NONINVASIVE VENTILATION FOR PREVENTION OF POSTTEXTUBATION
RESPIRATORY FAILURE IN OBESE PATIENTS

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Short title: prevention of postextubation failure in obese
Abstract

Background: Current recommendations for management of obese patients post extubation are based on clinical experience and expert opinions. We hypothesized that application of noninvasive ventilation during the first 48 hours after extubation in severely obese patients would reduce postextubation failure and avert the need for reintubation.

Methods: Following protocol-driven weaning trials, sixty two consecutive severely obese patients (BMI $\geq 35$ kg/m$^2$) were assigned to noninvasive ventilation (NIV) via nasal mask immediately post extubation and compared to 62 historically matched controls who were treated with conventional therapy. The primary end point was the incidence of respiratory failure in the first 48 hours post extubation.

Results: Compared to conventional therapy, the institution of NIV resulted in 16% (95% confidence interval 2.9%-29.3%) absolute risk reduction in the rate of respiratory failure. There was a significant difference in the ICU and hospital lengths of stay between the two groups ($p<0.001$ and $p=0.007$; respectively). Subgroup analysis of hypercapnic patients showed a reduced hospital mortality in the NIV group compared to the control group ($p=0.02$).

Conclusion: Noninvasive ventilation may be effective in averting respiratory failure in severely obese patients when applied during the first 48 hours post extubation. In selected patients with chronic hypercarbia, early application of NIV may confer a survival benefit.
Key words: Noninvasive ventilation, obesity, reintubation, obstructive sleep apnea
Introduction

Numerous studies have pointed to the complexity of respiratory management of critically ill obese patients during the period following liberation from mechanical ventilation [1, 2]. The development of respiratory instability, episodic desaturation during supine position, and the respiratory depressant effects of sedatives and opioid analgesia predispose these patients to prolonged periods of apneas, hypoxia, and severe hypercarbia culminating with respiratory failure. Yet, the incidence of these serious complications is not well documented. The rate of reintubation post extubation in the severely obese patients has been reported at 8% to 14% among patients undergoing mechanical ventilation for more than 48 hours [3, 4], but these estimates are likely to underestimate the true incidence of respiratory failure in this population.

Noninvasive ventilation (NIV) has been considered a promising therapy by an International Consensus Conference to avert respiratory failure after weaning [5]. However, randomized controlled studies in non obese patients have showed mixed results. While earlier studies failed to show any benefit from rescue NIV [6, 7], a more recent investigation has documented a beneficial effect of administering NIV immediately post extubation in selected patients at increased risk for extubation failure [8]. Ferrer and colleagues [8] have shown not only a reduction in the rate of respiratory failure but also a decrease in the rate of ICU mortality. Because severely obese patients are considered at high risk for developing respiratory complications [1, 9], we instituted a protocol requiring early application of NIV post extubation. We hypothesized that the preventive use of NIV would reduce the incidence of respiratory failure and the rate of
reintubation. To test this hypothesis, we conducted an observational study comparing noninvasive ventilation therapy to historical controls of conventional medical therapy during the first 48 hours post extubation.

Methods

Patient population

In a prospective study beginning September 2004, involving 52 beds in three intensive care units, all severely obese patients (BMI ≥ 35 kg/m²) requiring endotracheal mechanical ventilation for at least 48 hours at a University affiliated tertiary care center were eligible for enrollment. Exclusion criteria included recent facial, cranial, or cervical spine surgery, neuromuscular disorders, uncontrolled delirium, active upper gastrointestinal bleeding, and unplanned extubation. Patients who had a do-not-resuscitate order were also excluded. For those with more than one ICU admission, only the first event was included in the analysis to ensure independence of observation. A historic control group who met the same inclusion and exclusion criteria was chosen from severely obese patients admitted to the ICU in the preceding 29 months. The NIV and the historic group were matched for age (±5 years), BMI (±2 kg/m²), and APACHE II score (±2). The matching process was conducted using a computer-assisted software (SAS version 9.1, SAS Institute Inc., Cary, NC.) when all data from all patients were available. For each patient in the NIV group, matching was performed with a patient from the historic group according to the following hierarchy: baseline APACHE II score, BMI, and age. When matching was unsuccessful at end of this process, it was started again with extension of the age for matching (±5 years) and then extension of the range
of BMI (±2 kg/m^2). If there was more than one match, the patient in the historic group was selected by the best match according to the matching hierarchy. Using this algorithm, we identified matches for all the NIV patients.

