VIDEOS IN CLINICAL MEDICINE
SUMMARY POINTS

Noninvasive Positive-Pressure Ventilation

Christopher R. Kelly, M.D., Andrew R. Higgins, M.D., and Subani Chandra, M.D.

The following text summarizes information provided in the video.

OVERVIEW

The delivery of positive-pressure–ventilator support without an endotracheal tube was first studied in the 1930s.[1] Now known as noninvasive positive-pressure ventilation (NPPV), it can be used to manage both acute and chronic respiratory failure. In certain patient populations, NPPV offers the benefits of mechanical ventilation without the risks associated with intubation.[2] All health care providers prescribing this therapy must be familiar with patient-selection criteria, the available equipment, and the appropriate ventilator settings. The accompanying video reviews these issues, with a focus on acute respiratory failure.

In common use, the term NPPV refers to bilevel positive airway pressure (BPAP). In BPAP, the ventilator cycles between an expiratory positive-airway pressure (EPAP) and an inspiratory positive-airway pressure (IPAP), with the difference providing support that augments tidal volumes and thereby increases ventilation. The tidal volume correlates with the difference between the inspiratory and expiratory pressures and with other factors, such as the inspiratory time, the patient's inspiratory effort, and the mechanical characteristics of the patient's airways and lungs.

Another frequently used means of providing positive airway pressure is continuous positive-airway pressure (CPAP). In CPAP, the ventilator delivers a constant airway pressure throughout the respiratory cycle. Some ventilators automatically reduce the airway pressure during expiration to increase patient comfort. Although CPAP does not provide additional pressure during inspiration and therefore does not directly support ventilation, it has some effects (such as alveolar recruitment) that can indirectly improve ventilation.

From New York–Presbyterian Hospital, Columbia University Medical Center, New York. Address reprint requests to Dr. Kelly at the Department of Medicine, New York–Presbyterian Hospital, Columbia University Medical Center, 622 W. 168th St., PH-342, New York, NY 10032, or at crk2002@columbia.edu.

N Engl J Med 2015;372:e30.
DOI:10.1056/NEJMvcm1313336

INDICATIONS

BPAP should be considered in patients with respiratory distress. Clinical signs include dyspnea, tachypnea, and the use of accessory muscles of respiration. The measurement of arterial blood gas may reveal acidemia (arterial pH, <7.35), hypercapnia (partial pressure of carbon dioxide [Pa_{CO_2}], >45 mm Hg), or hypoxemia (e.g., ratio of the partial pressure of arterial oxygen [Pa_{O_2}] to the fraction of inspired oxygen [FI_{O_2}], <200).

Multiple randomized, controlled trials have proven the benefits of BPAP in patients with hypercapnic respiratory failure resulting from an acute exacerbation of chronic obstructive pulmonary disease (COPD)[3] and the benefits of both BPAP and CPAP in patients with cardiogenic pulmonary edema in the absence of shock or ischemia.[4] BPAP has been shown to benefit patients with immune compromise, fever, and pulmonary infiltrates who have acute hypoxemic respiratory failure.[5] It has also been shown to facilitate the transition from invasive ventilation to spontaneous breathing in patients with COPD.[6-7] There is currently insufficient evidence to recommend BPAP for the management of severe exacerbations of asthma, pneumonia, the acute respiratory distress syndrome, postoperative respiratory failure, respiratory failure in patients with do-not-intubate orders, and the palliation of respiratory distress in terminally ill patients, but these applications are areas of active investigation.[8-11]

Figure 1. **Oronasal Mask.**
The oronasal mask is the mask most frequently used to provide noninvasive airway access. It has a silicone cushion that forms a seal around the nose and mouth.

Figure 2. **Total-Face Mask.**

Figure 3. **Nasal Mask.**

Figure 4. **Nasal Pillows.**

CONTRAINDICATIONS

The only absolute contraindications to BPAP and CPAP are cardiac arrest and respiratory arrest. Relative contraindications include discomfort from the mask that cannot be resolved with adjustments, a high risk of aspiration because of impaired mental status (except when the impairment is due to hypercapnia), a large volume of secretions, recurrent vomiting, and recent upper-airway or upper gastrointestinal surgery.

EQUIPMENT

Interface

The defining feature of BPAP and CPAP is the interface between patient and ventilator that provides noninvasive airway access. In most cases, this interface is a mask.

