patient." The patient performs self-care with the

physician being the medical director; each has a role to play. The overall goal is the successful long-term management of a chronic and progressive illness.

PROGRAM STRUCTURE

Organization and Presentation

The organization of the pulmonary rehabilitation program is designed to embody important components of training within a framework that will effectively bring about a lasting behavioral change.³⁹ Some of the COPD population can be described as aging and debilitated. Their educational backgrounds vary, and some may not be at their cognitive zenith. These factors should be considered in the program design. Consequently, programs ought to be simple, uncluttered, and without extraneous information presented. The program structure should leave nothing to the imagination; it should emphasize the basics and lead the patient along direct paths of training.

Presentation of program material should be clear, concise, uncomplicated, repetitive, and require a minimum of clinical judgment and decision making from the patient. Skills that gel into habit can bring reliable and timely adherence to self-management. This has particular utility in regard to the exacerbation protocol, in which timing can make such a critical difference. In presenting the program method, it is useful for most patients to be educated about their disease process, so that their skill training will make sense to them. However, the training itself requires practice, repetitive reinforcement, and positive experience. By presenting all of the self-management techniques early in the program, the patient has maximal opportunity to practice skills under the team's observation, direction, and tutelage.

Location

The program may be carried out in a medical setting, such as the hospital or outpatient department, but this is not an invariable necessity. The physician's waiting room (after office hours) or a community center may be suitable, as these training programs do not require a plethora of sophisticated equipment. Most programs are conducted in an outpatient setting, although a small percentage of hospitalized patients are in limbo between recovery from an exacerbation, and being too weak to thrive at home. An inpatient program designed to bring those patients to outpatient status, operating in the skilled nursing side of the hospital, can bridge this gap.

Pulmonary Rehabilitation Team

Pulmonary rehabilitation is a multidisciplinary approach to disease management. Accordingly, the pulmonary rehabilitation team is an interdisciplinary, interactive, and coordinated cadre of health-care professionals who share the common goal of restoring or maintaining function and self-control in patients with pulmonary disability. Each member brings a special skill to the patient. In addition, each member of the team participates in decision making with the patient and the functioning of the team. Each member is regarded as a colleague of the physician director. The roles are overlapping with authority at the lowest level. The team functions in a collaborative fashion with the most important players being the patient and family, followed by the team, followed by the team leader. They are endowed with shared knowledge, mutual trust, and a common purpose. A well-functioning team coalesces into a collective personality with a philosophic leader who devotes as much time and effort to supporting the team as in leading it.¹¹⁴

A full team comprises a pulmonologist, nurse, respiratory therapist, occupational therapist, physical therapist, social worker, dietitian, and psychologist—all contributing to the team effort. Each team has a coordinator, who conducts the day-to-day operation; this is usually not the physician director. This individual is continually aware of each patient's status, as well as having a finger on the pulse of the team. During the course of pulmonary rehabilitation, all team members continuously observe the patients for early signs and symptoms of exacerbation, and initiate the exacerbation protocol, including contacting the patient's physician. As previously described, patients and their families eventually take on this responsibility. Each team has a medical director, who is responsible for the pulmonary rehabilitation program and its operation; this is not necessarily the patient's primary physician.

As the trend in health care is to downsize, teams are becoming smaller with fewer team members taking on multiple duty assignments. In fact, many programs are being administered by a team of one—usually a respiratory therapist or nurse, trained in multiple areas. Presumably this “pulmonary rehabilitation therapist” will be enriched with enough knowledge and clinical judgment to be able to call for specific assistance from other therapists and the physician as the need arises. Conceptually, there is an advantage to this development beyond cost savings. Coordinating a large team can be complicated and time consuming, whereas a smaller team can operate more efficiently. Also, the patient is taught multiple skills that must be synthesized into a daily

routine of self-care. A nurse or therapist so trained can impart that structure to the patient.

Independent of the size of the rehabilitation team, there is a requirement for conference and rounds. Conferences include the team members, psychologists, consultants, and insurance case managers along with the patient and family. Goals are identified, progress is evaluated, problems are solved, and treatment plans are made or modified based on the patient's progress and capability. This is also a forum for patient-family participation, as well as for the insurance case manager. The latter may be essential for program reimbursement.

