

NONINVASIVE VENTILATION

by Gary Ferguson, M.D.

Noninvasive ventilation may improve the breathing of some patients with chronic obstructive pulmonary disease (COPD). A trial of noninvasive ventilation is worth considering in COPD patients with high PaCO₂ who are doing poorly, have disrupted sleep, and require frequent doctor or hospital visits for shortness of breath despite otherwise optimal medical care.

Noninvasive ventilation helps to rest a patient's chest muscles, thereby helping a patient to breathe better.

An understanding of what noninvasive ventilation tries to accomplish is critical

to understanding which patients should receive this therapy and what benefits they may gain from it.

Oxygen therapy and ventilation correspond to the two distinct functions of the lungs: transfer of

oxygen to blood and removal of carbon dioxide from blood. Although patients with COPD may have deficits in both functions, they don't always fail in tandem. A patient with lung parenchymal damage secondary to severe pneumonia, for example, may have problems achieving adequate oxygenation, but usually has a normal ability to "blow off" carbon dioxide.

Such a patient only requires oxygen therapy. On the other hand, some patients cannot breathe sufficiently, which leads to an increased blood level of carbon dioxide. Non-invasive ventilation can help these patients get rid of excess carbon dioxide.

Ventilation Is Not Oxygen Therapy

Noninvasive ventilation and oxygen therapy have certain features in common, most notably the ability to improve a patient's blood gases. However, the two therapies differ significantly in their physiological action.



Patient using a pulmowrap at night for negative pressure ventilation.

UPDATE

**NONINVASIVE
VENTILATION**

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Benefits from Ventilation

Although the basis of the benefits that ventilatory support provides to patients is somewhat uncertain, noninvasive ventilation appears to allow patients to rest their breathing muscles.

Ventilation may also reset the carbon dioxide "thermostat" of a patient's brainstem, the central nervous system structure that controls breathing.

COPD patients have an abnormally increased breathing workload because of their underlying lung disease. Patients with COPD face the risk of overtaxing their breathing muscles by the increased work of breathing. In addition, COPD causes abnormal changes in the shape and configuration of breathing muscles that make them less functional. Finally, many COPD patients have breathing muscles that are reduced in size because of malfunction and metabolic problems. The sum of these effects is that the strength and endurance of the breathing muscles are clearly reduced in COPD patients, and these patients face an increased risk of developing muscle fatigue.

Some patients cannot breathe sufficiently, which leads to an increased blood level of carbon dioxide. Noninvasive ventilation can help these patients get rid of carbon dioxide.

Although the risk of muscle fatigue in COPD patients is great, few patients with elevated carbon dioxide levels have overt respiratory muscle fatigue. We hypothesize that in many patients the development of breathing muscle fatigue is avoided by a messenger-like factor that originates in the overworked breathing muscles. This factor signals the brainstem to reduce the patient's breathing and tolerate a higher blood CO₂ level, thereby avoiding overt fatigue and failure of the breathing muscles.

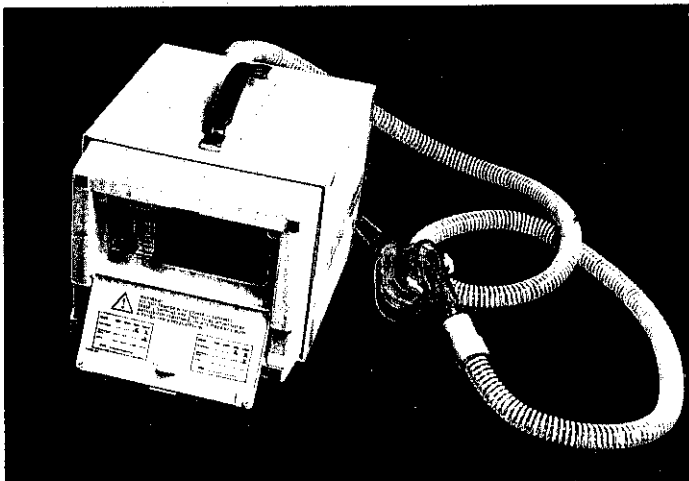
Noninvasive ventilation helps to rest a patient's breathing muscles, thereby helping a patient to breathe better. The blood CO₂ level drops, and the brainstem's sensitivity to CO₂ is reset back toward normal. As a result, most patients feel better, have less dyspnea, and appear to have fewer problems sleeping.

