

# Noninvasive Ventilation

## A Primer for Medical Center Administrators

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### Introduction

It is rare for a medical technology to simultaneously improve mortality, address patient discomfort, and reduce costs. Noninvasive positive pressure ventilation achieves this unusual health services “hat trick”. Unfortunately, noninvasive ventilation appears to be underutilized at many hospitals.

This paper presents noninvasive ventilation for an intended audience of CEOs, Chief Nursing Officers, and other medical center executives. The goal is to provide background information from a non-technical perspective that will help the medical center leadership team facilitate the appropriate use of noninvasive ventilation.

### Invasive ventilation

#### Endotracheal tube

The distinction between noninvasive and invasive ventilation derives from the fact that noninvasive ventilation does not require an endotracheal tube. An endotracheal tube is a plastic tube, typically 7 to 9 mm in diameter that is placed through the mouth, past the hard and soft palates, through the vocal cords and into the windpipe, or trachea (Figure 1). A soft balloon, the cuff, near the tube tip creates a seal against the trachea allowing a ventilator to blow air into the lungs to provide respiratory support.

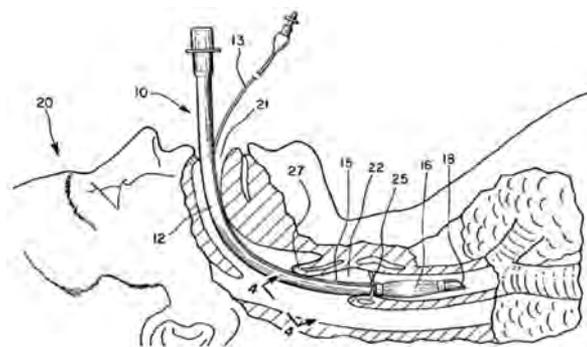


Figure 1. The endotracheal tube is placed through the mouth, past the tongue (at #21) and into the trachea (starts at #25). The cuff (#16) is a balloon that is inflated with the pilot tube (#13) to create a seal with the trachea. The invasiveness and discomfort of an endotracheal tube should be apparent.

Placement of the endotracheal tube is usually done by an experienced physician (such as an anesthesiologist, an emergency department physician, a pulmonologist, a surgeon, or an intensivist) to ensure that the tube is placed into the trachea and not into the esophagus. A mal-positioned endotracheal tube—if not immediately rectified—can harm the patient.

#### Side effects of the endotracheal tube

Even a properly-placed endotracheal tube has undesirable side effects linked to its “invasive” nature. First, the tube irritates the throat and windpipe. To manage the discomfort, patients require medication for pain and anxiety. This anesthesia contributes to immobility, with its own set of deleterious effects. Second, the tube is a foreign body that interferes with normal expectoration of pulmonary secretions. Saliva that is contaminated by bacteria from the stomach drips past the endotracheal tube into the lungs. The result can be a lung infection frequently referred to as ventilator-associated pneumonia, although a more appropriate term would be “endotracheal tube-associated pneumonia”. Ventilator-associated pneumonia not only has clinical consequences for the patient but soon may have financial consequences for the medical center. The Centers for Medicare and Medicaid Services (CMS) has indicated that it is considering adding ventilator-associated pneumonia to the hospital acquired conditions for which it intends to deny reimbursement. The typical cost for a patient hospitalization with ventilator-associated pneumonia is greater than \$130,000, creating substantial financial incentive for hospitals to prevent this potentially life-threatening, expensive complication.

It is important to note that some patients, such as those with severely altered cardiopulmonary function, can only be managed with endotracheal intubation. For these patients there will continue to be the need for invasive ventilation. The disadvantages of the endotracheal tube, however, have driven the development of noninvasive ventilation, which can provide superior respiratory support in properly selected patients.

