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☐ Review Article ☐

New Therapeutic Techniques and Strategies in Pulmonary Rehabilitation

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Patients with chronic obstructive pulmonary disease (COPD) or those with paralytic restrictive pulmonary syndromes caused by progressive neuromuscular disease, kyphoscoliosis or traumatic quadriplegia may require frequent hospitalization because of respiratory impairment and have increased morbidity and mortality. Pulmonary rehabilitation has been shown to decrease the frequency of hospitalization, ameliorate symptoms, increase exercise tolerance, and in one study, prolong life for individuals with COPD. It is now recognized that principles of pulmonary rehabilitation can also be used to avoid hospitalization, intubation, tracheostomy and bronchoscopy while enhancing quality of life, decreasing cost, and greatly prolonging life for individuals with paralytic restrictive syndromes and global alveolar hypoventilation as well.

Key Words: Pulmonary Rehabilitation, COPD, Neuromuscular Diseases, Mechanical Ventilation, Exsufflation

In Patients with intrinsic pulmonary disease, respiratory insufficiency initially results from failure of the respiratory mechanism to adequately oxygenate the blood, and therefore tissues. Hypoventilation with elevated carbon dioxide levels develops only in late stages or during acute periods of respiratory encumberment. In those with paralytic restrictive syndromes, however, hypoventilation results from what is primarily a ventilatory impairment and hypoxia develops only secondarily. Although these conditions are pathophysiologically distinct and require entirely different therapeutic approaches, to the detriment of their patients, physicians all to commonly treat the global alveolar hypoventilation patient with oxygen and medications that are useful only for the intrinsic lung disease patient.

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Mechanical Insufflation-Exsufflation

Greater than 5 liters per second of peak cough expiratory flow (PCEF) is required to generate effective expulsion of airway secretions. Individuals with severe paralytic restrictive pulmonary syndromes may have less than 1 liter per second of PCEF. This is because of weak inspiratory, and especially expiratory (Braun *et al.* 1983), muscles as commonly seen in individuals with amyotrophic lateral sclerosis, Duchenne muscular dystrophy, myotonic dystrophy and myasthenia gravis. Clearance of airway secretions is further compromised when there is concomittent weakness of oropharyngeal muscles. Patients with neuromuscular disease are usually only initially treated for ventilatory insufficiency and impaired coughing when they develop pneumonia from inability to clear airway, secretions and can not be weaned from mechanical ventilation

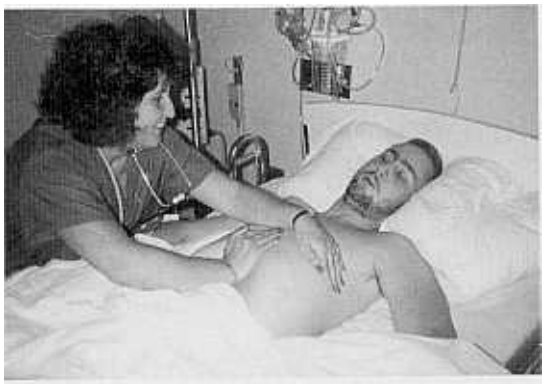

Fig. 1. Manually assisted coughing is most effective when preceded by a deep breath or mechanically assisted insufflation for patients with vital capacity less than 1.5 liters. One hand is placed on the epigastrum and delivers an abdominal thrust timed to the patient's opening of his glottis. The other hand is applied across the chest to give counter pressure. An abdominal thrust might also be delivered by both hands placed on the abdomen under each rib cage.

Fig. 2. An In-Exsufflator (J.H. Emerson Co, Cambridge,, MA) delivers an adjustable deep insufflation followed by an adjustable sustained exsufflation to create greater than 6 liters per second of expiratory flow and eliminate airway secretions.

once intubated and using intermittent positive pressure ventilation (IPPV). Likewise, many spinal cord injured patients have virtually intact oropharyngeal and inspiratory muscle capacity, but generate expiratory flows inadequate to clear airway secretions. For these patients, too, ineffective airway secretion clearance becomes life-threatening during otherwise minor upper respiratory tract infections. Indded, largely because of this, pulmonary failure is the most frequent cause of death during at least 11 years following injury in this population (Young *et al.* 1982). Post-abdominal surgery patients are also at risk for serious respiratory complications because of expiratory muscle impairment.