Who Benefits from Ventilation?

Despite the theoretical benefits that ventilation can achieve in COPD patients, in practice the therapy has had mixed results. Our group is now involved in research efforts aimed at determining why some COPD patients respond to ventilation and others don't. Most of the medical literature that documents success using ventilation consists of anecdotal reports of series of perhaps 5-20 patients who underwent negative-pressure therapy.

Noninvasive ventilation provides clinical benefit to only a small percentage of COPD patients. About three quarters of the COPD population won't benefit from ventilation because they do not have the appropriate indications, and should not even be started on therapy. A trial of ventilation should be limited to the COPD patients who have an elevated blood CO₂ level, and severe dyspnea or a general failure to thrive.

At National Jewish, we usually identify candidates for ventilatory support in our pul-



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Custom-made nasal mask and headgear for positive-pressure ventilation.

monary rehabilitation clinic. We flag patients who have not responded to their rehabilitation program, medications, and oxygen therapy. Any patient with a PCO_2 of more than 45 mmHg is a potential candidate for ventilation therapy; the normal value for PCO_2 is less than 40 mmHg. In general, the higher a patient's PCO_2 , the better are the chances that the patient will respond to ventilation.

However, even patients who meet the elevated CO_2 criteria may not always respond, and no well-established criteria currently exist for distinguishing likely responders from those who will fail. It appears that the best responders are patients whose bodies do not like living with an elevated PCO_2 . This manifests as dyspnea, disrupted sleep, and the need for frequent hospital or physician visits.

Patients who tend to fail are those whose bodies seem to have adjusted to a high PCO_2 by breathing slower. These patients feel fine the way they are, derive little benefit from ventilation therapy, and are unlikely to comply with such therapy if it is prescribed. In contrast, symptomatic patients are more likely to respond, and tend to be more compliant.

Types of Noninvasive Ventilation?

Noninvasive ventilation is a family of methods that, as the name suggests, helps

patients draw air into their lungs without introducing any tubing or other device into the patient's body. Noninvasive ventilators fall into two broad categories: those that rely on negative pressure, and, positive-pressure devices.

Negative pressure units act externally on the chest and abdomen, cyclically expanding the chest wall so that the pressure inside the chest becomes less than the ambient atmospheric pressure, thereby helping to inflate the patient's lungs. Expiration is a passive event that results from the elastic recoil of the lungs and chest wall. The best-known negative pressure machine is the iron lung, which was widely used several decades ago to treat polio patients. Polio patients were, in fact, the first population to undergo treatment with noninvasive ventilation.

The most common negative-pressure apparatus used today is the pneumowrap. It consists of an open mesh cage that surrounds the patient's chest, and which in turn is covered by a large shirt that fits over the cage and chest. A small vacuum device that is attached to the shirt periodically exerts negative pressure on the exterior of the chest cavity, thereby causing inspiration for air into the lungs.

Until the late 1980's, negative-pressure devices offered the only form of noninvasive ventilation available. More recently, doctors have also had the option of using positive-pressure ventilators, which rely on a compressor to push air into a patient's lungs. These units are small, easy to use, and may be used with a nasal mask rather than the endotracheal or tracheostomy tubes of invasive ventilators.

About three quarters of the COPD population won't benefit from ventilation because they do not have the appropriate indications, and should not even be started on therapy.

