

Noninvasive Positive-Pressure Ventilation: The Little Things Do Make the Difference!

The application of noninvasive positive pressure, either as continuous positive airway pressure or noninvasive positive-pressure ventilation (NPPV), has become established as the primary approach for ventilatory support in a number of clinical settings.¹ In fact there are at least 15 randomized, controlled clinical trials evaluating the effect of NPPV in the management of acute exacerbations of chronic obstructive pulmonary disease (COPD).² These data have demonstrated that NPPV during a moderate or severe acute COPD exacerbation decreases the incidence of endotracheal intubation, duration of mechanical ventilation, duration of intensive care unit (ICU) stay, duration of hospitalization, hospital costs, and, most importantly, mortality.^{2,3} Additional data, although not as compelling as the above, support the use of NPPV in the management of acute cardiogenic pulmonary edema, acute respiratory failure in immunocompromised patients, patients awaiting lung transplantation, and as a bridge between invasive ventilation and spontaneous unsupported breathing.¹ Clearly, NPPV is the standard of care for the management of acute respiratory failure in many of these circumstances. However, in many institutions the success rate for NPPV is much lower than that demonstrated in the literature.

SEE THE ORIGINAL STUDY ON PAGE 922

The reason for this lack of success is not the technique itself but all of the little things that go into a successful NPPV program. The most important issues in a successful NPPV program are the education of the staff providing NPPV (therapists, physicians, and nurses) and the approach used during the initial application of NPPV.

Education

All involved in the care of patients receiving NPPV should fully understand the indications, benefits, problems, and concerns associated with NPPV. If a member of the patient care team does not fully understand why and how NPPV is used, a single comment to the patient or family or an inappropriate action during patient care can turn a potential successful NPPV application into a failure.

Initial Application

Those ordering and applying NPPV should each physically and personally try to breathe with the application of NPPV in order to understand what the patient is experiencing! Staff would then understand that you should not order a specific positive end-expiratory pressure and pressure support level for a given patient without first applying NPPV and adjusting the device to the patient's response. Not all patients can be managed with 5 cm H₂O positive end-expiratory pressure and 8 cm H₂O pressure support, or any other specific combination. Yes, that is done, but if the application is not titrated to the patient's response and tolerance, then successful application will be limited.

Initial application of NPPV requires careful instruction of the patient. To obtain the patient's full cooperation he or she must understand the reason for using NPPV and the desired outcome: to avoid intubation. The initial pressure applied should be < 5 cm H₂O and the mask should be held (not strapped) to the patient's face, ideally by the patient. Remember, these patients are short of breath and fighting for each breath. They are frightened and claustrophobic. Pressure should only be increased as the patient's tolerance of NPPV improves. The goal during this initial application period is to gain the patient's confidence and acceptance of NPPV. Allowing the patient or caregiver to hold the mask allows the mask to be rapidly removed to accommodate the patient's questions and concerns. With some patients, practitioners must spend 1–2 hours working with the patient for NPPV to be successful. Yes, this is time-consuming, but the cost savings are large compared to the alternative, intubation. As the patient accepts the NPPV, pressures are increased to reach the gas exchange goal, but peak pressures should not exceed 20 cm H₂O, to minimize the risk of gastric distention and vomiting. Yes, everyone swallows some air during NPPV, but clinically important gastric distention is usually not a problem unless peak pressure exceeds 20–25 cm H₂O (gastric opening pressure). The placement of a nasogastric tube should not be necessary simply to provide NPPV. The presence of a nasogastric tube decreases the likelihood of the patient tolerating NPPV.