Study approval was obtained from the local Institutional Review Board prior to initiation of the study. Written informed consent was waived due to the observational nature of the study.

**Weaning protocol**

Starting February 2002, weaning trials were conducted according to a previously established protocol [10]. In brief, a weaning trial was initiated once the patient was fully awake, responsive, and had fulfilled the following criteria: \( \text{PaO}_2 > 70 \text{ mm Hg} \) with fraction of inspired oxygen (FiO2) ≤ 0.35 and positive end-expiratory pressure ≤ 5 cm H2O; rectal temperature > 36.6°C, a stable cardiovascular system (ie, systolic BP > 100 mm Hg, heart rate < 120 beats/min, absence of metabolic acidosis, and withdrawal of all vasopressors for > 12 hours. The screen for readiness to wean was performed between 7:00 am and 9:00 am based on a previously published weaning protocol shown to reduce duration of ventilation [10]. During screening, the ratio of respiratory frequency to tidal volume (f/VT) was assessed [11]. If f/VT was < 105, a spontaneous breathing trial was attempted for 30 minutes on CPAP, with 5 cm H2O pressure support if the endotracheal tube was ≤ 8 mm. Extubation was then ordered by the attending physician, otherwise the patient was placed back on mechanical ventilation if within 30 minutes of initiating spontaneous breathing trial (SBT) any of the following criteria was met: 1) change in heart rate of more than 20 beats per min from baseline prior to
initiating SBT persisting for 5 min or longer; 2) systolic blood pressure of less than 90 or change of more than 30 mmHg after initiating SBT persisting for 5 min or longer; 3) oxygen saturation < 90%, PaO₂ < 60 mmHg, or pH ≤ 7.35, 4) respiratory muscle fatigue or increased work of breathing suggested by the use of accessory respiratory muscles, paradoxical motion of the abdomen, or retraction of the intercostal spaces.

Post extubation, patients were placed on conventional medical therapy including oxygen therapy to keep arterial oxygen saturation > 90%, bronchodilators, chest physiotherapy, in addition to other treatments directed by the primary care physicians.

Noninvasive ventilation

In July 2004, we have adopted a protocol in our intensive care units to administer NIV for severely obese patients for the first 48 hours immediately post extubation. NIV was delivered using the bi-level positive airway pressure mode (BiPAP S/T-D Ventilatory Support System, Respironics Inc., Murrysville, PA) via a nasal mask. Nasogastric tubes were removed prior to institution of NIV. The inspiratory and expiratory pressures were set initially at 12 cm H₂O and 4 cm H₂O in a spontaneous mode, respectively [12]. The pressure settings were increased gradually to patient’s tolerance with the aim of achieving a respiratory rate <25 breaths/min and arterial oxygen saturation >90%. The fractional concentration of oxygen was titrated also to maintain an arterial oxygen saturation above 90 percent. Subjects were advised to use NIV continuously with periods of rest up to 60 min every six hours to have their meals, receive scheduled medications, or nursing care. Regular examination of the facial skin was made by the respiratory therapist to prevent skin ulceration from the tightly fitting
mask. NIV was maintained for the first 48 hours then the decision to maintain or
discontinue NIV was left to the admitting physician.

Medical care was provided by the same intensivist team, critical care nurses, and
respiratory therapists during the study period starting 2002 till the end of the current
study.

Criteria for respiratory failure and re-intubation

Re-intubation was performed immediately post extubation when any of the
following major clinical events were to occur: respiratory or cardiac arrest, irregular
respiratory rate associated with loss of consciousness or gasping for air, and severe
hemodynamic instability without response to fluids and vasoactive drugs [13]. In
addition, respiratory failure was defined as the presence or persistence after one hour
post extubation of any of the following parameters requiring reintubation or rescue NIV:
1) hypercapnia (arterial pH < 7.35 along with an increase in PaCO2 of more than 20%
from the time of extubation); 2) hypoxemia defined as arterial O2 saturation by pulse-
oximetry <90% or PaO2 <60 mmHg with a fraction of inspired O2 fraction> 0.5; 3)
decreased consciousness or psychomotor agitation rendering the patient unable to
tolerate noninvasive ventilation; 4) clinical signs suggestive of respiratory muscle fatigue
and/or increased work of breathing, such as the use of respiratory accessory muscles,
intercostal indrawing, or paradoxical motion of the abdomen, 5) severe delirium or
agitation, and 6) inability to clear secretions.