Airway suctioning via the nose or mouth does not effectively mobilize deep secretions and is poorly tolearated. Tracheostomies have been placed in many patients only to aspirate airway secretions. However, tracheal suctioning causes irritation, increases secretions, and may be accompanied by severe hypoxia (Bach *et al.* 1988) and possibly cardiac arrhythmia. The suction catheter usually does not enter the left primary bronchus and will, therefore, not help to clear the left bronchial tree (Fishburn *et al.* 1990). Tracheal suctioning at best effectively clears only tracheal secretions. It is ineffective in clearing life-threatening mucus plugs that adhere between the tracheostomy tube and tracheal wall and cuff. Chest percussion and postural drainage are commonly prescribed but are in themselves not adequate to clear the bronchial tree. Various techniques of manually assisted coughing are effective but underutilized (Fig. 1) (Sortor and McKenize, 1986). The effectiveness of these techniques is enhanced by preceding the manually assisted exsufflation with a deep insufflation. An intermittent positive pressure breathing machine or portable ventilator is useful for delivering maximum tolerated insufflations for this purpose.

We have found that a mechanical exsufflation device (Fig. 2) (The In-Exsufflator, J. H. Emerson Co., Cambridge, MA) is more effective than manually assisted coughing or tracheal suctioning and considerably less eggout via an anesthesia mask or tracheostomy tube. OEM Cof-flator; Barach *et al.* 1952; Barach *et al.* 1953; Bickerman Insufflation is followed by an independently adjustable exsufflation caused by a sudden drop in pressure of about 80 cm H_2O to 100 cm H_2O in 0.02 seconds. The negative pressure is usually sustained for 1.5 to 2 seconds and generates 5 to 11 liters per second of expiratory flow. This is more than can be generated by many physically intact individuals and is op-

timal for clearing airway secretions. With elimination of bronchial secretions and improvement in respiratory exchange, the patient's vital capacity (VC) can increase immediately by 15% to 50% and oxyhemoglobin saturations (SaO_2) normalize (Bach in press a). This technique permits earlier extubation of intubated or tracheostomized patients during ventilator weaning, and can be instrumental in permitting continued ventilatory support by noninvasive ventilatory aids during intercurrent respiratory tract infections.

Mechanical insufflation-exsufflation is very effective for patients with primarily restrictive pulmonary syndromes. Although it has been reported to be effective for patients with COPD (Barach *et al.* 1952; Barach *et al.* 1953; Bickerman and Itkin, 1954), airway instability and collapse would render it less useful for these patients. Techniques which provide rapid, cyclical, small amplitude expansion and compression of the chest with pressures biased for exsufflation, such as percussive intrapulmonary jet ventilation (Freitag *et al.* 1989) and external high frequency oscillatory ventilation, should be explored for this population (Hayek *et al.* 1985).

Alternative Methods of Ventilator Weaning for Patients With Globla Alveolar Hypoventilation

Pulse oximetry biofeedback and IPPV via a mouthpiece are useful tools for weaning patients from tracheostomy ventilatory support and for outpatient management of ventilatory failure. The patient should first be weanedh from oxygen therapy and maintain his fio2 greater than 55 mm Hg when normocapnic or hypocapnic. This can usually be accomplished by aggressive airway secretion elimination by mechanical insufflation-exsufflation and supportive medical care as necessary. The tracheostomy tube is then capped and a mouthpiece set up so that the patient can grab it and use it for IPPV when short of breath or when the SaO_2 falls below a traget level, e.g. 90% to 94% (Fig. 3). In this way the patient weans himself at his own pace. Thus, mouthpiece IPPV (Bach, 1991; Bach and Alba, 1991; Bach and Alba, 1993; Bach *et al.* 1985; Bach *et al.* 1987) is an excellent

Fig. 3. A patient with amyotrophic lateral sclerosis, 180 ml of vital capacity and no ventilator-free time using mouthpiece intermittent positive pressure ventilation.

alternative to pressure support ventilation or interspersing periods of tracheostomy IPPV with continuous postive airway pressure (CPAP) or ventilator free breathing for weaning patients (Bach, 1991; Bach and Alba, 1990b).

Oximetry Biofeedback for Patients with Global Alveolar Hypoventilation

For a patient with chronic alvelolar hypoventilation introduction to and use of mouthpiece or nasal IPPV can facilitate resetting of respiratory control centers, normalize alveolar ventilation, and decrease microatelectasis. The patient is then instructed to maintain his SaO_2 at or above a level set on the oximeter all day. He can either achieve this by unassisted breathing, or once he tires, by mouthpiece or nasal IPPV usually from a portable ventilator.

