Reengineering Respiratory Support Following Extubation*

Avoidance of Critical Care Unit Costs

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Study objective: We prospectively investigated alternative clinical practice strategies for critically ill trauma patients following extubation to evaluate the cost-effectiveness of these maneuvers. The primary change was elimination of the routine use of postextubation supplemental oxygen, with concurrent utilization of noninvasive positive pressure ventilatory support (NPPV) to manage occurrences of postextubation hypoxemia.

Design: Prospective, consecutive accrual of patients undergoing extubation.

Setting: Trauma ICU in a university hospital.

Interventions and measurements: All patients received mechanical ventilation using pressure support ventilation (PSV) with continuous positive airway pressure (CPAP) as the primary mode. The patients were extubated to room air following a 20-min preextubation trial of 5 cm H2O CPAP at FIO2 of 0.21, and demonstrating a spontaneous respiratory rate < 38 breaths/min, pH > 7.30, PaCO2 < 50 mm Hg, and PaO2 > 50 mm Hg. The subgroup of patients who became hypoxic (pulse oximetric saturation < 85%) within 24 h of extubation were treated with NPPV for up to 48 h duration. Patients who failed NPPV were reintubated.

Four hundred fifty-one (84%) patients were successfully extubated to room air. Seventy-two patients (13%) became hypoxemic within 24 h, and NPPV was administered. Fifty-two patients (72% of those who were hypoxic) responded to NPPV, while 20 patients failed to respond to therapy, were reintubated, and received mechanical ventilation for a mean of 4 days. Thirteen additional patients (2%) were reintubated for reasons other than hypoxemia. The overall reintubation rate for the group (n = 536) was 6.2%; for the postextubation hypoxic subgroup who failed NPPV, the reintubation rate was 3.7%. The elimination of routine supplemental oxygen via nasal cannula following extubation resulted in a potential direct cost avoidance of $50,006.88 for 451 patient days. Moreover, the 52 patients who were spared reintubation and mechanical ventilation provided an additional potential cost avoidance of $19,740.24 in unused ventilator days per patient.

Conclusion: Eliminating the routine use of supplemental oxygen and employing NPPV as a method to prevent reintubation can facilitate a more aggressive, cost-effective strategy for the management of the trauma ICU patient who has been extubated. (CHEST 1999; 116:1025–1028)

Key words: cost-effectiveness; extubation; hypoxemia; ICU; noninvasive positive pressure ventilation; oxygen; reintubation; surgery; trauma

Abbreviations: CPAP = continuous positive airway pressure; FIO2 = fraction of inspired oxygen; FRC = functional residual capacity; NPPV = noninvasive positive pressure ventilatory support; PACU = postanaesthesia care unit; FSV = pressure support ventilation; SpO2 = pulse oximetric saturation; TICU = trauma ICU

Historically, the ICU evolved from the postanesthesia care unit (PACU). In the early days of the PACU (the 1950s and 1960s), no reliable real-time method to detect postoperative hypoxemia existed, and the routine provision of supplemental oxygen to the PACU patient was an accepted approach to minimize concerns regarding an occurrence of postoperative hypoxemia.1,2 Today, routine monitoring of oxyhemoglobin saturation by transcutaneous pulse oximetry is a safe, effective, and widely used method that allows for the early detection of hypoxemia.1,2 Several studies have demonstrated a significant financial benefit by limiting the routine use of supplemental oxygen that is provided to postoperative patients in the PACU.1–4

Health-care practitioners are challenged daily to provide efficient, cost-effective care to patients. An
area of medicine in which cost consciousness and cost containment have received a high profile is the ICU, since ICUs typically consume >20% of the financial resources of a hospital. This goal can often be achieved by reevaluating current clinical management practices for appropriateness and efficacy. In our trauma ICU (TICU), we chose to examine the necessity of routine postextubation oxygen supplementation. It was hypothesized that routine postextubation oxygen supplementation is an unnecessary expense, with the potential to mask progressive atelectasis. Furthermore, if postextubation hypoxemia occurs, the early implementation of noninvasive positive pressure ventilatory support (NPPV) is an appropriate method to avoid progressive atelectasis, to optimize functional residual capacity (FRC), and therefore to avoid reintubation.