Selecting the Ventilation Device

Although the concept has only gained acceptance in the last five years, the noninvasive use of positive-pressure ventilators has now superseded negative-pressure treatment for COPD. Positive-pressure units are simpler

to operate. After learning how to use the machinery, patients can manage their therapy by themselves with only a maintenance visit from a technician every couple of months. The nasal mask used with positive-pressure

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devices is easy for patients to put on and take off, and it provides superior ventilation compared to negative-pressure units. Negative-pressure ventilation may be useful in patients

who cannot tolerate a nasal mask, such as patients who are claustrophobic.

Two types of positive-pressure machines are available: a volume-cycled ventilator, and the newer, pressure-support, or BiPap[®] ventilator. A volume-cycled unit is adjusted to deliver a specific volume of air, such as 500ml, to the patient during each breath. Another setting for this machine specifies the breathing rate, such as 20 times a minute. The pressure-support device is set to deliver a specific air pressure, such as 10 cm of water, at a certain rate. The patient determines the volume of each breath by deciding when to stop inspiration.

The decision for which type of positive-pressure device to initially prescribe for a patient is arbitrary. Some patients will feel more comfortable with one device or the other, but it is difficult to predict.

We tend to start patients with the pressure support unit, because it is somewhat simpler and easier to maintain. All a patient has to do is strap on the nasal mask and flip a switch. If patients don't feel comfortable on pressure support, we try a volume-cycled unit.

The medical literature indicates that negative-pressure devices, such as the pneumowrap, are generally less effective for resting breathing muscles compared to positive-pressure units. If a patient fails treatment with both pressure-support and volume-cycled units, a trial of negative pressure may be called for, but the chances that it will succeed are low.

Using Ventilation Therapy

Patients may derive significant clinical benefit from ventilation support even if their PCO₂ does not return to normal, especially if they have severe hypercapnia when starting treatment. For example, a patient who starts with a PCO₂ of 60 mmHg will notice significant improvements in function and dyspnea when, after several weeks of positive pressure ventilation, the PCO₂ is lowered to only 47 mmHg. In fact, it is better for the severely hypercapnic patient not to return to normal too quickly.

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Management?"

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Ventilation support is most often used only at night, while the patient is asleep. In fact, an issue that is now under study is whether most patients need treatment every night, or whether they can derive almost as much benefit from using their device only once or twice a week. Until this question is answered,

The noninvasive use of positive pressure ventilators has now superseded negative pressure treatment for COPD.

nightly treatment remains the standard of care. However, it is usually acceptable for patients to stop using their ventilator when they go on a brief trip, so that they do not need to carry the machinery with them.

Patients who need ventilatory support should understand that they may have to continue to use a machine for the rest of their lives. So far there is little data available on patient outcome if ventilation is withdrawn.

Because a ventilator is only used at night, its use may cause less psychologic trauma than oxygen therapy, which patients also need to use during the day. Indeed, patients often have an improved mental state after starting ventilation because of the benefits of reducing their PCO_2 .

The cost of ventilation support is generally covered by insurers, including Medicare and Medicaid. A typical rental fee is \$1,000 - 1,500 per month, which means that an insured patient's out-of-pocket expense may be \$200 - \$300 monthly.

The introduction of pressure-support devices has made these traditional rental fees controversial, because a new pressure-support unit only costs about \$6,000. Patients may therefore want to consider buying their device. This route will, of course, preclude the availability of technical support and upgrades to newer models, but pressure-support units are very simple to use and require little maintenance.

It is important to reemphasize that ventilator therapy is not a first-line therapy, and should only be considered for COPD patients

who continue to have dyspnea and do poorly despite pulmonary rehabilitation, medication, and oxygen therapy. Another point to remember is that only a fraction of COPD patients can be expected to improve with ventilation. About a quarter of patients with severe COPD have the elevated PCO_2 that makes them candidates for ventilation.

Among this 25% of patients, perhaps half would tolerate, and clinically improve with, ventilation. And for these responders, about half will do best with a pressure-support device; the other half will prefer a volume-cycled unit.

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