Clinical Applications of Body Ventilators

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Interest has been increasing in providing ventilatory support in the home for patients with chronic respiratory failure, mainly with the use of positive pressure ventilation via a chronic tracheostomy. However, body ventilators that assist ventilation by applying intermittent negative or positive pressure to the thorax, abdomen, or airway without requiring an artificial airway, can offer distinct advantages for selected patients over systems requiring a permanent airway. These ventilators include the iron lung, portable lung (Portalung), pneumowrap, chest cuirass, pneumobelt, rocking bed, and positive pressure provided via a face or nose mask. They have successfully stabilized or reversed chronic hypercarbia when used intermittently in patients with slowly progressive chronic respiratory failure due to certain neuromuscular diseases and kyphoscoliosis. How they achieve this stabilization has not been clarified, but reversal of chronic respiratory muscle fatigue following periodic rest probably contributes. These ventilators are generally less effective than positive pressure ventilation through a tracheostomy and should be reserved for patients with relatively stable chronic respiratory failure and intact upper airways. However, they have the advantages of simpler operation and less expense, and they allow maintenance of a normal airway.

In recent years, there has been increasing interest in the use of home ventilators for patients with chronic respiratory failure. A number of recent reports dealing with the home management of ventilator-assisted patients have described the use of positive pressure ventilation via a chronic tracheostomy. However, other investigators have successfully supported patients with chronic respiratory insufficiency using intermittent ventilation provided by ventilators that require no airway intubation. These ventilators, referred to as body ventilators, include negative pressure ventilators and positive pressure devices administered via a face mask. The following discusses the mechanisms responsible for the success of assistance using these ventilators, practical clinical applications, and specific disease entities for which body ventilators have been found useful.

MECHANISMS FOR IMPROVEMENT IN RESPIRATORY STATUS FOLLOWING INTERMITTENT VENTILATORY ASSISTANCE

The contribution of muscle fatigue to acute respiratory failure has been established in recent years. Defined as an acute loss of contractile force after exhausting work, muscle fatigue occurs when the demand on the muscle for work exceeds its energy supply. The overburdened muscle generates large quantities of lactate and consumes much oxygen, but functions inefficiently, performing relatively little work.

In acute respiratory failure, respiratory muscle fatigue develops as the work of breathing increases to meet accelerating ventilatory demands. The muscle requires increasing portions of the cardiac output to meet mounting metabolic demands. Particularly when respiratory complications occur in the face of low cardiac output states such as cardiogenic shock, the demand for energy rapidly exceeds the supply, respiratory muscle fatigue ensues, and gas exchange deteriorates. Prompt institution of mechanical ventilation and rest of the respiratory muscles can interrupt the inevitable downward spiral toward death.

When respiratory failure is chronic, such as may occur in patients with COPD or neuromuscular diseases, the contribution of muscle fatigue to the respiratory system dysfunction is less clear than in patients with acute respiratory failure. There is no question that patients with either type of disease have compromised respiratory muscle function and are prone to frequent episodes of acute fatigue. The COPD causes hyperinflation, placing the respiratory muscles at a mechanical disadvantage, and neuromuscular disease causes progressive muscle weakness and associated chest wall deformities. When the muscle dysfunction is severe, these patients exist in a precarious balance with mini-
nal ventilatory reserve. Slight increases in energy demand precipitate acute muscle fatigue, and repeated bouts of acute muscle fatigue without adequate rest could lead to chronic respiratory muscle fatigue.

Whether chronic muscle fatigue actually contributes to respiratory failure in patients with chronic stable hypercapnia is unknown. The chronic respiratory failure in such patients could derive from failure of any component of the respiratory system, including the ventilatory control center, chemoreceptors, afferent and efferent nerves, respiratory muscles, chest wall, the lungs themselves, or more likely, some combination of these components. In addition, hypercarbia, hypoxemia, and malnutrition all decrease respiratory muscle strength and endurance and could contribute. Identification and quantification of the contribution of chronic muscle fatigue to chronic respiratory failure is hindered not only by the number of other factors that must be considered, but also by the lack of a precise definition. However, if we accept that chronic muscle fatigue refers to that component of respiratory muscle dysfunction that is reversible after rest in patients with chronic respiratory failure, then evidence for such a reversible component derives from several studies.