**Materials and Methods**

Five hundred thirty-six consecutive patients in a 20-bed trauma ICU were prospectively evaluated following extubation over an 11-month period. The study was approved by the institutional review board for the protection of human subjects. Burn patients and patients with tracheostomies were excluded. The mean age was 48 years old (range, 15 to 96), with a mean injury severity score in the low 20s. All patients received mechanical ventilation using pressure support ventilation (PSV) with continuous positive airway pressure (CPAP) as the primary mode of ventilation. Initial ventilation on arrival in the TICU was provided with synchronized intermittent mandatory ventilation of 6 to 8/min at a tidal volume of 10 mL/kg, with a baseline of 5 cm H2O CPAP, 5 cm H2O PSV, and fraction of inspired oxygen (FiO2) sufficient to achieve a pulse oximetric saturation (SpO2) ≥92%. In lieu of the report by Baker et al6 of a log-linear decrease in FRC with oxygen concentrations >30%, it is our practice to reduce FiO2 to ≤0.35 as rapidly as possible. At the onset of spontaneous patient respiratory effort, synchronized intermittent mandatory ventilation was quickly reduced to 1/min, and spontaneous tidal volume was augmented with PSV if needed. Ventilation end points for PSV were a spontaneous respiratory rate <38 breaths/min, pH ≥7.30, and PaCO2 ≤50 mm Hg (in a normally eucapnic patient). Ventilation was provided with either a Puritan-Bennett 7200ae (Nellcor Puritan-Bennett; Carlsbad, CA) or a Hamilton VeoNar (Hamilton Medical; Reno, NV).

Minimal ventilatory support was considered as 5 cm H2O PSV, 5 cm H2O CPAP, and FiO2 of 0.30. On achieving this level, a clinical evaluation of likely airway protection and presence of an acceptable level of consciousness is performed. Patients passing the subjective assessment were extubated to room air following a 20-min preextubation trial of 5 cm H2O CPAP at FiO2 of 0.21, and demonstrating spontaneous respiratory rate of <38 breaths/min, pH ≥7.30, PaCO2 ≤50 mm Hg, and PaO2 ≥50 mm Hg. All patients were routinely monitored with pulse oximetry and bedside S-T segment ECG following extubation.

The subgroup of patients who became hypoxemic (SpO2 <88% or PaO2 <50 mm Hg) within 24 h of extubation and demonstrated no other compelling reason to consider reintubation were bridged using NPPV for a period of up to 48 h. The application of NPPV hinged on selection of an appropriate interface to meet the patient’s needs, ie, mask or nasal CPAP, or a bilevel ventilation system (BIPAP; Respironics; Pittsburgh, PA). The choice of bilevel pressure ventilation vs CPAP was based on the clinicians’ perceived need for inspiratory volume support (ie, tachypnea, dyspnea, carbon dioxide retention). Clinical end points remained the same: spontaneous respiratory rate ≤38 breaths/min, pH ≥7.30, PaCO2 ≤50 mm Hg (in a normally eucapnic patient), and SpO2 ≥92% at FiO2 <0.35. The mode of therapy was explained to the patient, and reassurance was provided. If bilevel pressure ventilation was chosen as the NPPV mode, an initial low inspiratory pressure of 5 to 10 cm H2O was provided, along with a minimal CPAP setting of 5 cm H2O. Following a determination of the correct fit and an attempt at the most comfortable application, the interface was secured, with padding on the ears, forehead, occiput, and nasal bridge. Inspiratory pressure was then titrated to patient comfort. After establishing ventilation, 5 to 15 cm H2O CPAP was titrated to maintain SpO2 >92%. If mask or nasal CPAP was chosen, a baseline of 10 cm H2O was set. The FiO2 did not exceed 0.35.