In a vast majority of instances, the patient's physician is not a member of the pulmonary rehabilitation team. Nevertheless, the physician is the one who will treat these patients for the rest of their lives. Ideally, the patient's primary physician will understand the principles and operation, as well as actively participate in the program and with the collaborative self-management approach. As patients are taught self-assessment, they also learn when and how to contact their physician and how to report their symptoms. In this model, the physician is made aware of what the patient is being taught and becomes responsive to the patient's contact. When patients report signs and symptoms of an exacerbation in its early stages, the physician responds to rapidly abate them. The physician must provide medication prescriptions ahead of time so that the patient will have them on hand to take at the first sign of the exacerbation. After the patient calls, the physician will provide guidance as to the next steps in management. This communication and guidance will often include the patient's family as well.

Immediately following the rehabilitation program, the patients should make an appointment with their physicians to present themselves at their postrehabilitative peak. If their physician does not see them until the next exacerbation, that physician's frame of reference is at a lower expectation; thus, medical decisions will be made accordingly.

Patient Guidebook

The rehabilitation guidebook is the program in written form. Its format should be short, simple, clear, and reflect the essence of the program.³⁹ It should be upbeat and encouraging with specific subject matter being easy to locate. A single-page summary of the program and the patient's responsibilities, located near the front of the guidebook, will remind the patient of the essentials of self-management long after the program has ended. An introduction that describes the benefits of self-management will lend reason and encouragement,

supportive to long-term adherence. A description of the heart, lungs, the disease, and rationale for pulmonary rehabilitation provides a useful foundation for self-management training. The core of the guidebook must be relevant and readable, showing understanding of the feeling part of the disease and coping with chronic illness. Repeating important concepts in different contexts serves to emphasize the importance of those concepts. A reference section with community resources and a glossary should also be included. A personalized information section in a convenient place, to keep important names and phone numbers including the physician, hospital, pharmacies, and other emergency numbers like 911 is also essential. A current list of the patient's medication is important in self-management. The guidebook should be convenient, friendly, non-threatening, and accessible.

Patient Support Groups

The rehabilitative process is lifelong and patients are known to be nurtured and recharged by support groups.¹¹⁵ Through the better breather clubs, patients and their families learn that others are fighting the same battles and are suffering the same ordeals. The continuing education often provided brings hope to demoralized patients. Group-supported events, lectures, games, and travel enable patients to enjoy life despite lung disease. Outings to the mall, picnics, horse races, and ocean cruises are only some of the activities that enrich their lives, boost their morale, and give them a reason to continue the fight.

BENEFITS FROM PULMONARY REHABILITATION

Outcome Studies in General

Designing an outcome study requires careful thought and planning. The experimental and control subjects should be drawn from the same population and randomly allocated into experimental and control groups. Studies that compare *after vs before* suffer from an order or maturation effect. Patients always have expectations and it is always possible that the effect that was detected could be due to another reason, or simply that it was time for that effect to take place. A suffering patient will nearly always benefit from a clinician who comes highly recommended. Unfortunately, most studies investigating the benefits of rehabilitation fall into the *after vs before* category.¹¹⁶

The benefits from pulmonary rehabilitation can be described in terms of the gains made during the course of the program, and which of those gains were maintained in the ensuing months and years follow-

ing the program. Pulmonary rehabilitation studies compare heterogeneous patients and heterogeneous programs. Yet most studies show the same or similar benefits. This begs the question of the importance of some components vs others. It is possible that all programs studied are similar enough to demonstrate benefit, and exposure to any program will be sufficient to alleviate some of the disability associated with COPD. Studies that investigated the impact of size or length of the program have failed to reveal any effect.¹¹⁷ Specific findings from within the structure of pulmonary rehabilitation are described in the sections that follow.