## Noninvasive ventilation

### A bit of history: noninvasive negative pressure ventilation

Noninvasive ventilation encompasses respiratory support using alternatives to the endotracheal tube. There are two types of noninvasive ventilation. First, there is negative pressure ventilation, exemplified by the iron lung. The iron lung is a box in which the patient is placed and which draws air into the lungs by decreasing the pressure in the box. Essentially, the iron lung sucks the patient's chest out and air rushes into to fill the vacuum created in the patient's lungs. The iron lung was used extensively during the polio epidemics of the 1950s and 1960s (Figure 2).



Figure 2. Patients with polio and respiratory muscle paralysis are treated with the iron lung at Rancho Los Amigos Hospital, Downey, California, in the early 1950s.

The patient in the iron lung is physically inaccessible, making nursing care burdensome. Better outcomes achieved with invasive ventilation in the 1960s led to the rapid disappearance of negative pressure ventilation in the 1970s. It is rarely used today.

### Current approach: noninvasive positive pressure ventilation

#### *The noninvasive interface*

The other type of noninvasive ventilation is noninvasive positive pressure ventilation. This is similar to invasive ventilation in that air is blown into the lungs rather than sucked in by a vacuum created around the chest. Instead of using an endotracheal tube, however, noninvasive positive pressure ventilation uses an “interface” to make a connection between the ventilator and the patient. A wide variety of interfaces are available to accommodate variation in face anatomy and patient preferences (Figure 3).

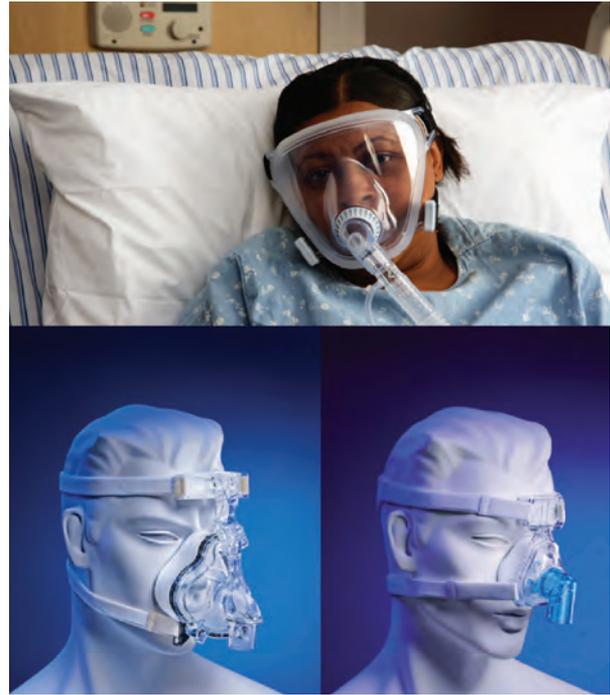


Figure 3. A variety of interfaces are available for use in noninvasive ventilation of patients with acute respiratory failure, including the total face mask (top, also Figure 4), full face mask (bottom left), and the nasal mask (bottom right).

### The noninvasive ventilator system

The noninvasive positive pressure ventilation system consists of both an interface and a noninvasive ventilator device. Unlike invasive ventilators, which operate with the air-tight seal created by the cuff of the endotracheal tube, noninvasive ventilators must manage air leaks that occur between the mask and the patient's face. The present generation of noninvasive ventilators calculates the changing leak and rapidly adjusts the airflow to replace the lost air in milliseconds. This feature is called leak compensation. Even more important, noninvasive ventilators sense when a patient's breathing starts and stops, synchronizing the mechanical respiratory support with spontaneous patient effort. Identifying patient effort in the midst of flow variation caused by leaks requires special software algorithms—a distinguishing feature of noninvasive ventilators (Figure 4).



Figure 4. A patient is supported by a noninvasive ventilator using a total face mask. The noninvasive ventilator consists of a blower, to generate airflow, linked to a computer-based control system that automatically compensates for leaks around the mask and uses sophisticated algorithms to ensure synchronization with patient breathing.