These techniques can be used up to 24 hours a day if necessary. Most patients can immediately appreciate that by taking slightly deeper breaths or using noninvasive methods of IPPV SaO_2 can exceed 95% within seconds. Thus, particularly when the patient practices these techniques before an episode of acute respiratory failure, he can avoid intubation or be safely extubated and switched to noninvasively delivered IPPV (Bach and Alba, 1990a; Bach, 1993). Mouthpiece IPPV should be used during sleep

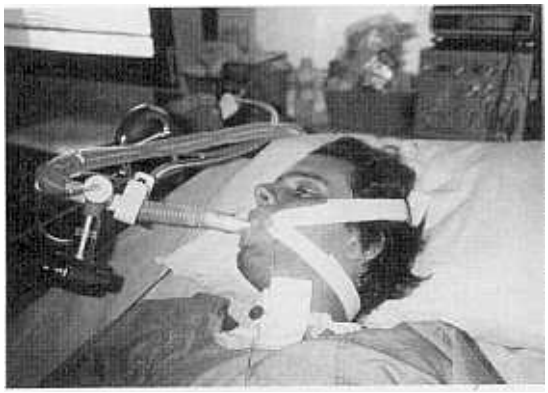

Fig. 4. A traumatic tetraplegic with no ventilator free time being switched from tracheostomy to mouthpiece intermittent positive pressure ventilation. He uses a Bennett lip seal to firmly retain the mouthpiece during sleep.

with the mouthpiece firmly retained with a Bennett lip seal (Fig. 4). For patients using nasal IPPV, different nasal interfaces should be tried to optimize comfort and eliminate air leakage (Bach, in press C). Oximetry monitoring can evaluate efficacy of nocturnal noninvasive IPPV use (Bach, 1991; Bach *et al.* 1985; Bach *et al.* 1987; Bach and Alba, 1990b). The oximeter should be capable of collating and averaging data hourly, summarizing oxyhemoglobin desaturations, and printing out the data for a permanent record, e.g. Ohmeda Biox 3760 oximeter, Ohmeda Inc, Louisville, Co.

Management of Intercurrent Respiratory Tract Infections

The 24 hour attention of well-trained attendants or family members and use of mechanical exsufflation up to every 15 minutes as necessary permits even patients with little or no VC and no indwelling tracheostomy tube to be safely managed at home during upper respiratory infections. Continuous SaO_2 monitoring is useful to evaluate for or to assess the severity of atelectasis. This is seen as a continuous decrease in the SaO_2 baseline despite continuous use of noninvasive IPPV. Sudden mucus plugging, on the other hand, often causes an acute, sometimes severe, decrease in SaO_2. Once the mucus plug is cleared by mechanical exsufflation or other assist technique, the SaO_2 returns to baseline. Many long-term ventilator dependent patients have become experts at training their attendants how and when to apply these measures.

Because of exacerbation of respiratory muscle weakness during respiratory infections (Mier-Jedrzejowicz, 1988), the daily regimen of assisted ventilation invariably needs to be extented if it Extended is not already 24 hours. Frequent "sighs" may be necessary for manually assisted coughing. Some patients on mouthpiece or nasal IPPV switch to a body ventilator for greater rest and easier access to the mouth and nose to clear secretions. If hospitalization is to be avoided during respiratory infections, supplemental oxygen administration and sedatives should be avoided and broad spectrum antibiotics, adequate humidification, and hydration provided as necessary. On-call respiratory therapists of conscientious home care companies can play key roles in mantaining ventilatory equipment, a mechanical exsufflation device and an oximeter in the home, and in patient and family training.

Noninvasive Ventilatory Support

Any patient with less than 50% of predicted normal supine vital capacity should undergo SaO_2 monitoring and possible noninvasive pCO_2 monitoring during sleep. The capnograph, which measures end-tidal pCO_2, and pulse oximeter must summarize and print out the data (Bach and Alba, 1990a; Bach *et al.* 1987).