Garay et al reported sustained reversal of hypercarbia and mild improvement in pulmonary function following nocturnal ventilatory assistance in a group of eight patients with chronic respiratory failure due mainly to neuromuscular diseases or kyphoscoliosis. Curran, and Slaingard et al have also reported sustained reversal of hypercarbia in patients with Duchenne muscular dystrophy. Braun and Marino reported improved ventilatory mechanics in a group of 14 patients with severe COPD after five months of daily intermittent assisted ventilation. These studies demonstrate that the intermittent use of body ventilators can correct or improve gas exchange abnormalities in patients with chronic respiratory failure, often in association with improvement in respiratory muscle function. Rochester et al have observed marked reductions in the electrical activity of inspiratory muscles of patients with severe COPD or kyphoscoliosis during assisted ventilation using body ventilators, demonstrating that the muscles do indeed rest. The improvements in these patients brought about by intermittent ventilatory assistance may be due to the reduction of workload for the respiratory muscles and recovery from chronic fatigue.

Other factors may also contribute to the improvement. Atrophy of type 2 fibers and depletion of metabolites have been described in biopsy specimens of respiratory muscles from patients with chronic airway obstruction, suggesting a nutritional component that could be reversible. In addition, Bousos has proposed that chronic hypercapnia results partially from alterations in output from the respiratory control center. He postulates that the respiratory center alters the breathing pattern in an effort to minimize the work of breathing, avoiding extreme fatigue, but leading to chronic hypercapnia. Intermittent ventilatory assistance may increase ventilation sufficiently to decrease PaCO₂, allowing for a gradual resetting of the respiratory control center and a sustained improvement in gas exchange. Such an effect might be particularly important during sleep, when ventilatory assistance could prevent the expected rise in PaCO₂. The resulting improvement in gas exchange could directly improve respiratory muscle function by lessening the depressant effects of hypercapnia and hypoxemia on muscle contractility and endurance time.

In summary, the mechanisms responsible for the

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**Figure 1. Tank ventilator or "iron lung."**

J.H. Emerson Co, Cambridge, MA. Head of patient protrudes through neck collar on left. Movement of leather bellows (not visible) on opposite end of tank generates negative pressure. Hand crank to far right can be disengaged from pump motor and allows manual operation. Port-holes allow access to patient.
stabilization of patients with chronic respiratory failure by intermittent ventilatory assistance are not precisely known, but reversal of chronic muscle fatigue probably contributes. Reduction of chronic hypercapnia allowing resetting of the ventilatory center, maintenance of an improved level of gas exchange, and reversal of nutritional imbalances may also contribute.

**Practical Applications of Body Ventilators**

**Negative Pressure Ventilators**

Negative pressure ventilators apply intermittent subatmospheric pressure around the thorax abdomen, and periodically expand the chest wall and inflate the lungs. Exhalation occurs by passive contraction of the lungs due to elastic forces. The efficiency of such ventilators depends upon the surface area of the chest and abdomen over which the negative pressure is applied, and compliances of the lungs and chest wall.

The prototype negative pressure ventilator is the tank ventilator or "iron lung," first conceived by Dalziel in 1843 (Fig 1). The currently used model was developed during the late 1920s. The iron lung consists of a horizontal metal tank with side portholes, approximately 0.8 M wide, 2.5 M long, and weighing 325 kg. The patient rests inside on his back on a thin foam rubber mattress, and his head protrudes through a porthole at one end. A neck collar surrounding the porthole is tightened, and negative pressure is generated by a pump-driven leather bellows at the opposite end. Because the iron lung applies negative pressure to the patient's entire body, excepting the head, it is extremely efficient and reliable. In the past, it has been used to ventilate patients with acute respiratory failure due to congestive heart failure or pneumonia.