The Mask

Does the mask used to apply NPPV impact outcome? This is clearly a controversial issue. NPPV has been successfully applied with both nasal and full-face masks during acute COPD exacerbations.¹⁻³ Nasal pillows have been used to a lesser extent in the acute care setting than have full-face masks. In this issue of *RESPIRATORY CARE* there is a randomized, controlled trial by Antón et al,⁴ who compared NPPV via nasal mask versus via full-face mask with 14 COPD patients suffering mild COPD exacerbations. The authors indicate that there was no difference between nasal and full-face mask during NPPV, except for a greater decrease in respiratory rate with the full-face mask. However, I believe the authors have underappreciated the importance of that respiratory rate difference. The respiratory rate was 21.7 ± 5 breaths/min in the nasal mask group and 26.8 ± 4.4 breaths/min in the full-face mask group before NPPV. The change in pH and P_{CO_2} was the same with the 2 masks they studied, as was the change in pleural pressure and transdiaphragmatic pressure. But the change in respiratory rate with NPPV was greater with the full-face mask (26.8 breaths/min lowered to 17.7 breaths/min—a 9 breaths/min decrease) than with the nasal mask (21.7 breaths/min lowered to 18 breaths/min—a 4 breaths/min decrease).

It is unfortunate that Antón et al did not calculate the esophageal and transdiaphragmatic pressure-time product change per breath and, more importantly, per minute. Since the decrease in respiratory rate was significantly greater with the full-face mask than with the nasal mask, I would expect the esophageal and transdiaphragmatic pressure-time product per-minute-change also to favor the full-face mask. Thus, I disagree with the authors' interpretation of their results. The full-face mask resulted in a greater short-term physiologic benefit in those COPD patients who were not in marked distress, and that benefit was achieved in just 15 minutes.

The results from Navalesi et al⁵ also support the use of full-face masks. With a series of 26 stable hypercapnic patients they randomly compared, for 30-min periods, full-face masks, nasal masks, and nasal pillows. They found that minute ventilation was higher with the full-face mask because of an increase in tidal volume. P_{aCO_2} was significantly lower with the full-face mask or nasal pillows, whereas the nasal mask was best tolerated. Kwok et al⁶ also compared the nasal to the full-face mask, with a series of patients in acute respiratory failure. They found that all variables except for patient tolerance were similar between the 2 masks. There was no significant difference with regard to intubation rate or mortality, but patients tolerated the full-face mask significantly better than the nasal mask.

To further add to this controversy, in each of these studies⁴⁻⁶ only 1 mask of each type was evaluated. In our experience no single full-face or nasal mask is well tolerated by all patients. In fact, I would recommend taking various types and sizes of nasal and full-face mask to the bedside to ensure that the mask used best corresponds to the patient's facial anatomy.

Most recently Schettino et al,⁷ using a lung model, demonstrated that moving the exhalation port of noninvasive bi-level pressure ventilation systems to the bridge of the nose of the mask decreased the rebreathed CO_2 volume and lowered the pressure necessary to decrease the P_{aCO_2} . In addition, the mask with the lowest dead space resulted in the lowest CO_2 rebreathing with each exhalation port location.

In the 3 comparative studies⁴⁻⁶ a Whisper Swivel exhalation port was always used. It is interesting to speculate whether the results of these studies would have been different with different masks. My personal bias with regard to patients suffering acute respiratory failure is to use a full-face mask, ideally with the exhalation port at the bridge of the nose. With a stable COPD patient or a patient suffering a mild exacerbation either are acceptable, based on patient tolerance. Stressed patients always breathe through their mouths, so leak is much greater with a nasal than with a full-face mask. Kwok et al⁶ strongly coached patients to breathe through their noses and used chinstraps to avoid leaks with the nasal mask.

The Ventilator

The choice of mechanical ventilator is also a concern during NPPV. Theoretically any mechanical ventilator can provide NPPV. However, during an acute exacerbation success is more likely if (1) patient-ventilator synchrony can be easily determined, (2) fraction of inspired oxygen (F_{IO_2}) can be easily adjusted, and (3) problems with ventilation are monitored and alarmed. Pressure, flow, and volume waveforms make it much easier to identify asynchrony. In the United States the only ventilators designed to compensate for leaks during NPPV are those designed to provide NPPV, but many of those units do not show waveforms and are poorly monitored and alarmed. The ICU ventilators meet all of the stated criteria but do not compensate for leaks. Using an ICU ventilator requires careful assessment of the transition from inspiration to expiration. Some new ICU ventilators allow adjustment of inspiratory termination criteria, which improves the ventilator's ability to respond appropriately to leaks.