These studies are most conveniently performed on an out-patient basis. Many patients with supine VCs less than 30% of predicted require at least nocturnal ventilatory support (Bach and Alba, 1990a). Patients with less than 12% of predicted vital capacity often require aid around the clock (Bach and Alba, 1990a). Since patients with chronic alveolar hypoventilation almost invariably refuse elective tracheostomy for IPPV, acute ventilatory failure can be avoided only by noninvasive aids. Conditions for their use include the weaning of any cooperative intubated or tracheostomized patient with ventilatory insufficiency or any patient with chronic alveolar hypoventilation and the following: sufficient oropharyngeal muscle strength for an maximum insufflation capacity

(Bach, Alba 1990a) of at least 500 ml or adequate for swallowing and speaking; no history of substance abuse; no need of supplemental oxygen to maintatin a pO_2 greater than 60 mmHg in the presence of normal or low pCO_2; access to effective means to clear airway secretions when necessary; no seizure disorder; and no orthopedic conditions that interfere with the use of a patient-ventilator circuit interface.

Ventilatory assistance or support can be provided by body ventilators, devices that act directly on the body, or IPPV via a mouthpiece, nose, or oral-nasal interface. Negative pressure body ventilators create negative pressure on the chest and abdomen and air then flows into the lungs through the nose and mouth. These devices include the Rocking Bed (Goldstein *et al.* 1987), Iron Lung (Mckhann, 1986), Porta Lung, wrap ventilator, and Chest shell (Kinnear, *et al.* 1988; Splaingard *et al.* 1985; Bach and Penek, 1991). They are not feasible or are ineffective in the sitting position. Except for the Iron Lung and Porta Lung, they are generally not useful in the presence of scoliosis or extreme obesity. It may take 10 minutes or more for a personal care attendant to place a patient in a wrap ventilator. Sleeping with a significant other may not be possible. Travel with body ventilators is at best inconvenient, and these devices are associated with obstructive sleep apneas in most patients using them (Bach, Penek 1991). For these reasons noninvasive IPPV techniques, including most conveniently mouthpiece and nasal IPPV, are the methods of choice for long-term ventilatory support for most patients. Negative pressure body ventilators continue to be useful, however, for temporary assistance for some patients during acute respiratory infections (Bach *et al.* 1985; Bach *et al.* 1987), and during tracheostomy site closure (Bach, 1991; Bach and Alba, 1990b).

The intermittent abdominal pressure ventilator consists of an inflatable bladder in an abdominal belt. The bladder is cyclically inflated by a positive pressure ventilator that pushes the abdominal contents up against the diaphragm and ventilates the patient. This generally augments the patient's tidal volume by 200 to 400 ml but much greater volumes are often possible (Bach and Alba, 1991). It is not effective in the presence of scoliosis, extremes of body weight, or when used in the supine position. It is most effective in the sitting position at 75~85°. It is the daytime ventilatory support preferred by most patients with less than one hour of free time from ventilatory assistance because it is cosmetic, practical, effective and ideal for concurrent glossopharyngeal breathing and wheelchair use (Bach and Alba, 1991).

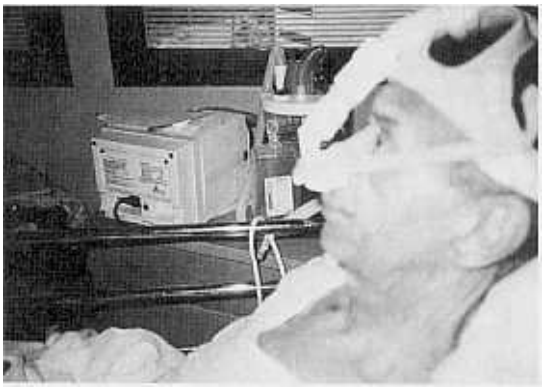

Fig. 5. *An commercially available "CPAP" mask being used to deliver nasal intermittent positive pressure ventilation for 24 hour ventilatory support for this patient with advanced amyotrophic lateral sclerosis.*

Noninvasive IPPV techniques are effective alternatives to tracheostomy IPPV and body ventilator use. Mouthpiece IPPV is the method of daytime support preferred by most patients capable of one hour or more of ventilator free time, and is also preferred by patients with less than one hour of free time for whom the intermittent abdominal pressure ventilator is not effective. Nocturnal administration of nasal IPPV is preferred by most patients who require aid only during sleep (Fig. 5) (Bach and Alba, 1990a). Custom molded interfaces are useful for patients for whom the commercially available generic interfaces (CPAP masks) are uncomfortable or inadequate to prevent insufflation leak (Bach, in press; Bach *et al.* 1993; McDermott, 1989). Oral-nasal interfaces are occasionally useful, particularly for patients with difficulty donning or using the strap retention systems of mouthpiece or nasal IPPV (McDermott *et al.* 1989). Individually molded nasal interfaces (McDermott *et al.* 1989), including the commercially available SEFAM interfaces (Lifecare, Lafayette, CO) are also useful in

managing obstructive sleep apnea. Versatility in the use of noninvasive ventilatory aids and effective management of intercurrent respiratory infections are of paramount importance for averting unnecessary hospitalizations and avoiding tracheostomy.