Ventilation with the iron lung is initiated by selecting a ventilatory rate some five to ten breaths below the patient's spontaneous rate (12 to 22 breaths per minute) and gradually increasing the negative pressure until "capture" occurs and the patient can no longer speak during the inspiratory phase (usually -7 to -15 cm H2O). The negative pressure is then adjusted until a desired minute volume is achieved. Arterial blood gas levels should be obtained after several hours of ventilation to make certain that the desired level of ventilation has been reached. Closure of a valve on the tank makes delivery of positive pressure during exhalation possible, but this option is generally reserved for assisted coughing.

In addition to its bulkiness, weight, and frightening appearance in the eyes of many patients, disadvantages of the iron lung include limited access to and immobility of patients inside. Restricted motion may cause persisting musculoskeletal back or chest pains that may respond to treatment with customized cushioning or anti-inflammatory drugs. Patients with skeletal deformities may experience difficulty fitting through the neck collar. Concerns have been raised in the past regarding adverse hemodynamic effects of negative pressure ventilation, but the effect is identical to that of positive pressure ventilation generating the same transpulmonary pressure. Despite the many drawbacks of the tank ventilator, its efficiency and reliability make it desirable for chronic ventilatory assistance, particularly in more severely compromised patients.

A modified version of the iron lung (Portalung) has recently been introduced (Fig 2). Designed by an individual with respiratory paralysis due to poliomyelitis who had used the iron lung for many years, it is constructed of fiberglass, is much smaller than the iron lung, and weighs approximately 45 kg. Otherwise, principles of operation and performance characteristics are nearly identical to those of the iron lung. It must be powered by a high volume negative pressure ventilator.

The "pneumowrap," "raincoat," "poncho," or "wrap" is another negative pressure ventilator that was developed during the poliomyelitis epidemics of the 1950s (Fig 3). Consisting of a wind-proof, water-permeable nylon parka suspended over a rigid plastic or metal chest-piece, it applies negative pressure over the anterior portion of the chest and abdomen, and is somewhat less efficient than the iron lung. The wrap is designed to function with a rigid backplate that improves its efficiency, but causes back discomfort and is
usually omitted. Patients must lie supine, and the device has a tendency to pull patients upward, frequently causing musculoskeletal back, chest, or shoulder pain. Coldness due to air circulation within the raincoat may occur but is ameliorated by placing a heater near the ventilator intake valve. Despite these shortcomings, the device is easy to apply and fit, is readily portable, and is a popular choice for intermittent ventilatory assistance.

. The chest cuirass, or "tortoise shell," has been in use for over 60 years and was extensively used during the polio epidemics of previous decades (Fig 4). It consists of a rigid shell fitting firmly over the anterior portion of the chest connected to a negative pressure ventilator. Because it applies negative pressure over a smaller surface area than either the iron lung or wrap, it is the least efficient of the negative pressure ventilators. Its efficiency improves if negative pressure is applied over both the chest and abdomen rather than the chest alone. Proper fitting can be a problem with the device, particularly in patients with kyphoscoliosis, and tailor-made fiberglass shells are often necessary. As with the other ventilators, musculoskeletal, back, and chest pains are a frequent problem, and skin abrasions can occur if fitting is not correct. Although ease of application and portability are attractive features, the cuirass ventilator lacks the efficiency of other negative pressure ventilators, and it may not adequately assist ventilation in obese, kyphoscoliotic, or severely compromised patients.

Typical settings and relative costs of these ventilators are shown in Table 1.

Ventilators That Displace Abdominal Contents

Ventilators that function primarily by exerting force on the abdomen and indirectly causing motion of the diaphragm include the rocking bed, first introduced as a resuscitative device during the 1930s, (Fig 5) and the intermittent abdominal pressure respirator or "pneumobelt," developed during the 1950s. Extensively used during the polio epidemics, the rocking bed functions by rocking the patient in a vertical axis over an arc of 40° to 45°, using the force of gravity upon the abdomen to effect diaphragmatic motion. When the head of the bed rocks downward approximately 15°, gravity pulls the patient's abdomen, and hence, the diaphragm cephalad and exhalation is assisted. Rocking upright approximately 30° moves the diaphragm caudal, assisting inhalation. Greater rocking arcs increase ventilation but become uncomfortable for the patient.

