



REVIEW

## Recent advances in mechanical ventilation

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**ABSTRACT:** Important advances have been made over the past decade towards understanding the optimal approach to ventilating patients with acute respiratory failure. Evidence now supports the use of noninvasive positive pressure ventilation in selected patients with hypercapnic respiratory failure and chronic obstructive pulmonary disease, cardiogenic pulmonary edema, and for facilitating the discontinuation of ventilatory support in patients with chronic pulmonary disease. The concept of a lung protective ventilatory strategy has revolutionized the management of the acute respiratory distress syndrome. The process of liberation from mechanical ventilation is becoming more standardized, with evidence supporting daily trials of spontaneous breathing in all suitable mechanically ventilated patients. This article critically reviews the most important recent advances in mechanical ventilation and suggests future directions for further research in the field.

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In the past decade, remarkable progress has been made toward understanding the optimal use of noninvasive ventilation, the management of the acute respiratory distress syndrome, and approaches to discontinuation of ventilatory support. This article reviews the evidence behind the most important recent developments in mechanical ventilation and practical issues in the application of this new data. Although this article is not a systematic review by definition, over 300 articles published within the past decade were evaluated via MEDLINE searches, review of Cochrane Library articles, and examination of selected articles' bibliographies; over 150 articles were considered in detail for inclusion. The goal of this article is to provide a concise review of landmark, representative or particularly illustrative recent trials in ventilator management and their contributions to current clinical practice.

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Although important advances have been made in recent years in the area of prevention of ventilator-associated pneumonia, this topic has been recently reviewed elsewhere and will not be covered in this article.<sup>1,2</sup>

### Noninvasive positive pressure ventilation

Noninvasive positive pressure ventilation, commonly referred to as bi-level positive airway pressure, has gained broader acceptance in recent years as studies have demonstrated efficacy in several clinical settings. The evidence most strongly supports the use of noninvasive ventilation in acute exacerbations of chronic obstructive pulmonary disease, cardiogenic pulmonary edema, immunocompromised patients with acute respiratory failure, and selected patients with difficulty weaning from the ventilator. Although noninvasive ventilation has been proven effective in various causes of chronic respiratory insufficiency, this article will only address its applications in the acute hospital setting.<sup>3</sup>

**Table 1** Contraindications to use of noninvasive ventilation

Impending cardiovascular collapse or respiratory arrest
Excessive secretions or massive upper gastrointestinal bleeding
Upper airway obstruction
Recent facial, upper airway, or upper gastrointestinal surgery
Patient unable to protect airway, including altered mental status
No monitored beds available (relative)

## Introduction to noninvasive ventilation

At the outset, a few epidemiologic issues should be considered. First, nearly all studies of noninvasive ventilation are by necessity unblinded, introducing the possibility of bias. Second, most of the studies are small, and their relative contributions should be weighed as such. Finally, many of the studies in this field suffer from a heterogeneity of underlying disease, whether by design or necessity, making the results all the more difficult to interpret or apply with confidence.

In this review, as in most of the literature on this subject, the term “noninvasive ventilation” will be used to refer to positive pressure ventilatory support delivered through a nasal or full face mask with different levels of pressure support set for inspiration and expiration (frequently 10–15 and 5–8 cm H<sub>2</sub>O); it may be delivered with or without a backup rate. This type of ventilation should be clearly distinguished from continuous positive airway pressure, in which a constant level of pressure support is delivered without regard for the respiratory cycle.

Patients should be carefully assessed for possible contraindications to the use of noninvasive ventilation before its implementation (Table 1). When employed in the care of patients with acute respiratory failure, noninvasive ventilation should always be used in a highly monitored setting such as an intensive care unit, step-down unit, or emergency department. Noninvasive ventilation should not be used in patients with impending cardiovascular collapse or respiratory arrest, because those patients will soon require endotracheal intubation. Patients who are unable to protect their airway, usually from altered mental status, should not receive noninvasive ventilation. Although it may be tempting to use noninvasive ventilation in this setting, particularly when hypercarbia is present, such patients are at very high risk for failure of noninvasive ventilation. Other important issues in the management of patients on noninvasive ventilation such as patient-ventilator interface, cost-benefit analyses, and specific ventilator settings are beyond the scope of this article and will not be addressed.<sup>4</sup>

## Noninvasive ventilation in chronic obstructive pulmonary disease

Noninvasive ventilation was first and has been most extensively demonstrated to be effective in acute, severe

exacerbations of chronic obstructive pulmonary disease. Many randomized controlled trials have compared noninvasive ventilation to usual care in this setting and found noninvasive ventilation to be associated with a reduced rate of endotracheal intubation.<sup>5-9</sup> In addition, most published trials have suggested a reduction in mortality with noninvasive ventilation compared with conventional therapy.<sup>5,8-10</sup> In the past 2 years, 3 systematic reviews were published confirming that noninvasive ventilation reduces in-hospital mortality and decreases the need for intubation in patients with acute, severe chronic obstructive pulmonary disease exacerbations.<sup>11-13</sup> One meta-analysis suggested that most of the benefits of noninvasive ventilation extend to those patients with severe chronic obstructive pulmonary disease exacerbations as measured by a pH of <7.3;<sup>12</sup> this finding was not, however, confirmed in a more recent systematic review of 14 randomized controlled trials.<sup>13</sup> In addition, multiple articles have noted that the response to noninvasive ventilation within the first 2 hours as measured by improvements in pH and PaCO<sub>2</sub> is predictive of the modality’s success or failure.<sup>14,15</sup> This concept may also be applied to the use of noninvasive ventilation in other disorders.<sup>16</sup>

## Noninvasive ventilation in immunosuppressed patients with acute respiratory failure

Noninvasive ventilation may be useful in patients who are profoundly immunosuppressed, particularly those who have undergone solid organ transplantation or those with hematologic malignancy, in whom mortality after endotracheal intubation is particularly high. One study randomized 40 patients with acute hypoxemic respiratory failure after solid organ transplant to conventional treatment, including high flow oxygen by face mask, or noninvasive ventilation.<sup>17</sup> Patients randomized to noninvasive ventilation had a lower rate of endotracheal intubation, shorter intensive care unit stays, and lower intensive care unit mortality, although in-hospital mortality did not differ significantly between the two groups (Figure 1). A second study also randomly assigned patients to either noninvasive ventilation or usual care but included febrile immunosuppressed patients with acute hypoxemic respiratory failure and pulmonary infiltrates.<sup>18</sup> Most patients in the study were immunosuppressed as a result of therapy for hematologic malignancy. In this study sample, intermittent noninvasive ventilation was associated with lower rates of endotracheal intubation, serious complications, and intensive care unit and all-cause mortality (Figure 1). Although these 2 studies were fairly small and captured slightly different patient samples, taken together they suggest that noninvasive ventilation may be beneficial in severely immunocompromised patients with acute hypoxemic respiratory failure.

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