Static Lung Function

Pulmonary rehabilitation investigations have almost unanimously demonstrated no improvement in resting pulmonary mechanics or gas exchange values.^{2,3} Also, no slowing of physiologic deterioration has been demonstrated in the years following pulmonary rehabilitation.¹¹⁸ Lung function testing, particularly spirometry, describes the patient's present level of physiologic deterioration, but it is a poor predictor of how well a patient is likely to benefit from a rehabilitation program.¹¹⁹

Exercise Performance

One of the most striking and consistent outcomes of pulmonary rehabilitation is the improvement in exercise performance. A recent randomized study compared comprehensive pulmonary rehabilitation comprising both exercise and education, with education alone.¹²⁰ By including exercise, they found a large improvement in exercise endurance and maximal exercise tolerance that was maintained for 12 months following rehabilitation. In addition, they demonstrated a consistent reduction in muscle fatigue after exercise, along with improvement in key elements of quality of life, including dyspnea scores.¹²⁰ Two other studies revealed a concomitant improvement in exercise performance and quality of life.^{121,122} Exercise protocols have varied widely from low-intensity, slowly paced walks, to high-intensity bicycle ergometry and treadmill protocols. Controlled trials using high-intensity protocols demonstrated that even patients with low levels of exercise function have been able to improve their anaerobic thresholds.⁴⁷ Most studies performed over the last 30 years have used symptom-limited protocols like walking to tolerance. These studies have almost unanimously demonstrated improvements in exercise endurance and maximal exercise tolerance; the few studies based on high-intensity training showed improvements in anaerobic thresholds.⁴⁷

Benefits associated with exercise training in pul-

monary rehabilitation include reducing dyspnea,¹²⁰ lowering muscle fatigue,^{120,123,124} greater ability to exercise at a higher workload with a lower heart rate,¹²³ better quality of life,¹²² increased strength from weight training,⁵³ improved muscle efficiency,¹²⁴ greater mastery, better psychosocial function,^{53,104,125} (although not a consistent finding),¹²⁰ more work days,¹²⁶ and enhanced general ADL function.^{53,127} Improvement in self-efficacy is specifically correlated with developing greater exercise endurance.¹²⁸ The mechanisms for improving exercise capacity include increased aerobic capacity, greater motivation, improved tolerance to dyspnea,^{120,129} and better ventilatory muscle function.¹³⁰ Many of the exercise-associated benefits diminish after 12 months as a result of reduced patient compliance.^{120,122,131}

Pulmonary rehabilitation is beneficial, independent of disease severity.¹²⁵ In patients with mild disease, many of the same benefits are experienced,^{126,132} and the same is true for the patients with severe disease.^{133,134} It has been documented that elderly patients improve their exercise performance following pulmonary rehabilitation.¹³⁵

Functional Status

Functional status improvement is a central goal of any rehabilitative effort. The four dimensions of functional status include the following: (1) functional capacity; (2) functional performance; (3) functional reserve; and (4) functional capacity utilization.¹³⁶ Functional capacity describes the patient's maximum work capacity, which is rarely attained even by healthy persons. Functional performance is the level at which the patient is actually working. Functional reserve is capacity minus performance or the region that is entered when patients push themselves. The functional capacity utilization represents the percentage of capacity in which the patient is presently functioning.¹³⁶

Pulmonary rehabilitation can affect all four dimensions. Functional indexes have been measured by physical performance and dyspnea scales, reflective of functional capacity. Studies using the 6-min walk test and three functional indexes (Medical Research Council index, modified pneumoconiosis research unit score, and the modified dyspnea index) have demonstrated improvement in functional performance and functional capacity.¹²⁷ It is not always easy to ascertain whether functional capacity utilization is increased, since both the functional performance and capacity are improved.