Data collection
Sociodemographic and clinical data were analyzed. These included age, gender, BMI, reason for mechanical ventilation, APACHE II score [14] on admission to the ICU and at the time of liberation from mechanical ventilation, and duration of mechanical ventilation before extubation. Respiratory rate, heart rate, spontaneous tidal volume, and the rapid shallow breathing index were obtained prior to extubation. The causes for respiratory failure were classified as described in the preceding section. In the historic group, the need for rescue NIV in the first 48 hours post extubation was considered a failure of the standard medical therapy. Complications recorded post extubation included hospital-acquired pneumonia and nosocomial blood stream infection irrespective of its origin. These were defined according to the Centers for Disease Control criteria [15]. At time of discharge, the total lengths of stay and hospital mortality rate were recorded.

Statistical analysis

The primary end point was the incidence of respiratory failure in the first 48 hours post extubation. After reviewing reintubation rates in our critical care units in this high risk group over one year period, 62 patients were required in each group in order to detect a 20% absolute reduction in the risk of respiratory failure with the application of prophylactic NIV relative to 25.8% in the conventionally treated group, with a power of 80 percent and a type I error of 5 percent. Secondary outcomes were lengths of intensive care unit and hospital stay and hospital mortality.

Results are expressed as mean ± SD. Continuous variables for the two groups were compared with Student’s t test for normally distributed data or the Mann-Whitney
U-test otherwise. Qualitative or categorical variables were compared with the Chi-square test or Fisher’s exact test. A difference was considered statistically significant when the alpha probability was less than 0.05 (all two-tailed).

Results

Over the period spanning from February 2002 to June 2004, we have identified 101 severely obese patients who required endotracheal intubation for ≥ 48 hours. Eighteen had tracheostomy placed without extubation trial, one was transferred to another facility, and two had a terminal weaning. Eighty eligible patients were then considered for inclusion. Seven patients were excluded for the following reasons: uncontrolled delirium (n=3), unplanned extubation (n=2), facial surgery (n=1), and cranial surgery (n=1) leaving seventy three patients in a pool to access for matching to the NIV group. From July 2004 to September 2005, 83 severely obese patients required intubation ≥48 hours. Fourteen patients had a tracheostomy and one had a terminal weaning. Six met one of the exclusion criteria: 3 for unplanned extubation, one for do-not resuscitate order, one for uncontrolled delirium, and one for facial surgery. The remaining 62 patients of the NIV group were then matched to the conventionally treated participants (figure 1). The two groups were similar in age, gender, BMI, underlying comorbidities, and APACHE II score (table 1). Similarly the causes for endotracheal mechanical ventilation were comparable in both groups. Obstructive apnea was documented in 22% and 27% of the NIV group and the conventional medical therapy group, respectively. The corresponding apnea hypopnea indices were 45.4±7.5 hr⁻¹ (range 14-112) and 40.8±6.3 hr⁻¹ (range 6-94) (p=0.64). None of the patients in the historic group had CPAP therapy in the first 48 hours post extubation.
Table 2 displays the physiologic indices of participants prior to extubation. In the NIV group, the mean inspiratory and expiratory positive airway pressures were $17.2 \pm 3.5$ cm H$_2$O (range 12-26) and $7.2 \pm 1.6$ cm H$_2$O (range 5-12), respectively. The average use of NIV was $16.2 \pm 2.6$ hours per day for the first 48 hours post extubation. Nine complained of oral dryness due to inability to keep a tight seal. Four responded to placement of a chinstrap and five were switched to a full face mask. Two had abrasion of the dorsum nasae but none of the patients developed evidence of gastric distension, aspiration, or epistaxis. Twenty three patients remained on the bi-level positive pressure ventilation beyond the 48 hours of whom seventeen had evidence of hypercarbia during a trial of spontaneous breathing. In comparison, the mean inspiratory and expiratory positive airway pressures for the conventionally treated group were $15.5 \pm 3.5$ cm H$_2$O (range 10-22) and $6.4 \pm 2.2$ cm H$_2$O (range 4-10), respectively, but the difference was not statistically different between the two groups ($p=0.17$ for IPAP and $p=0.2$ for EPAP; respectively). In contrast, the average use of NIV was significantly lower at $9.8 \pm 5.8$ hours ($P<0.001$) as 8 of the 12 severely obese patients who received rescue NIV required reintubation within the first 24 hours after the onset of respiratory failure.