### The noninvasive program

Good outcomes from noninvasive programs require attention not only to equipment but also to staff training. A protocol can facilitate appropriate selection of patients and consistent management through the noninvasive care cycle. The protocol shown in Figure 5 was developed at the Tufts-New England Medical Center by Nicholas Hill, MD, to guide physicians, respiratory therapists and nurses. The protocol, together with a comprehensive training program, can address what appears to be underutilization of noninvasive ventilation at many institutions. The protocol explicitly defines how to: (1) identify patients who are suitable for noninvasive ventilation, (2) initiate support, (3) adjust support to patient breathing needs, and (4) remove support when it is no longer needed. Importantly, it provides guidance on how to recognize that noninvasive ventilation is not meeting patient needs so that the clinician can transition to invasive ventilation safely. Dr. Hill has shown that a program of education coupled with standardized physician order forms can enhance adherence to the protocol and increase the appropriate use of noninvasive ventilation.

### Patients for whom noninvasive ventilation has proven benefit

There are over 1,000 articles on the use of noninvasive ventilation, with over 100 of these reporting randomized, controlled trials. The literature identifies three groups of patients for which noninvasive has proven benefit.

#### Chronic Obstructive Pulmonary Disease (COPD)

Patients with exacerbations of chronic obstructive pulmonary disease (COPD) form the most important group of patients for which noninvasive ventilation has proven

beneficial. COPD is a lung disease in which the breathing passages become blocked making it difficult for air to pass in and out of the lungs. Smoking is an important contributing factor, with asthma, bronchitis, and emphysema frequently associated conditions. Patients with COPD can develop infections, which make their chronic breathlessness acutely worse. These exacerbations of COPD can be marked by life-threatening drops in oxygen levels in the blood (hypoxemia) and excessive levels of carbon dioxide (hypercapnea and acidosis). Invasive ventilation, with its risk of ventilator-associated pneumonia, has a high mortality when used for COPD exacerbations. There are multiple randomized, controlled studies showing that noninvasive ventilation reduces mortality, patient discomfort, and length-of-stay for exacerbations of COPD compared to invasive ventilation. There is also literature showing that not only is noninvasive ventilation more effective in terms of clinical outcomes, but it is also less costly.<sup>1</sup>

#### Pulmonary edema from congestive heart failure

Patients with pulmonary edema from heart failure are a second group of patients for which there is strong evidence to support the application of noninvasive ventilation. In congestive heart failure the heart muscle inefficiently pumps blood, requiring high pressures during the filling portion of the cardiac cycle. Fluid is forced out of the lung blood vessels and fills the lung air sacs, interfering with respiration. Patients can experience extreme breathlessness that can be life-threatening. Noninvasive ventilation can help re-expand lung segments that have collapsed with fluid, reduce patient effort, and augment heart performance, giving time for drugs to correct the underlying cardiac failure. There are multiple randomized, controlled studies showing mortality benefit over invasive ventilation for noninvasive ventilation in pulmonary edema from heart failure. A recent study by Denise Wilfong, MD has highlighted the importance of early management of pulmonary edema by pre-hospital caregivers, showing a cost saving of over \$4,000 per pre-hospital application of CPAP, a form of noninvasive ventilation.<sup>2</sup>

#### Impaired immune function

The third group for which there is compelling evidence for the benefit of noninvasive ventilation includes patients with impaired immune function. Patients with transplants take drugs to combat rejection. These drugs diminish immune function and reduce resistance to infection. Invasive ventilation is thus hazardous for patients with impaired immune function due to the high risk of ventilator-associated pneumonia. There are randomized, controlled studies that show reduced intensive care unit mortality rates and lengths of stay for patients with transplants treated with noninvasive ventilation compared to conventional therapy.