Activities that have meaning to the patient include self-care, mobility, eating, home management, and social and recreational activities. Dyspnea is the

central limiter for these activities. A pulmonary functional status and dyspnea questionnaire shows, with internal consistency, functional improvement following pulmonary rehabilitation.¹³⁷ Patients trained on specific tasks, known to be important to their ADL, develop greater capacity to perform those tasks at the same or lower level of dyspnea.¹³⁸

Dyspnea

Patients seek medical help and pulmonary rehabilitation programs because of dyspnea. Most pulmonary rehabilitation studies that have measured dyspnea have demonstrated an improvement in this key area.^{120,129} Frequently, dyspnea improvement is related to improvement in exercise performance.¹³⁹ Dyspnea management strategies, exclusive of pulmonary rehabilitation and exercise, have not been uniformly effective.¹⁴⁰ Program components, known to specifically relieve dyspnea over time, include exercise training,¹²⁰ breathing retraining,¹⁴¹ better disease management,⁸ functional training,¹³⁸ and oxygen therapy.⁹¹ In addition to specific program components, the program in general has a salutary effect on dyspnea.¹²⁰ In turn, the relief of dyspnea supports the overall program as it reinforces patient motivation.

Quality of Life

Quality of life is one of the most compelling determinations attempted in evaluating pulmonary rehabilitation; it is also lush with conjecture and pitfalls. Recent efforts have been directed toward understanding quality from the patient's point of view. Other efforts have focused on anchoring quality of life to health status. One investigator breaks quality of life into the following components: (1) emotional functioning; (2) social role functioning; (3) ability to perform ADL; and (4) ability to participate in enjoyable activities.¹⁴² Several attempts have met with varying success, that consistently identify factors relating to quality of life and the negative impact of a chronic and progressive illness.^{143,144}

More direct indicators of quality of life, as they relate to infirmity, have been utilized. Two general measures, the Quality of Well-being Scale¹⁴⁵ and the Sickness Impact Profile (SIP)¹⁴⁶ have been used to assess relief of symptoms and improvement in quality of life in COPD patients. The SIP seems to be insensitive to mild lung disease or dyspnea.¹⁴⁷ As a result, the St George's Respiratory Questionnaire and the Chronic Respiratory Questionnaire were developed to be more disease specific and sensitive to small changes in that disease state.¹⁴⁷ The St George's Respiratory Questionnaire is self-administered, and has been utilized in adult chronic lung

disease patients as a measure of health and well-being. It correlates with FEV₁, 12-min walk test, and the coping strategies of avoidance and emotional reaction. In evaluating the benefits of pulmonary rehabilitation, these specific questionnaires have been utilized to show improvements in multifactorial scores, several years following the rehabilitation program. The results of these instruments appear consistent and repeatable.¹⁴⁸

The Short-Form 36, which covers nine health domains, was found to relate to severity of dyspnea comparing with the baseline dyspnea index but not to resting lung function. The scores most closely related were social and physical functioning, vitality, pain, health perceptions, and health transition.¹¹⁹ Again, dyspnea appears to be a key factor relating to quality of life. There are several areas of agreement in quality of life measures, but complete correlation has not yet been found.¹⁴⁹ The SIP and Short-Form 36 tend to provide more generalized information, whereas the St. George's Respiratory Questionnaire and Chronic Respiratory Questionnaire may be more specific to this patient population.

Specific elements important to quality of life have demonstrated improvement. Many psychological variables, including anxiety and depression, have been substantially ameliorated by pulmonary rehabilitation.¹³⁹ Activity and self-confidence have also been enhanced by rehabilitation,¹²³ as have other rehabilitative elements, including endurance, strength, dyspnea, and ADL.¹³⁸

Health-care Utilization

Most studies investigating the effect of pulmonary rehabilitation on health-care utilization have demonstrated a significant reduction in emergency department treatments, physician office visits, and inpatient days,^{150,151} however, this has not been a unanimous finding.¹²⁰ Several studies have compared health-care utilization in years following pulmonary rehabilitation vs the year prior to the program. These studies have generally demonstrated a consistent reduction in hospital days over the succeeding years.^{126,132,152-155} One study showed a shift in activity from hospital-based care to telephone calls. One could speculate that this shift reflects a more effective communication between patient and physician, which resulted in better disease management. In more recent studies, rehabilitation has been shown to reduce hospital days with that benefit continuing in patients regularly participating in a continuation exercise program.¹⁵¹ One study demonstrated a significant increase in hospitalization and outpatient visits in the control group, while showing a significant decrease in both inpatient and outpa-

tient utilization in the rehabilitation group.¹⁵⁶ A study that combined respiratory services with community agencies in a cooperative effort showed significant reduction in hospitalizations and emergency department visits.¹⁵⁷