The institution of NIV post extubation resulted in 16% (95% confidence interval [CI] 2.9%-29.3%) absolute reduction in the risk of respiratory failure compared to the conventionally treated group (10% vs 26%; relative risk [RR], 0.38; 95% confidence interval [CI], 0.16-0.89). Table 3 outlines the causes of respiratory failure in both groups. Because NIV rescue therapy resulted in 3 patients avoiding reintubation out of the 12 receiving standard therapy, the rate of reintubation was not statistically significant between the two groups (10% vs 21%; RR 0.46; 95% CI 0.19-1.14). The majority of
events responsible for respiratory failure occurred in the first 24 hours as 19 out of the 22 cases of respiratory failure were reported 8.6±4.9 hr post extubation. The time to respiratory failure post extubation was longer for the NIV group (16.0 ±8.9 hr) relative to those assigned to the standard therapy (8.6±6.1 hr) but the difference fell short of statistical significance (p=0.14).

Although the nosocomial rate of blood stream and respiratory infections was not significantly different between the two groups, patients who received NIV therapy had a shorter ICU and hospital length of stay compared to those who were assigned to the conventional medical therapy (p<0.001 and p=0.007; respectively). Hospital mortality however was comparable between the NIV group and the conventional therapy group.

In a post hoc analysis of the 47 patients who had hypercarbia during a trial of spontaneous breathing, the incidence of respiratory failure was significantly reduced in those assigned to the NIV group (p=0.03) (Table 4). There was also a trend toward a reduction in the frequency of reintubation (p=0.1). The total incidence of blood stream and respiratory infections was observed in 4 (16%) out of 25 of the NIV group with hypercarbia and 12 (55%) out of 22 of the conventional therapy group (p=0.01). As a result, mortality rate was significantly higher for patients with hypercarbia assigned to conventional therapy (p=0.03). Respiratory failure with prolonged mechanical ventilation was responsible for 8 of the 11 deaths compared to 2 out of the 4 deaths in the hypercarbic NIV group (p=0.56).
Discussion

The main finding of this study is that the use of NIV therapy in severely obese patients resulted in 16% absolute reduction in the rate of respiratory failure post extubation compared to conventional medical therapy. Noninvasive ventilation was notably more beneficial in those who showed evidence of persistent hypercarbia during weaning trials.

Earlier investigations suggested that the prophylactic use of NIV in morbidly obese patients during the first 24 hours postoperatively reduced significantly pulmonary dysfunction after gastroplasty and accelerated reestablishment of preoperative pulmonary function [12]. Joris and colleagues [12] demonstrated that the application of bi-level positive airway pressure set at 12 and 4 cm H2O improved significantly the peak expiratory flow rate, the forced vital capacity, and the oxygen saturation on the first postoperative day. This improvement was attributed to a combined effect of improved lung inflation, prevention of alveolar collapse, and reduced inspiratory threshold load. However, the study did not investigate the potential benefit of bi-level positive airway pressure on the incidence of postoperative pulmonary complications nor did it assess the impact on mortality or length of stay.

Subsequent studies that have examined the role of noninvasive ventilation in the post extubation period have assessed outcomes only after respiratory failure has occurred. Two randomized controlled trials [6, 7] involving a heterogenous group of patients found that the use of noninvasive ventilation post extubation did not reduce the rate of reintubation when compared to standard medical therapy. In contrast, our study
found that early intervention with NIV post extubation reduced the frequency of respiratory failure and demonstrated a trend toward avoiding reintubation. The difference in these observations can be explained by the fact that our protocol required immediate institution of NIV post extubation rather than intervening after clinical signs of respiratory failure became evident. Once respiratory distress ensues, delay in reversing respiratory failure has been shown to contribute to organ dysfunction and poor outcomes [16]. Along this line, Jiang and colleagues [17] examined the efficacy of prophylactic noninvasive ventilation in a randomized trial by assigning 93 patients to either biphasic positive airway pressure or unassisted oxygen therapy, but the rate of reintubation in the trial was not statistically significant between the two groups. However, the study recruited participants “indiscriminately” including those with unplanned extubation. The relevance of patients’ selection was highlighted in two recently published trials [18, 19]. In a multicenter randomized controlled trial, Nava and coworkers [18] found prophylactic NIV to be more effective in preventing reintubation than standard medical therapy in patients at risk. Ferrer and coworkers [19] reached a similar conclusion by showing that the early use of NIV averted respiratory failure in selected patients considered at risk for respiratory failure post extubation.