The rocking bed requires no special fitting, frees the patient from restricting appliances, and eases the administration of physical and respiratory therapy. Presumably because it rocks only in one plane, it does not cause motion sickness, and proper positioning of the patient's head and knees prevents sliding. Although patients usually find it comfortable to use, bulkiness, lack of portability, and relative inefficiency limit the broader application of the rocking bed.

The pneumobelt consists of a cloth corset containing an inflatable rubber bladder. The bladder portion is fitted over the abdomen and is inflated intermittently by a positive pressure ventilator. As shown in Figure 6, inflation of the bladder pushes abdominal contents
Table 1—Settings, Efficiency, Costs, Advantages and Disadvantages of Body Ventilators

<table>
<thead>
<tr>
<th>Settings*</th>
<th>Rate (Breaths/min)</th>
<th>Pressure (cm H2O)</th>
<th>Efficiency†</th>
<th>Costs‡ (dollars/mon)</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron lung</td>
<td>14-24</td>
<td>- 10–35</td>
<td>++</td>
<td>297</td>
<td>Reliable, efficient</td>
<td>Bulky, heavy</td>
</tr>
<tr>
<td>Porta lung</td>
<td>14-24</td>
<td>- 10–35</td>
<td>++</td>
<td>4000†</td>
<td>Efficient, Portable</td>
<td>Bulky</td>
</tr>
<tr>
<td>Pneumo wrap</td>
<td>14-28</td>
<td>- 15–45</td>
<td>+</td>
<td>110</td>
<td>Portable, easy fitting</td>
<td>Back &amp; chest discomfort</td>
</tr>
<tr>
<td>Chest shell</td>
<td>14-28</td>
<td>- 15–45</td>
<td>+</td>
<td>30</td>
<td>Portable</td>
<td>Difficult fitting</td>
</tr>
<tr>
<td>Pneumo belt</td>
<td>16-28</td>
<td>+ 15–45</td>
<td>+</td>
<td>33</td>
<td>Portable, adaptable to wheelchair</td>
<td>Requires upright position</td>
</tr>
<tr>
<td>Rocking bed</td>
<td>12-18</td>
<td>-</td>
<td>+</td>
<td>129</td>
<td>Comfortable, no restraints</td>
<td>Bulky</td>
</tr>
<tr>
<td>Positive pressure mask</td>
<td>14-24</td>
<td>+ 10–30</td>
<td>++</td>
<td>475††</td>
<td>Portable, wheelchair use</td>
<td>Few can adapt, secretions difficult to control</td>
</tr>
</tbody>
</table>

*Range of rates and pressures in common clinical use.
†Estimation of efficiency based upon relative tidal volume generated by given ventilator pressure. ++ = most efficient, ++ = less efficient, + = least efficient.
‡Costs for equipment only, based upon 1986 monthly rental rates, Life Care, Inc., Woburn, MA. Rental rates vary considerably between vendors.
§Monthly cost for ventilators must be added to costs for devices.
||Porta lung is not available for rental through Life Care, Inc. Purchase price is listed.
*§Cost for Moynihan 170 C negative pressure ventilator.
**Cost for Bantam Ventilator, Thompson Products, Boulder, CO.
††Cost for PLV100 positive pressure ventilator, Life Care, Inc.

inward, displacing the diaphragm upward, and assisting exhalation. Deflation of the bladder allows passive downward motion of the diaphragm. Tidal volume is proportional to the pressure applied to the abdomen via the corset, usually between 30 and 50 cm H2O. Because the downward motion of the diaphragm relies on gravitational forces, the pneumobelt functions effectively only when the patient is sitting or standing at an angle of approximately 30° or greater, and optimally at 75°. Hence, its nocturnal use is limited only to patients who can sleep sitting upright.