### **Patients for whom noninvasive ventilation is an option**

While the evidence is strongest for patients with acute respiratory failure from COPD exacerbation, pulmonary edema, and impaired immune function, there are other groups for whom noninvasive ventilation is an important option. These other groups include patients with the following conditions:

- Postoperative respiratory failure
- Asthma
- Pneumonia
- Acute Respiratory Distress Syndrome

In these patients close monitoring is mandatory. The clinical team must be prepared to immediately intubate the patient and initiate invasive ventilation in patients who fail noninvasive ventilation.

### **Conclusion**

Noninvasive ventilation is one of those rare medical technologies that both improves patient outcomes and reduces treatment costs. The technology requires an organized and well-trained team of physicians, nurses, and therapists. For selected groups of patients with acute respiratory failure—with the focus on COPD exacerbations, heart failure pulmonary edema, and immunocompromised hosts—noninvasive ventilation is preferred to conventional therapy with invasive ventilation.

### **Key Ideas**

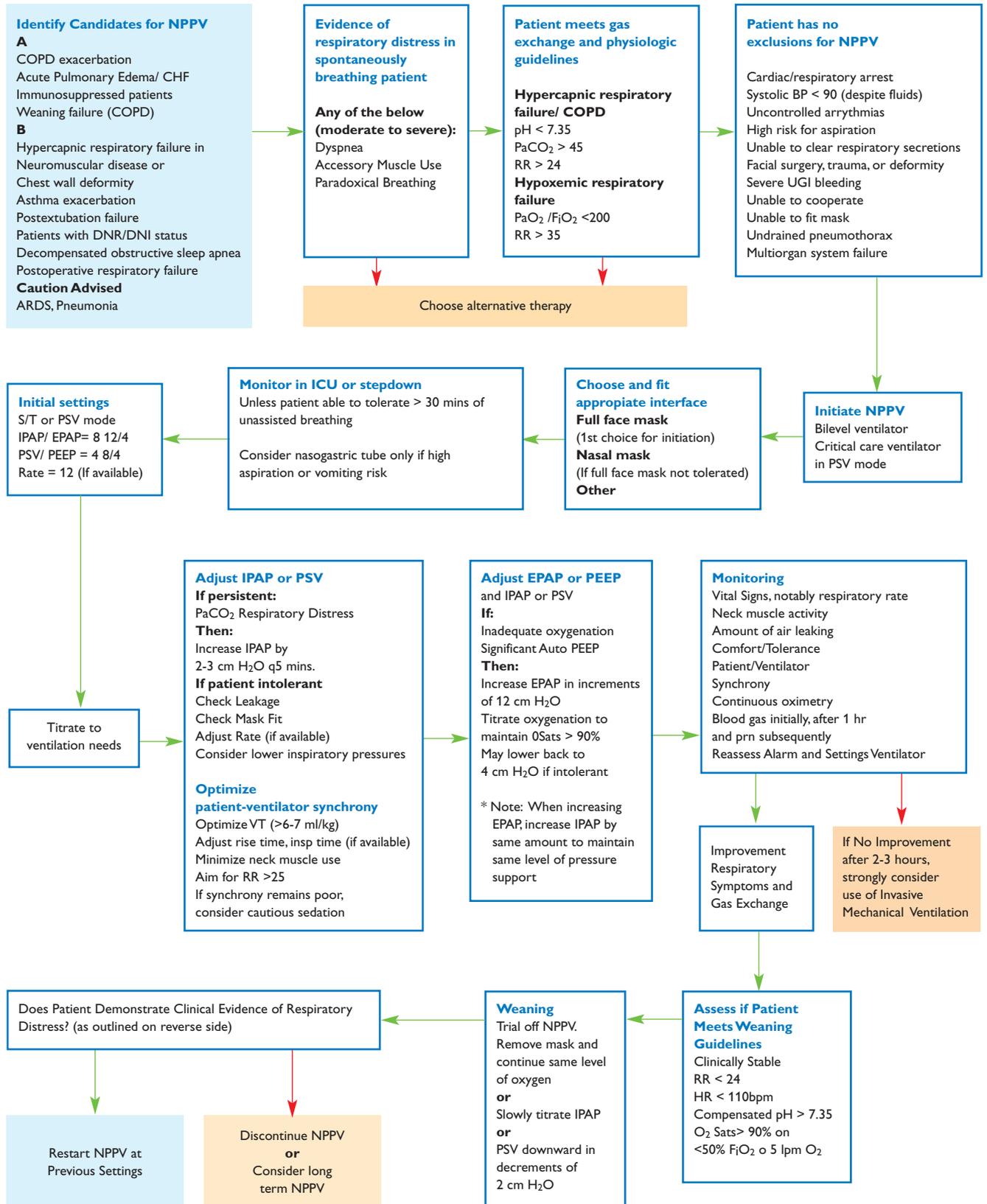
- Noninvasive ventilation is the standard-of-care for treatment of severe exacerbations of chronic obstructive pulmonary disease (COPD).
- There is substantial evidence to support the use of noninvasive ventilation for patients with the following conditions:
  - pulmonary edema resulting from cardiac disease
  - impaired immune systems.
- There is evolving evidence for the use of noninvasive ventilation in other conditions or disease states, such as pneumonia, asthma, and the acute respiratory distress syndrome.
- Particularly for chronic obstructive pulmonary disease, there is compelling evidence that noninvasive ventilation reduces mortality, morbidity, and costs.