Many types of masks are available, but in urgent care situations, the oronasal mask (Fig. 1) is the most commonly used. This mask has a silicone cushion that forms a seal around the nose and mouth. If applied too tightly, however, the oronasal mask can be uncomfortable and may abrade the skin on the bridge of the nose. Alternatives include total-face masks, nasal masks, and nasal pillows. The total-face mask (Fig. 2) encompasses the entire face, including the eyes.[12] It does not abrade the nose, but some patients may find it claustrophobic. The nasal mask (Fig. 3) and nasal pillows (Fig. 4) generally cause less claustrophobia, but the mouth must remain closed to prevent air leakage.[12,13]

Ventilators

Noninvasive ventilators for inpatients typically have a variety of ventilation settings, alarm settings, and ventilation modes (BPAP or CPAP). Most ventilators display real-time information about the patient's breathing in both numeric and graphic formats, including the phase of the respiratory cycle, the respiratory rate, tidal volume, minute ventilation, peak inspiratory pressure, and volume of air leak.

The available settings depend on the mode being used. In CPAP mode, the basic settings include CPAP itself and F_{IO_2}. In BPAP mode, the basic settings include IPAP, EPAP, and F_{IO_2} (Fig. 5). BPAP is most often delivered in the combination spontaneous-and-timed, or S/T, mode, in which the settings also include the minimum respiratory rate and the inspiratory time, or I-time. If the patient's respiratory rate is slower than the minimum rate, the ventilator triggers the additional breaths at regular intervals, delivering IPAP for the duration of the I-time. If the patient's respiratory rate is faster than the minimum rate, the patient triggers all breaths, and the ventilator delivers IPAP whenever spontaneous inspiration is detected. The ventilator can cycle between EPAP and IPAP in response to the patient's spontaneous breathing effort or after a prespecified interval of time.

PROCEDURE

When a patient is in respiratory distress, provide initial support and call for the help of a trained respiratory therapist, who can set up the ventilator and troubleshoot any technical problems. If time permits, obtain a baseline measurement of arterial blood gases. Describe the essential features of BPAP to the patient. Doing so usually helps decrease anxiety and may improve tolerance of the treatment.

To prepare the ventilator, first select the mode. Patients with hypercapnic respiratory failure resulting from COPD should receive BPAP. Patients with cardiogenic pulmonary edema without shock or ischemia may receive either CPAP or BPAP, since both provide positive end-expiratory pressure, which is beneficial in ventricular dysfunction. If the patient has hypercapnia, however, BPAP is more appropriate.

Enter the initial settings. Start with low pressures and adjust the pressures upward as needed. If BPAP is being used, set the initial inspiratory and expiratory pressures to 10 cm and 5 cm of water, respectively. Accept the settings to activate the mode.

Put the mask on the patient. Be sure the straps are tight enough to secure the mask but do not cause unnecessary discomfort. You should be able to place two fingers easily between the straps and the patient's head. The mask should fit comfortably over the nose and mouth without extending beyond the chin. If the patient is uncomfortable, or if a large air leak is noted, reposition the mask or use a mask of a different size or type.

Adjust the alarms in accordance with the clinical scenario and ventilator settings. Assess the patient whenever an alarm occurs.

Monitor the patient's symptoms and vital signs closely, and address any ventilator-related complications as needed (Table 1). Adjust the F_{IO_2} to achieve the desired oxygen saturation. Measure arterial blood gases again after 30 minutes to determine whether any further changes to the ventilator settings are required. If there is persistent hypercapnia, increase the minute ventilation by changing either the tidal volume or the respiratory rate. Recall that the tidal volume will increase as the difference between the IPAP and EPAP increases. Note that increasing the minimum respiratory rate will affect ventilation only if the patient's rate of spontaneous breathing is slower than this rate.

If there is persistent hypoxemia, increase either the fraction of inspired oxygen or the EPAP. Note that if the EPAP is increased, the IPAP should be increased proportionally so that the amount of pressure provided in support of breathing does not change.

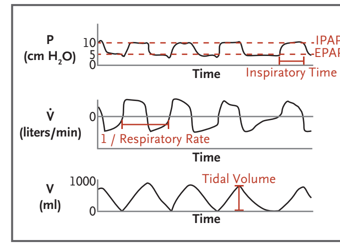

Figure 5. Display of Real-Time Data in a Standard Noninvasive Ventilator in BPAP Mode.

Current ventilators can graphically represent airway pressure (P), air flow (V̇), and tidal volume (V) over time. In bilevel positive-airway-pressure (BPAP) mode, these waveforms are determined by factors that include the inspiratory positive-airway pressure (IPAP), expiratory positive-airway pressure (EPAP), respiratory rate, and inspiratory time. BPAP is often delivered in the spontaneous-and-timed, or S/T, mode, in which the ventilator delivers a mandatory breath if the patient's spontaneous respiratory rate is slower than a prespecified rate. The duration of the inspiratory portion of the mandatory breath is equal to the prespecified inspiratory time.