Another potential explanation for the observed benefit in the NIV cohort pertains to the fact that our study population is considered at high risk for obstructive sleep apnea. Although we were aware of the presence of obstructive sleep apnea in 25% of our study population, unrecognized OSA has been implicated in worsening respiratory failure and unexpected transfer to the ICU post liberation from mechanical ventilation [20, 21]. Gupta and coworkers [22] reported twenty four percent serious complications
post hip and knee replacement in 101 patients with the diagnosis of OSA within 72 hours post extubation including reintubation and urgent continuous positive airway pressure application. In the absence of high quality evidence supporting the routine use of CPAP in severely obese patients with OSA post liberation from mechanical ventilation, the early application of NIV in our case could have averted potential worsening in respiratory status of OSA patients from residual effects of sedatives and narcotics that could have developed hours post extubation.

Most of the published studies assessing the use of NIV in acute respiratory has relied on oro-nasal or facial masks [6,7,18,19]. Although there are no published studies, to our knowledge, on the superiority of one method over the other in the obese population, we have found based on our prior experience a better tolerance for nasal masks in the morbidly obese because they tended to be less claustrophobic. One controlled trial comparing the efficacy of nasal and oronasal masks in 26 non obese patients with stable hypercapnia caused by COPD or restrictive disease found that the oronasal mask was more effective in lowering PaCO₂ but the nasal mask was better tolerated than either the nasal pillow or the oronasal mask [23]. However, another preliminary report from a controlled trial comparing nasal and oronasal masks found that PaCO₂ and respiratory rate fell at equal rates when the masks were used for patients with respiratory distress [24]. Because of the ongoing debate, further studies are needed to elucidate the optimal interface for the most effective response in the obese population with respiratory failure.
Our observations point to preferential benefit of NIV in severely obese patients with underlying hypercapnia. The effectiveness of NIV in reducing the rate of hypercapnic respiratory failure has been suspected from earlier studies involving patients with COPD exacerbations [25, 26]. In a nonrandomized trial, Hilbert and colleagues [26] reported 47% attributable risk reduction in the need for endotracheal intubation for hypercapnic COPD patients assigned to noninvasive ventilation post extubation. The study noted also a significant decrease in mean duration of ventilatory assistance for the treatment of post extubation distress and in the length of ICU stay. Comparable to our observations, noninvasive ventilation was more effective in patients who exhibited hypercapnia during the spontaneous breathing trial. However, our data extended those findings by demonstrating a reduced rate of blood stream and hospital-acquired pulmonary infections which were translated into shorter length of stay and improved hospital mortality. It is noteworthy to mention that aside from possible random effects as a consequence of the limitations of post-hoc analysis, the study was not powered to address the outcome of prophylactic NIV in hypercapnic obese patients. This hypothesis should be investigated in a future prospective, randomized controlled trial.

Among the limitations of our study is the use of historically matched controls [27]. A frequently cited source of bias with historical controls is the mere fact that implementing a prospective study may improve patient outcome. Moreover, historical comparisons of two cohorts are influenced by change in disease patterns and treatment strategies and are considered to favor the group treated with the new method. However, except for the application of NIV therapy, the presence of protocols-driven ICU
management coupled with low staff turnover in our institution would argue against this possibility. Moreover, differences in pulmonary function among participants might favor one group over the other particularly if an obstructive pattern happens to be more frequent in the NIV group. In the absence of pulmonary function tests, this possibility should be taken into consideration when interpreting the results of the study. Another limitation of our study pertains to the potential of high prevalence of sleep apnea in the study population which might introduce a bias in the favor of the NIV group. Pending a randomized controlled trial, the risk of respiratory complications and poor outcome of prolonged ventilation in this high risk group population should be balanced against the observed benefits of a historical controlled investigation.

In conclusion, prophylactic use of NIV in severely obese patients post extubation is warranted. Early application of NIV may be effective in averting respiratory failure before the development of respiratory distress and may be responsible for decreasing mortality in selected patients with chronic hypercarbia.

Acknowledgments

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Financial Disclosure

None of the authors have a financial relationship with a commercial entity that has interest in the subject of this manuscript.