Costs/Benefits

The cost of managing a population of COPD patients is enormous. This is particularly true for patients who have reached the point of multiple hospitalizations and emergency department admissions. In the past, that cost was borne by the patient's insurance or some other third party. With managed care, hospitals and physician groups are becoming directly responsible for cost and cost management. Emergency department treatment may cost as much as \$1,000 and a day in the hospital may cost \$2,000 or more. The cost of conducting a pulmonary rehabilitation may be as high as \$4,000 with the average cost being about \$2,000.¹⁵⁸ The average program would pay for itself if it prevented one inpatient day or two emergency department admissions. Most studies have demonstrated a much greater reduction in both outpatient treatments and inpatient days of 10 to 20 days a year for patients regularly in the hospital.^{150,151,153,154} Recent studies have evaluated utilization and costs by today's standards. An estimated \$95,000 was saved in one study group over the 2-year period of the study, taking into account the cost of the program.¹⁵⁶ Hence, the weight of the studies presented demonstrates a substantial reduction in both inpatient and outpatient health-care utilization from pulmonary rehabilitation and this reduces the cost of care.

By today's rules, the clinician must not only understand the economics of the disease process being treated, but the logistics of who is responsible for that cost, and over what time period that responsibility will last. Whereas it may seem reasonable to calculate the benefits of rehabilitation over several years, the immediate cost of the program may be disproportionately weighed by the payer. The notion that a program will pay for itself years down the line is not adequate by today's standards. This consideration has an influence over which patients will have the opportunity for rehabilitation. The patient with early disease is not costly to the system, whereas the patient at an advanced stage, who has already been hospitalized, is very costly. Both short-term and long-term solutions to the hemorrhage of their health-care fund will be sought, and many decisions may be made on immediate economic basis only. However, the clinician, who is designing programs for the chronically ill patient, is certainly in the

position of creating programs that reduce costs through clinical effectiveness.

Survival

Several elements of pulmonary rehabilitation are known or believed to improve survival of COPD patients. These include smoking cessation, better compliance with LTOT, improved nutrition, exercise and an active lifestyle, and avoidance and early treatment of exacerbation. And yet, to our knowledge, no studies have convincingly demonstrated that pulmonary rehabilitation programs lengthen survival. Several investigations have studied the prognosis of patients following pulmonary rehabilitation and have found that a number of severely ill patients die within the first year of the program.¹⁵⁹ Confounding interpretation of survival rate is the fact that a significant percentage of the population die of factors not related to the disease process. Also, COPD, itself becomes a systemic disease as organ systems become damaged by tissue hypoxia. As one can surmise, identifying and maintaining an adequate control group drawn from the same population of patients can be problematic.

Survival likely varies in relation to the component of COPD that predominates, emphysema, asthma, or bronchitis, in the patients studied.¹⁶⁰ Patients with a large degree of reversibility will likely benefit from a therapeutic approach that targets inflammation. Certainly, steroids have been shown to improve survival from COPD exacerbations; however, the impact of long-term oral and inhaled steroids is unknown but is the subject of several ongoing investigations.

SURGERY FOR COPD

Successful transplantation of single and double lungs is now almost commonplace at major medical centers. Candidates for these operations are carefully selected for their disease severity, comorbidity, along with indications and contraindications that would predict surgical success. In preparing patients for such a major operation, pulmonary rehabilitation is almost universally advocated to increase their strength, endurance, knowledge, and confidence for the long road to postoperative recovery. Recently, laser bullectomy, to remove or deflate giant restrictive bullae, has been introduced. This served to reignite interest in a previous concept, that by removing the more diffuse emphysemic portions of lung from patients with heterogenous disease, elastic recoil and diaphragmatic effectiveness could be partially restored.^{161,162} Presently, most lung volume reduction surgery is accomplished via a bilateral lung

stapling procedure through either an anterior mediastinal approach or video-assisted thoracoscopy. While the widespread application of this procedure is still controversial, some centers are reporting impressive clinical and physiologic changes in selected patients.¹⁶³ Several studies have reported significant improvements in lung volume and flows (up to 80%); with similar increases in elastic recoil indexes. Supplemental oxygen requirements have been obviated in some patients. Indications and contraindications have not been fully delineated and not all centers have met with the same degree of success. Accordingly, Medicare reimbursement has been placed on hold, pending the results of a multicenter randomized study comparing this surgery, plus pulmonary rehabilitation, or with pulmonary rehabilitation alone. In this case, pulmonary rehabilitation is regarded as a standard of comparison.