Sleep Disordered Breathing

Sleep disordered breathing is a common entity that can develop into or complicate global alveolar hypoventilation, and that may also complicate COPD. Sleep disordered breathing refers to the occurrence of apneas and hypopneas that may be centrally derived or result from upper airway obstruction. The obstructive sleep apnea syndrome (OSAS) in which the patient is symptomatic, apneas and hypopneas exceed 10 per hour and are primarily obstructive, has potentially serious cardiovascular and neuropsychiatric sequelae (Bradley and Phillipson, 1985). Overt OSAS occurs in at least 3% of the general population but its incidence increases greatly with age, in males, and with other endocrine, space occupying, and neuromuscular conditions (Lombard and Zwillich, 1985). It also occurs in most patients with ventilatory insufficiency using negative pressure body ventilators (Bach and Penek, 1991; Levy *et al.* 1989) or electrophrenic nerve pacing.

Significant weight reduction can improve or completely resolve the obstructive sleep apnea syndrome in most obese patients (Levy *et al.* 1989). However, this is all to frequently only temporarily accomplished.

CPAP is effective for patients without significant hypercapnia. Independently varying inspiratory and expiratory pressures or Bi-PAP (Bi-PAP machine, Respironics Inc, Monroeville PA) improves effectiveness and comfort. For many obesity hypoventilation patients or patients with a combined paralytic restrictive ventilatory insufficiency and concurrent sleep disordered breathing, noninvasive IPPV as described earlier can both assist ventilation and maintain upper airway patency.

As noted earlier, CPAP, Bi-PAP, and noninvasive IPPV can be delivered via commercially available CPAP masks from Lifecare Inc., Lafayette, Co; Respironics Inc, Monroeville PA; Puritan-Bennett Inc, Boulder CO, and others. These inexpensive masks may be uncomfortable, and the key reason for the failure of patient compliance with long-term CPAP therapy in 43 of 125 recently studied patients (Waldhorn *et al.* 1990). Custom molded nasal interfaces, previously described, should then be considered.

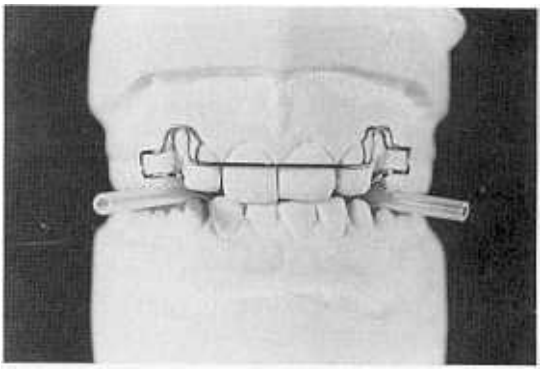

Fig. 6. An itra-oral appliance used to treat obstructive sleep apnea (courtesy of Dr. John R. Haze, D.D. S., Montville, N.J.).

A convenient long-term solution, effective for many OSAS patients, is an orthodontic splint that brings the mandible and tongue forward (Bonham *et al.* 1988; Clark and Nakano, 1989) (Fig. 6). This is commonly preferred. Supine positioning of the patient during sleep may also be effective. Nasopharygeal tubes and surgical options including tracheostomy, uvulopalatopharyngoplasty, and mandibular advancement procedures should be only a last resort (Katsantonis *et al.* 1985; Riley, 1986; Thawley, 1985).

Chronic Obstructive Pulmonary Disease

The chronic obstructive pulmonary diseases include chronic bronchitis, emphysema, asthma, and cystic fibrosis, conditions that usually have significant elements of both airway obstruction and parenchymal lung disease. COPD is usually caused by cigarette smoking and it is the fifth leading cause of death in the United States. It affects 10~40% of all Americans and its incidence has doubled since 1970. Fifty percent of patients have activity limitations and 25% are

bed disabled (Higgins, 1988). With the aging of the general population, a significant increase in its prevalence is expected in the years to come.