The pneumobelt comes in a variety of sizes, but fitting can be a problem. The corset should be firmly tightened and the upper portion should extend to the

Figure 5. Rocking bed (Emerson) shown in the head-down position, rocks on an axis situated at mid-bed level through an arc of approximately 40°. The head and knee portions of the bed have been adjusted upward slightly.
adjusted upward to compensate for air leakage through the nose, and aerophagia may occur. Despite these limitations, selected patients can learn to use the devices effectively, and the need for placement of a permanent airway can be postponed for years. Special flexible mouthpieces can also be installed on a wheelchair so that patients may assist their ventilation as needed during the daytime. Ease of application and portability make positive pressure mouth or nose ventilation an attractive alternative for patients with respiratory insufficiency, but many will find the devices intolerable.

Other Forms of Ventilatory Assistance

Two forms of ventilatory assistance not utilizing body ventilators or airway intubation will be discussed briefly. The first, glossopharyngeal or “frog” breathing, is a technique learned by individuals with respiratory compromise and intact upper airway structures, usually patients with neuromuscular disease that has spared bulbar structures. Glossopharyngeal breathing consists of gulping motions of the tongue and posterior oropharynx that force 50 to 60 ml boluses of air into the lungs. Repeated every 0.6 s, these gulps allow 600 ml tidal volumes every 10 s, and a 5 to 6 L minute ventilation that can be sustained for several minutes up to hours, depending upon the individual. Glossopharyngeal breathing can also be used to achieve vital capacities exceeding 2 L to assist in coughing. Unfortunately, although some patients learn glossopharyngeal breathing spontaneously, most find it difficult to learn and can sustain adequate levels of ventilation for brief periods only. Also, any reduction in lung or chest wall compliance, as may occur with kyphoscoliosis or obesity, will render the technique less effective. Nevertheless, it can be an important temporizing mode of ventilation in occasional patients, allowing increased independence.

The second form of ventilatory assistance, phrenic nerve pacing, is applicable to only a few special circumstances. Consisting of chronically implanted phrenic nerve electrodes powered transcutaneously by a radio transmitter, phrenic nerve pacing requires intact lower motor neurons and a functional diaphragm in a patient with dysfunction of the respiratory center or upper motor neuron. Hence, the technique is applied mainly to patients with central hypoventilation or high cervical cord lesions, freeing them from dependence upon artificial ventilators.

Selection of Body Ventilators for Individuals

General Guidelines

The initiation of ventilator use is by necessity a trial and error process. Although each patient will have specific needs and preferences that will help in narrow-
ing the alternatives, it is difficult to know beforehand which ventilator or combination of ventilators will work best. A variety of devices should be tried, and selection based upon demonstrated efficacy as well as patient preference. Also, the best time to initiate ventilatory assistance and optimal duration of ventilation use are not precisely known and probably depend upon the etiology of the respiratory insufficiency and other individual characteristics. In general, candidates for a trial of intermittent ventilation using body ventilators include patients with neuromuscular disease or kyphoscoliosis, intact upper airway function, and relatively stable respiratory failure (PaCO₂ > 45 mm Hg), or similar patients recovering from acute respiratory failure who have required emergency intubation and are weaning from positive pressure ventilation. Prior to initiation of the trial, the alternatives for ventilatory support should be discussed in detail with the patient and his family, and the option left open for refusing ventilatory support.

If the patient opts for ventilatory assistance, the trial should be performed in a monitored setting. Patients are usually very anxious when first using these unfamiliar devices, and although the devices interfere minimally with spontaneous breathing, frequent initial adjustments are often necessary. If possible, the trial should begin with smaller, less frightening ventilators such as the pneumobelt or pneumowrap. Alternatively, in more severely compromised patients, more efficient ventilators, such as the iron lung, may be required initially.