**Results**

Four hundred fifty-one of 536 patients (84%) were successfully extubated to room air. Thirteen patients were reintubated for reasons unrelated to hypoxemia: stridor, altered mental status, tachypnea, excessive secretions, or sepsis. The overall reintubation rate for the group (n = 536) was 6.2%; for the postextubation hypoxemic group who failed NPPV intervention, the intubation rate was 3.7%, comparable to previously published reports of these preextubation trial criteria.8 The subgroup of 72 extubated patients (13%) who became hypoxemic (SpO2 <88%) within 24 h of extubation were treated with NPPV for up to 48 h. Of these 72 patients, 52 (72% of those becoming hypoxemic) responded to treatment while 20 patients failed to respond to therapy. These 20 patients were subsequently reintubated and received mechanical ventilation for a mean of 4 days. Successful extubation was then possible using the same protocol. All patients who received NPPV tolerated the application. No adverse events resulted from the application of NPPV or the reintubation of the 20 patients who failed NPPV. A subset analysis of these 72 patients demonstrated a mean and median age threshold of 50 and 51, respectively, above which NPPV was more likely to fail; 13 of 36 (36%) of those reintubated were ≥50 years old vs 7 of 36 (19%) for patients <50 years of age. (Table 1).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Age &lt; 50 yr</th>
<th>Age ≥ 50 yr</th>
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<tbody>
<tr>
<td>Mean (median) duration of conventional ventilation, d</td>
<td>8.5 (3)</td>
<td>8 (3)</td>
</tr>
<tr>
<td>Mean (median) duration of NPPV, d</td>
<td>1.5 (1)</td>
<td>1.9 (2)</td>
</tr>
<tr>
<td>Patients who failed NPPV, %</td>
<td>19</td>
<td>36</td>
</tr>
<tr>
<td>Mean (median) duration of reintubation/ventilation, d</td>
<td>4.3 (4)</td>
<td>4.6 (5)</td>
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*The mean age of the study population was 50 years old (median, 51; range, 16 to 85).*
There was no difference between the two NPPV subgroups regarding mean days of preextubation conventional ventilation, mean days of NPPV, or mean days of ventilation following reintubation (as provided by the institution business offices; p > 0.05).

The charges applied by our institution for supplemental oxygen therapy (not including charges for the respiratory therapist or bedside nurse) are $23/h for oxygen, plus $21/d for a nasal cannula. No bubble-type humidification devices are used due to their inefficiency. The direct costs incurred by the hospital (as provided by the institution business offices) for oxygen therapy is based on a ratio of costs to charges of 0.19 for oxygen ($4.37/h), and a set cost of $6 for the nasal cannula. The charge for mechanical ventilation is $1190/d, while NPPV is only $191/d. Again, the direct cost, based on a ratio of costs to charges multiple of 0.19, results in costs of $226.10/d for mechanical ventilation and $36.29/d for NPPV vs $104.88/d for oxygen.

A potential direct cost avoidance of $110.88/d or (for the 451 patients) a potential direct cost avoidance of $50,006.88 resulted from the elimination of routine supplemental oxygen via nasal cannula following extubation. Moreover, 52 patients who were spared reintubation and mechanical ventilation (for an average of 2 days) provided an additional potential direct cost avoidance of $19,740.24 in unused ventilator days per patient.

**DISCUSSION**

Cost is currently a major driving force in the United States health-care delivery system. Concurrent with rampant acquisitions, mergers, and hospital downsizing, consumers of health care are demanding costly, quality health care at bargain prices. One method by which hospitals can approach these challenges is to streamline both the consumption of resources and the generation of costs in the ICU setting. The ICU consumes a disproportionately large part of United States health-care resources (approximately 20% of the total hospital costs), yet it comprises <10% of all hospital beds. Intensivists and clinicians need to reexamine and reevaluate current ICU practices, determine their relative value, and devise appropriate and effective treatment protocols.

In this study, we demonstrated that extubation to room air is safe and cost-effective, and that the use of NPPV is successful in preventing reintubation in the majority (72%) of patients experiencing postextubation hypoxemia (SpO2 < 88%). Extubation to room air not only avoided unnecessary charges, but permitted the early identification of patients with probable underlying atelectasis who were most likely to benefit from alveoli recruitment afforded by positive end-expiratory pressure support CPAP. The staircase protocol approach to the application of NPPV was used in all 72 patients who experienced hypoxemia after the initial extubation starting with 5 to 10 cm H2O CPAP, titrated to achieve an oxygen saturation ≥ 92% to a maximum CPAP of 15 cm H2O. An age of >50 years old identified patients who were more likely to fail NPPV as a bridge to avoid reintubation. The reason for this is unclear and may only represent a lesser degree of respiratory muscular pump reserve. Although these 72 patients could have been managed by the more traditional methods of applying only supplemental oxygen without CPAP, oxygen administration was not a guarantee of clinical improvement and would not be expected to address the common underlying pathophysiologic derangement of atelectasis.