Forced expiratory volume in one second (FEV_1) may decrease by 60 ml per year in COPD patients, a rate almost twice normal. Exertional dyspnea occurs most often when the FEV_1 is less than 1500 ml.

Dyspnea and exacerbations of respiratory insufficiency associated with respiratory infections or other acute medical conditions are the most frequent reasons these patients are admitted to the hospital, sometimes several times during the course of a year. This is even more likely for patients who retain CO_2 as well as have impaired oxygenation.

Reduction in dyspnea, increased maximum oxygen consumption and exercise tolerance, and fewer hospitalizations from respiratory impairment were observed in eight recently reviewed comprehensive pulmonary rehabilitation programs (Rondinelli and Hill, 1988). These significant improvements in quality of life may be sustained by continued rehabilitation goal-oriented activities. This is particularly important because patients with mild to moderate emphysema and chronic bronchitis without a major reversible component may survive 20 to 40 years.

A thorough presentation of the principles of evaluation and rehabilitation of chronic obstructive pulmonary disease patients is beyond the scope of this work. The reader is referred to standard text books devoted to this topic (Casaburi, and Petty, 1993; Haas *et al.* & Hodgkin, 1992). Three recent developments bearing on ambulatory management of these patients will be discussed: transtracheal oxygen delivery, respiratory muscle rest, and therapeutic exercise.

Transtracheal Delivery of Oxygen

Arterial pO_2 levels can decrease before an observed rise in pCO_2 because CO_2 diffuses more rapidly across the respiratory exchange membrane. Thus, hypoxia in the presence of normal or hyperventilation (pCO_2 less than 43 mmHg) characterizes intrinsic lung disease. Such Patients may develop overt respiratory failure with or without hypercapnia during acute pulmonary infections. Oxygen therapy should be used for these patients up to 24 hours a day if the pO_2 is less than 60 mmHg and oxygen delivery concentrations increased during exercise. Oxygen therapy decreases reactive pulmonary hypertension and polycythemia, improves cognitive function, and may decrease the frequency of hospitalizations and prolong life. Transtracheal oxygen delivery is best for continuous use. It avoids waste around the nose and mouth, avoids the "dead space" of the nasopharynx, and prevents discomfort and drying associated with nasal cannulas and face masks (Casaburi and petty, 1993).

Exercise and Ventilatory Muscle Rest

Despite high ventilation rates in COPD, the ventilatory response to both hypercapnia and hypoxia may be reduced. This is often exacerbated during sleep. The increase in pulmonary vascular resistance that occurs in the presence pulmonary tissue hypoxia is exacerbated by acidosis, and when severe, leads to right ventricular failure. The use of oxygen therapy alone exacerbates CO_2 retention and acidosis, and such patients may have respiratory muscle fatigue and hypoventilation at least in part corrected by periods of respiratory muscle rest by assisted ventilation. Techniques to assist ventilation have already been reviewed.

Braun and Marino (Braun, Marino 1984) studied 14 patients with severe chronic airflow limitation and CO_2 retention treated at home by daily negative pressure assisted ventilation for at least 5 months. During periods of unassisted breathing, these patients demonstrated a decrease in mean $PaCO_2$ from 54 mmHg to 45 mmHg, improvement in daytime arterial blood gases, improvement in vital capacity, relief of dyspnea, improved inspiratory and expiratory muscle strength, increased daily activity and a seven-fold reduction in yearly hospitalizations. Others have shown that body ventilator use three to six hours per day, one to three days per week can significantly improve pulmonary function and arterial blood gases (Crop and Dinarco, 1987). However, in a controled study Shapiro *et al.* demonstrated no benefit from a possibly inadequate regimen of 2 to 3 hours per day of body ventilator (Shapiro

et al. 1992). Since the majority of patients who use body ventilators overnight have significant periods of airway obstruction during sleep, and since such obstruction will increase respiratory muscle effort rather than decrease it, benefit would be most likely from daytime body ventilator use with the patient awake.