Following measurement of spontaneous breathing rate and minute ventilation, the ventilator rate is set slightly below the spontaneous rate, and assisted tidal volume is adjusted so that the assisted minute ventilation exceeds spontaneous by approximately 15 to 20 percent. Some coaching is usually required to get the patient to synchronize his breathing with that of the machine. If the ventilator is too uncomfortable, or if it fails to augment spontaneous breathing sufficiently, another ventilator is tried. Using this approach, it is usually possible to rapidly select acceptable ventilators and prepare the patient for intermittent ventilator use at home.

Close monitoring of gas exchange is generally unnecessary because the small increase in minute ventilation avoids severe hyperventilation, and patients can breathe spontaneously. Occasional patients with COPD have experienced obstructive apnea while using negative pressure devices during sleep, and initial nocturnal monitoring of oxygen saturation and end tidal PCO₂ may be advisable in patients with COPD. However, most patients can be monitored with occasional measurement of arterial blood gas levels.

Gas exchange should eventually improve with continued ventilatory assistance, PaCO₂ ideally remaining between 40 and 50 mm Hg during spontaneous breathing. Improvements in gas exchange may occur slowly over a period of days to weeks, (Hill N, unpublished observations), but failure of the device to consistently augment minute ventilation and to gradually improve gas exchange necessitates replacement with a more effective device. If PaCO₂ remains above 50 mm Hg after several weeks, increased time spent using the ventilator, addition of another ventilator for intermittent daytime use, or an adjustment in settings to increase assisted minute ventilation, may further lower the PaCO₂.

The above guidelines are somewhat arbitrary because the optimal application of body ventilators has not been rigorously evaluated, and modifications will be necessary for individual patients. Regimens at different centers vary with regard to selection criteria for patients, preferred ventilatory assist devices, and choice of initial settings. However, this general approach has been shown to effect long-term stabilization or reversal of chronic respiratory failure in selected individuals.44

USE OF BODY VENTILATORS IN THE MANAGEMENT OF SPECIFIC DISEASES

Neuromuscular Diseases

The greatest application of body ventilators has been to assist patients with slowly progressive neuromuscular diseases. Many of the ventilators were used extensively during the polio epidemics of the 1930s through the 1950s, even on patients with acute respiratory failure.59 Of course, respiratory failure caused by acute neuromuscular syndromes such as Guillain-Barré syndrome or myasthenia gravis is now usually managed with prompt intubation and positive pressure ventilation.33

Presently, patients with muscular dystrophies, particularly of the Duchenne, Becker, and limb-girdle types, comprise the group of patients most often managed with body ventilators.44 These patients undergo a progressive loss of respiratory function that correlates well with functional status and leads inexorably to respiratory failure.24 The onset of the respiratory failure is often insidious; patients may experience only morning headaches or nightmares, without dyspnea, despite arterial blood gas values showing marked hypercarbia.30 Arterial blood gas values should be monitored closely in these patients once severe restrictive lung disease (FVC <1L) develops, in an effort to identify deteriorating patients before terminal respiratory failure develops. Although randomized studies testing the efficacy of body ventilators in patients with muscular dystrophy have, for ethical reasons, never been done, body ventilators have improved gas exchange and functional status for up to seven years following the onset of severe hypercarbia in these
patients, and there can be no question that the ventilators prolong survival.

Patients who suffered bouts with paralytic poliomyelitis years ago and partially recovered are at risk for late deterioration and development of respiratory failure. Timely intervention with body ventilators may stabilize these patients. Bilateral diaphragmatic paralysis causes hypoventilation which may be reversed with body ventilators, particularly ones that function by displacing the diaphragm, such as the pneumobelt or rocking bed. Chronic respiratory failure caused by multiple sclerosis, acid maltase deficiency, or by a variety of other neuromuscular syndromes characterized by the gradual onset of respiratory failure, has also been managed with body ventilators.

Despite the success of body ventilators in stabilizing chronic respiratory failure in many forms of neuromuscular disease, patients must be evaluated carefully. Neuromuscular diseases affecting upper airway structures, such as amyotrophic lateral sclerosis (ALS), are generally better managed with tracheostomies and positive pressure ventilation if ventilatory support is to be instituted. Body ventilators are best reserved for patients with slowly progressive neuromuscular diseases, relatively stable hypercapnia, and intact upper airway and swallowing mechanisms.