Oxygen is not a harmless substance; a number of series have demonstrated adverse effects on postoperative patients receiving perceived nontoxic levels of inspired oxygen. Supplemental oxygen has been shown to promote a loss of lung volume by absorption atelectasis with loss of FRC and residual volume in a log-linear fashion when the Fio2 is > 30%. The administration of supplemental oxygen following extubation may also delay the early detection of underlying progressive atelectasis, hypventilation, or airway obstruction as a cause of hypoxemia, with the potential of increasing morbidity and mortality for these patients.

The traditional management of postoperative hypoxemia has been to provide supplemental oxygen or to perform endotracheal intubation with the initiation of mechanical ventilation. However, the provision of supplemental oxygen does not ensure adequate oxygen delivery or prevent untoward events, nor does it treat the underlying pathophysiologic defect causing the hypoxemia. Postoperative hypoxemia is believed to result from a loss of FRC, a decrease in pulmonary compliance, and alterations in ventilation/perfusion matching that lead to increased intrapulmonary shunting or venous admixture. The postextubation application of supplemental oxygen in the nonhypoxic patient seems unwarranted. Mechanical ventilation may be an effective method to treat postoperative hypoxemia when the focus is on lung volume recruitment, yet it carries a significant morbidity, mortality, and expense related to the procedure itself, combined with the subsequent alterations in pulmonary physiology that it causes. If the lung is allowed to collapse during the expiratory phase of the ventilator cycle, the purported benefits may be negated. Recent literature in the management of acute respiratory insufficiency due to a variety of causes supports the use of NPPV CPAP applied noninvasively by face or nasal mask has been used successfully to manage refractory hypoxemia.
in patients with cardiogenic and noncardiogenic pulmonary edema. The addition of CPAP to NPPV improves gas exchange, especially when tidal exchange occurs above the lower inflection point on the pressure volume curve, by ostensibly increasing mean airway pressure. NPPV may increase FRC and improve pulmonary compliance and ventilation/perfusion matching, resulting in a decreased intrapulmonary shunt. It has been effectively used as a first-line therapy in patients with acute respiratory insufficiency due to hypercapnea and hypercarbia. Meduri et al. have shown that NPPV can correct gas exchange abnormalities in patients with acute respiratory failure, thus avoiding mechanical ventilation in 70% of patients. Data from Wysocki et al. show that NPPV is associated with a low rate of complications, resulting both in decreased duration of mechanical ventilation and ICU stay. NPPV is effective for the management of acute hypoxemic and postextubation respiratory insufficiency, with success rates varying from 40 to 70%.

While information exists regarding cost-effectiveness analysis, acquiring valid raw data from the institution is, at times, frustrating. Consequently, we chose to evaluate cost avoidance, rather than a supposed cost savings. The potential direct cost avoidance may be significant, or likewise may vary considerably between institutions. Monitoring patients with pulse oximetry following extubation allows for the detection of hypoxemia and has become a de facto standard of care. Earlier identification of hypoxic patients should lead to early intervention, not by reintubation and initiation of mechanical ventilation, but by the timely use of NPPV. We have shown that NPPV is cost-effective when compared to intubation and mechanical ventilation. This approach allows the intensivist or clinician to efficiently utilize resources and effectively manage patients by eliminating unnecessary ventilator days. We advocate elimination of the routine use of supplemental oxygen for TICU patients immediately following extubation; for patients with documented hypoxemia refractory to routine postoperative pulmonary care, supplemental oxygen is indicated. The actual impact of this strategy on ICU or hospital length of stay was not addressed in this paper; however, based on previous reports, we can assume that any approach that decreases the duration of intubation will impact on the duration of ICU stay. Moreover, the overall hospital length of stay at our institution is often influenced by multiple nonpatient-care issues (eg, lack of placement opportunities and funding), therefore prohibiting the opportunity to comment regarding the impact of this approach on overall patient length of hospital stay or the rehabilitation process.

References
1 DiBenedetto RJ, Gravenstein N. Against routine postoperative oxygen administration in the PACU. J Clin Monit 1995; 11:408–410
3 Rosenberg MK. The cost of oxygen therapy in the postanesthesia care unit [letter]. Anesth Analg 1994; 79:816
12 DiBenedetto RJ, Gravenstein N. Against routine postoperative oxygen administration in the PACU. J Clin Monit 1995; 11:408–410
19 Eisenberg JM. Clinical economics. JAMA 1989; 262:2579–2586