We have found that nasal and mouthpiece IPPV can also provide respiratory muscle rest for cooperative COPD patients. Electromyographic monitoring of diaphragm activity during mouthpiece or nasal IPPV demonstrates greater decrease in activity by these techniques than when using body ventilators. Since these methods are more convenient they may be preferred to the use of body ventilators in the future. The patients with more severe CO_2 retention may benefit the most since CO_2 retention itself has been demonstrated to decrease muscle strength (Juan *et al.* 1984).

Several studies have suggested better prognosis for COPD patients since 1975 when long term home tracheostomy IPPV became more Widespread (Hudson, 1983; Petty; Sadoul *et al.* 1986, Vanderbergh *et al.* 1968). As with patients with paralytic restrictive respiratory insufficiency, two groups of patients may be suited to ventilatory support at home. The first and smaller group includes those who reguire aid around the clock, usually by tracheostomy, but who are medically and psychologically stable. These patients tend, however, to require frequent hospital re-admission and to have a poorer prognosis than ventilator dependent patients with neuromuscular disease (Sadoul *et al.* 1986). The second group may benefit from nocturnal assistance alone. As with patients with progressive neuromuscular disease, patients with chronic hypercapnia during sleep are candidates for nocturnal assisted ventilation. Although in patients with paralytic restrictive respiratory insufficiency, nocturnal ventilatory support alone can prevent cor pulmonale and episodes of acute respiratory failure (Bach, in pressd; Bach and Alba, 1990; Bach *et al.* 1987; Bach *et al.* 1985), many patients with COPD also require supplemental oxygen therapy.

Although it is commonly observed that patients with mild to moderate disease do best in therapeutic exercise programs, positive results have been reported for exercise conditioning of a group of advanced COPD patients with hypercapnia (Foster *et al.* 1988); 117 of the 120 patients studied had FEV_1 less than 1 liter. Following rehabilitation and exercise re-conditioning there were statistically significant 7% to 8% improvements in pulmonary function variables including VC (120 ml), FEV_1 (40 ml), and maximum inspiratory pressures (3.1 cm H_2O). Arterial pCO_2, pO_2, PH, and maximum expiratory pressures did not change significantly. Initial VC, FEV_1 and maximum inspiratory pressures could not be predicted on the basis of the pCO_2 level but the higher the initial pCO_2 the more pCO_2 fell and pO_2 rose during the rehabilitation program. Ambulation distance increased very significantly for all patients. Patients' ability to perform activities of daily living changed in parallel with the walking distance. Although hypercapnic patients with COPD have weaker respiratory muscles than eucapnic patients (Stubbing *et al.* 1980; Rochester, Braun 1985), the fact that they tolerated a rigorous re-conditioning program suggests that exercise does not necessarily precipitate diaphragm fatigue in this population.

It may be that interspersing periods of respiratory muscle rest with exercise, a key principle in the pulmonary rehabilitation of patients with spinal cord injury (Huldtgren *et al.* 1980), may also be optimal for patients with COPD. Mechanical assistive breathing devices should be used when pCO_2 exceeds 50 mmHg or pO_2 fails to improve beyond 40 mmHg despite inhalation of 100% oxygen. Improved pulmonary function, daytime gases, increased vital capacity, decreased fatigue and increased well-being have been reported in programs providing respiratory muscle rest with exercise reconditioning (Braun *et al.* 1983; Gutierrez *et al.* 1980).

CONCLUSION

Manually assisted cough and mechanical insufflation exsufflation are important but underutilized ways to clear airway secretions. These methods are especially useful when used in conjunction with noninvasive IPPV to avoid intubation, or facilitate extubation and ventilator weaning. They can be used as much as 24 hours a day as alternatives to tracheostomy or body ventilator use. These techniques expedite community management of ventilator assisted

individuals by avoiding the need for invasive suctioning and ongoing wound care. For these techniques to be effective and to prevent further suppression of ventilatory drive, supplemental oxygen administration must be avoided unless pO_2 is less than 60 mmHg despite normlization of pCO_2. Custom molded interfaces for the delivery of noninvasive IPPV can also be used to deliver CPAP and Bi-PAP for patients with sleep disordered breathing. Noninvasive IPPV or body ventilator use can rest respiratory muscles and may also benefit patients with advanced COPD. These techniques when used in conjunction with pulmonary rehabilitation programs geared towards providing psychosocial support, patient eduction and exercise reconditioning are therapeutic options that significantly improve the quality of life of these patients. For both paralytic restrictive and obstructive pulmonary patients, these techniques decrease cost and frequency of hospitalizations.

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