**Kyphoscoliosis**

Kyphoscoliosis often occurs in association with neuromuscular disease, but, if severe enough, will alone lead to respiratory insufficiency. In general, curvature of the spine exceeding 100° results in dyspnea on exertion, and curvature exceeding 120° results in severe restrictive lung disease and ventilatory insufficiency. Kyphoscoliosis lowers chest wall compliance, increases the work of breathing, and predisposes to respiratory muscle fatigue and failure. Intermittent ventilatory assistance can be effective in sustaining ventilation. Unfortunately, the severe anatomic distortion accompanying kyphoscoliosis renders application of body ventilators very difficult. Patients may be unable to fit in the iron lung or pneumowrap due to this distortion, and fitting of the cuirass may require special molding. Severe kyphoscoliosis virtually precludes the use of the rocking bed or pneumobelt, and if the patient can tolerate it, mouth or nose positive pressure ventilation may be the best alternative.

**Chronic Pulmonary Disease**

Body ventilators are clearly beneficial when used to assist individuals with essentially normal lungs but abnormal respiratory muscles or chest walls. Long-term benefit in patients with abnormal lungs has not been so clearly demonstrated. However, because respiratory muscle fatigue contributes to respiratory failure in patients with severe COPD, body ventilators capable of resting the respiratory muscles would be theoretically beneficial. Although tank ventilators were used several decades ago to assist in the management of patients with acute exacerbations of COPD, experience with the long-term use of body ventilators in patients with stable severe COPD is limited. Braun and Marino demonstrated improvement in gas exchange and respiratory muscle function after patients with severe COPD used the pneumowrap for five months. However, more investigation will be necessary before we can determine the characteristics of patients with COPD who are likely to benefit from body ventilators, and what the effect on functional status and survival will be.

**Conclusions**

Body ventilators; devices that function by applying intermittent negative or positive pressure to the thorax, abdomen, or airway without requiring an artificial airway, have been used for many decades. There has been a resurgence of interest in them because they can stabilize or improve gas exchange when used intermittently in patients with slowly progressive chronic respiratory failure. They are particularly attractive for home use because they require little technical expertise and are less expensive than systems requiring tracheostomies.

Although it is unknown precisely how intermittent use of body ventilators improves gas exchange in chronic respiratory failure, reversal of chronic respiratory muscle fatigue and resetting of the respiratory center to a lower carbon dioxide level probably contribute. The optimal duration of ventilator use and whether respiratory muscles require complete or only partial rest are also unclear but may depend upon individual patient characteristics.

Selection of the appropriate ventilator or combination of ventilators requires consideration of the patient's illness, ventilatory status, body habitus, comfort, and personal desires, as well as ventilator efficiency, portability, and ease of fit. Patients should be given the option of refusing ventilatory assistance altogether, and should be able to breathe spontaneously for at least several consecutive hours if body ventilators are to be considered. In general, permanent tracheostomy and positive pressure ventilation are preferable for patients capable of only brief spontaneous breathing periods. When deemed candidates for body ventilators, patients should be allowed to try a variety of ventilators, and when a ventilator is selected, nocturnal use should be encouraged in order to maximize daytime independence. If necessary, ventilation can be assisted during the daytime with a pneumobelt or with positive pressure administered via a mouthpiece, face, or nose mask.
Body ventilators can improve gas exchange and forestall death or the need for permanent tracheostomy in patients with severe kyphoscoliosis or neuromuscular diseases such as muscular dystrophy. Although there is some evidence to suggest that body ventilators improve gas exchange and respiratory muscle function in patients with COPD, their role in the management of severe COPD remains to be clarified. The lesser cost and relative ease of operation of body ventilators can be significant advantages over ventilator systems requiring a tracheostomy in patients receiving only intermittent periods of ventilatory assistance in the home.

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