The Mode

With those ICU ventilators on which inspiratory termination criteria cannot be altered, especially those with low-flow termination criteria in pressure support, the use of pressure assist/control results in better patient-ventilator synchrony than does pressure support.⁸ Remember that the only difference between pressure assist/control and pressure support (other than a backup rate) is the variable that terminates inspiration:⁹ with pressure support the variable is flow and with pressure assist/control it is time. If the ventilator's set inspiratory time is set to coincide with the patient's neurologically controlled inspiratory time, synchrony is improved. Observation of a few continuous positive airway pressure breaths can identify the inspiratory time. Remember that in stressed patients inspiratory time is < 1 second, sometimes as short as 0.6 second.

Humidity

We have also found that adding a heated passover humidifier to the NPPV system greatly improves patient tolerance of NPPV and, we believe, decreases the frequency of NPPV failure caused by dry retained secretions. The upper airway is not bypassed with NPPV, but many patients are fluid-depleted when NPPV is initiated and they have secretion issues. This, coupled with the rapid inspiratory flows and the high percentage of dry oxygen added to the inspiratory flow, further worsens secretion problems. We find that a temperature of 25–30° C is sufficient to appropriately humidify inspired gas.

Summary

A successful NPPV program is best defined as a program that pays attention to the details. Proper education of caregivers and patients is critical. The approach to the patient during initial application is vital. The proper mask for the individual patient, the most appropriate ventilator and mode, and adequate humidification of the inspired gas is frequently the difference between success and failure.

Yes, the little things do make a *big* difference during application of NPPV!

Robert M Kacmarek PhD RRT FAARC

Respiratory Care Services
Massachusetts General Hospital
Boston, Massachusetts

REFERENCES

1. Mehta S, Hill N. Noninvasive ventilation. *Am J Respir Crit Care Med* 2001;163(2):540–577.
2. Keenan SP, Gregor J, Sibbald WJ, Cook D, Gafni A. Noninvasive positive pressure ventilation in the setting of severe, acute exacerbations of chronic obstructive pulmonary disease: more effective and less expensive. *Crit Care Med* 2000;28(6):2094–2102.
3. Keenan SP, Sinuff T, Cook DJ, Hill NS. Which patients with acute exacerbation of chronic obstructive pulmonary disease benefit from noninvasive positive-pressure ventilation? A systematic review of the literature. *Ann Intern Med* 2003;138(11):861–870.
4. Antón A, Tárrega J, Giner J, Guell R, Sanchis J. Acute physiologic effects of nasal and full-face masks during noninvasive positive-pressure ventilation in patients with acute exacerbation of chronic obstructive pulmonary disease. *Respir Care* 2003;48(10):922–925.
5. 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(6):1785–1790.
6. Kwok H, McCormack J, Cece R, Houtchens J, Hill N. Controlled trial of oronasal versus nasal mask ventilation in the treatment of acute respiratory failure. *Crit Care Med* 2003;31(2):468–473.
7. Schettino GPP, Chatmongkolchart S, Hess, D Kacmarek RM. Position of exhalation port and mask design affect CO₂ breathing during noninvasive positive pressure breathing. *Crit Care Med* 2003;31(8):2178–2182.
8. Calderini E, Confalonieri M, Puccio PG, Francavilla N, Stella L, Gregoretti, C. Patient-ventilator asynchrony during noninvasive ventilation: the role of expiratory trigger. *Intensive Care Med* 1999; 25(7):662–667.
9. Williams P, Kratochvil J, Ritz R, Hess DR, Kacmarek RM. Pressure support and pressure assist/control: are there differences? An evaluation of the newest intensive care unit ventilators. *Respir Care* 2000;45(10):1169–1181.

Correspondence: Robert M Kacmarek PhD RRT FAARC, Respiratory Care Services, Massachusetts General Hospital, 55 Fruit Street, Boston MA 02114. E-mail: rkacmarek@partners.org.