Table 1. Complications Associated with Noninvasive Ventilation and Suggested Responses.

Complication	Response
Air leak	Ensure that the mask is the correct size and has been fitted correctly.
	Use a mask of a different size or type.
	Tighten the straps.
	Reduce airway pressures, if possible.
Skin irritation or abrasion	Loosen the straps.
	Use a mask of a different size or type.
	Apply artificial skin or a dressing over the affected area.
Claustrophobia	Redirect the patient by having the patient watch television, talking to the patient, or having a family member talk to the patient.
	Use a less obtrusive mask (e.g., nasal pillows).
	Consider inducing light sedation in the patient.
Nasal congestion, sinus pain, or ear pain	Provide topical decongestants or antihistamines if there are no contraindications.
	Humidify the inspired air.
	Reduce airway pressures, if possible.
Mucosal dryness	Humidify the inspired air.
	If a nasal mask is being used, apply a chin strap to reduce air flow through the mouth.
Mucus plugging	Humidify the inspired air.
	Give the patient brief breaks from ventilation, if possible, and perform maneuvers that will help to clear the airway, such as chest percussion.
	Reduce airway pressures, if possible.
Pulmonary barotrauma or pneumothorax	Stop ventilation or, at minimum, reduce airway pressures. Insert chest tube, if appropriate.

If the patient has persistent respiratory distress despite adjustments to the ventilator or mask, or if a contraindication to BPAP develops, such as vomiting, perform endotracheal intubation immediately. In contrast, if respiratory failure is reversed with BPAP, the level of ventilatory support can be reduced until the patient is ready to attempt spontaneous breathing again.

SUMMARY

NPPV can help to stabilize the condition of patients with acute respiratory failure and prevent the need for intubation. The patients most likely to benefit include those with acute hypercapnic respiratory failure caused by a COPD exacerbation and those with cardiogenic pulmonary edema in the absence of shock or ischemia.

No potential conflict of interest relevant to this article was reported.
Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

REFERENCES

1. Barach AL, Martin J, Eckman M. Positive pressure respiration and its application to the treatment of acute pulmonary edema. Ann Intern Med 1938;12:754-95.
2. Mehta S, Hill NS. Noninvasive ventilation. Am J Respir Crit Care Med 2001;163:540-77.
3. Brochard L, Mancebo J, Wysocki M, et al. Noninvasive ventilation for acute exacerbations of chronic obstructive pulmonary disease. N Engl J Med 1995;333:817-22.
4. Gray A, Goodacre S, Newby DE, Masson M, Sampson F, Nicholl J. Noninvasive ventilation in acute cardiogenic pulmonary edema. N Engl J Med 2008;359:142-51.
5. Hilbert G, Gruson D, Vargas F, et al. Noninvasive ventilation in immunosuppressed patients with pulmonary infiltrates, fever, and acute respiratory failure. N Engl J Med 2001;344:481-7.
6. Ferrer M, Sellarés J, Valencia M, et al. Non-invasive ventilation after extubation in hypercapnic patients with chronic respiratory disorders: randomised controlled trial. Lancet 2009;374:1082-8.
7. Esteban A, Frutos-Vivar F, Ferguson ND, et al. Noninvasive positive-pressure ventilation for respiratory failure after extubation. N Engl J Med 2004;350:2452-60.
8. Lim WJ, Mohammed Akram R, Carson KV, et al. Non-invasive positive pressure ventilation for treatment of respiratory failure due to severe acute exacerbations of asthma. Cochrane Database Syst Rev 2012;12:CD004360.
9. Nava S, Ferrer M, Esquinas A, et al. Palliative use of non-invasive ventilation in end-of-life patients with solid tumours: a randomised feasibility trial. Lancet Oncol 2013;14:219-27.
10. Schettino G, Altobelli N, Kacmarek RM. Noninvasive positive pressure ventilation reverses acute respiratory failure in select "do-not-intubate" patients. Crit Care Med 2005;33:1976-82.
11. Zarbock A, Mueller E, Netzer S, Gabriel A, Feindt P, Kindgen-Milles D. Prophylactic nasal continuous positive airway pressure following cardiac surgery protects from postoperative pulmonary complications: a prospective, randomized, controlled trial in 500 patients. Chest 2009;135:1252-9.
12. Girault C, Briel A, Benichou J, et al. Interface strategy during noninvasive positive pressure ventilation for hypercapnic acute respiratory failure. Crit Care Med 2009;37:124-31.
13. Navalesi P, Fanfulla F, Frigerio P, Gregoretti C, Nava S. Physiologic evaluation of noninvasive mechanical ventilation delivered with three types of masks in patients with chronic hypercapnic respiratory failure. Crit Care Med 2000;28:1785-90.