### **Disclosure**

Adam Seiver, MD, PhD, MBA serves as Vice President and Chief Medical Officer for Hospital Respiratory Care, a business unit within Philips Healthcare, Inc.

Figure 5: This protocol ensures consistent identification of patients who are suitable for noninvasive ventilation, guides the initiation of support and its adjustment to support individual patient breathing needs, and clarifies when support is no longer needed and thus can be removed. (Protocol courtesy of Nicholas Hill, MD).

## Management of acute respiratory distress/failure using Noninvasive Positive Pressure Ventilation (NPPV)



## Annotated Bibliography

Meduri GU, Conoscenti CC, Menashe P, Nair S. Noninvasive face mask ventilation in patients with acute respiratory failure. *Chest*. 1989 Apr;95(4):865-70.

**This is one of the seminal papers in noninvasive ventilation. Umberto Meduri, MD drew on clinical experience using mask-based ventilation for patients with neurological disease to apply the technique to a new patient population—patients with acute respiratory failure. The 10 patients in this study did well, with responses comparable to what would have been expected with conventional, invasive ventilation.**

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 Jun;28(6):2094-102.

**Deborah Cook, MD and her colleagues represent the premier investigators in a field that combines the results of many other published studies to provide a systematic summary of results (meta-analysis). This paper uses meta-analysis to derive the probability patients with COPD exacerbation will follow different clinical courses under treatment with invasive and noninvasive ventilation. These probabilities are used in a decision analysis to show that patients treated with noninvasive ventilation would have both lower mortality and lower costs (\$7,211 versus \$10,455, in Canadian dollars).**

Hill NS, Brennan J, Garpestad E, Nava S. Noninvasive ventilation in acute respiratory failure. *Crit Care Med*. 2007 Oct;35(10):2402-7.

**This outstanding recent review is authored by a leading international expert on noninvasive ventilation, Nicholas Hill, MD. The paper concisely reviews the evidence supporting the use of noninvasive ventilation for a comprehensive set of respiratory conditions.**

## References

<sup>1</sup> 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 Jun;28(6):2094-102.

<sup>2</sup> Hubble MW, Richards ME, Wilfong DA. "Estimates of cost-effectiveness of prehospital continuous positive airway pressure in the management of acute pulmonary edema." *Prehosp Emerg Care*. 2008 Jul-Sep;12(3):277-85).





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