DRAWBACKS OF PULMONARY REHABILITATION

Despite the many benefits of pulmonary rehabilitation, there are some drawbacks. Given a population of 15 million COPD patients in the United States, most of whom would benefit from pulmonary rehabilitation, the present accommodation is for about 10,000 patients at any given time.¹⁵⁸ This calculates to <0.1%. Thus, pulmonary rehabilitation is not presently a solution that could support full population access. Pulmonary rehabilitation is administered over a short period of time for a COPD population whose illness is chronic and progressive. Also, benefits dissolve over time, with measurable loss after the first year.^{120,131} Pulmonary rehabilitation is costly. Despite the fact that it reduces the cost of health care in the long run, the program does entail significant up-front expense. Finally, the primary physicians are rarely involved in the rehabilitative effort, and thus, they are unable to either support program methods or integrate the program into their plan of care for the patient. The solutions to these problems will require creative attention.

DISEASE MANAGEMENT—THE IDEAL SYSTEM

In stepping back and viewing COPD as a disease process with a clinical picture of progressive deterioration, an ideal system of care could be built on a disease management model. Disease management is a comprehensive and coordinated system of care that deals with the disease state, rather than just the acute episode. The basic components are prevention, wellness, treatment, patient tracking, and follow-up.⁴² It

is based on self-management to prevent the disease from progressing, daily self-care, patient-physician collaboration, exacerbation management, and protocols for admission to short-term care facilities. Advance directives, as well as continuing directives, would reflect the changing needs of the patients and their families. Actually, much of the foregoing description is pulmonary rehabilitation, integrated into ongoing care, and with the patient's physician at the helm. By this means, rehabilitative tools including prevention, exercise, and exacerbation protocol would be available to all patients, as a part of their standard care, over the entire course of the disease.

CONCLUSIONS

Pulmonary rehabilitation, which includes smoking cessation, self-management, exercise, and optimization of medical management, is a highly effective and cost-efficient means of caring for COPD patients. Exercise has a key role in enabling the other benefits; however, exercise alone would not be expected to bring about all of the changes seen in pulmonary rehabilitation. Education, self-management, and psychological support improve the awareness of the patient and increase his or her understanding of the disease, but when used alone, they are of limited value.

In essence, pulmonary rehabilitation is a set of tools and disciplines that attends to the multiple needs of the COPD patient. On the positive side, it addresses the disability component of the disease. Patients become hopeful and confident that they can enjoy quality lives in the face of severe dyspnea. They gain endurance and strength, are better able to function, suffer less anxiety, depression, and panic, and become freed from the necessity to constantly access the health-care system. They attain better psychomotor performance and greater mastery over their illness. On the downside, it is a discreet, one-time program, separate from, and in addition to, standard medical care. It is available to few patients relative to a massive population who could benefit. The patient's physician is rarely a part of the program and thus unable to support a long-term response. This dichotomy does not seriously detract from the multiple benefits of the program; it simply lends greater insight into important challenges in treating these patients.

Although pulmonary rehabilitation is highly beneficial, often exceeding expectation, an ideal system would entail redesigning standard medical care to create a disease management model that would include rehabilitative tools and disciplines in a system of self-management and regular exercise. This is

as opposed to pulmonary rehabilitation being a loose appendage to standard care. This therapeutic construct would best enable patients to enjoy continuing benefit over the full course of their disease, interface with their physician, and have this care available to the full population of COPD patients. Thus, pulmonary rehabilitation would take its place in the mainstream of disease management through its integrative role in the multidisciplinary continuum of services, as defined by the National Institutes of Health Pulmonary Rehabilitation Research Workshop of 1994.¹

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