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Legends

Figure 1. Flow diagram of the study population. DNR=Do-not resuscitate; NIV=Noninvasive ventilation
References


Table 1. Baseline characteristics of the study population

<table>
<thead>
<tr>
<th></th>
<th>NIV</th>
<th>Conventional therapy</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age, years</strong></td>
<td>47.6±11.7</td>
<td>50.1±12.5</td>
<td>0.27</td>
</tr>
<tr>
<td><strong>Gender (M/F)</strong></td>
<td>37/25</td>
<td>33/29</td>
<td>0.59</td>
</tr>
<tr>
<td><strong>BMI (kg/m²)</strong></td>
<td>47.4±10.7</td>
<td>45.6±7.6</td>
<td>0.29</td>
</tr>
</tbody>
</table>

**Comorbidities**

- **Chronic heart diseases**
  - NIV: 6 (10)
  - Conventional therapy: 8 (13)
  - P: 0.78
- **Chronic pulmonary diseases†**
  - NIV: 13 (21)
  - Conventional therapy: 16 (26)
  - P: 0.67
- **Hypertension**
  - NIV: 39 (63)
  - Conventional therapy: 30 (48)
  - P: 0.15
- **Diabetes mellitus**
  - NIV: 33 (53)
  - Conventional therapy: 27 (43)
  - P: 0.37
- **Obstructive sleep apnea**
  - NIV: 14 (23)
  - Conventional therapy: 17 (27)
  - P: 0.68

**Underlying causes for mechanical ventilation**

- **Cardiac failure**
  - NIV: 15 (24)
  - Conventional therapy: 11 (18)
  - P: 0.51
- **Sepsis**
  - NIV: 8 (13)
  - Conventional therapy: 14 (22)
  - P: 0.24
- **Respiratory failure**
  - NIV: 33 (53)
  - Conventional therapy: 27 (44)
  - P: 0.37
- **Gastrointestinal‡**
  - NIV: 3 (5)
  - Conventional therapy: 4 (6)
  - P: 0.83
- **Neurologic§**
  - NIV: 3 (5)
  - Conventional therapy: 6 (10)
  - P: 0.49
- **APACHE II on admission**
  - NIV: 21.8±4.6
  - Conventional therapy: 23.1±5.7
  - P: 0.17

*Chronic heart disorders include coronary artery disease, valvular heart diseases, and cardiomyopathy of any cause.
†Chronic respiratory disorders refer to the presence of obstructive lung disease, chronic hypercapnia, interstitial, or occupational lung disease.

‡ Underlying gastrointestinal causes for mechanical ventilation included pancreatitis, diffuse colitis, and cholecystitis.

§ Underlying neurologic causes for mechanical ventilation included cerebrovascular accidents and seizure disorders.
Table 2. Characteristics of the patients at the time of extubation

<table>
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<th>Conventional therapy</th>
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<tr>
<td>Duration of mechanical ventilation, days</td>
<td>7.9±3.6</td>
<td>8.8±4.2</td>
<td>0.23</td>
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<tr>
<td>APACHE II at the time of extubation</td>
<td>14.8±3.4</td>
<td>15.5±3.5</td>
<td>0.32</td>
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**Physiologic indices during spontaneous breathing trial**

<table>
<thead>
<tr>
<th></th>
<th>NIV</th>
<th>Conventional therapy</th>
<th>P value</th>
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<tbody>
<tr>
<td>Heart rate, min⁻¹</td>
<td>96.9±18.8</td>
<td>99.3±19.9</td>
<td>0.51</td>
</tr>
<tr>
<td>Respiratory rate, min⁻¹</td>
<td>23.7±4.3</td>
<td>22.6±4.7</td>
<td>0.43</td>
</tr>
<tr>
<td>f/VT ratio*</td>
<td>74.6±11.6</td>
<td>71.5±13.7</td>
<td>0.16</td>
</tr>
<tr>
<td>Arterial pH</td>
<td>7.39±0.05</td>
<td>7.4±0.06</td>
<td>0.58</td>
</tr>
<tr>
<td>PaCO₂, mmHg</td>
<td>47.1±8.9</td>
<td>44.8±7.7</td>
<td>0.13</td>
</tr>
<tr>
<td>PaO₂, mmHg</td>
<td>83±14</td>
<td>84±12</td>
<td>0.67</td>
</tr>
<tr>
<td>PaO₂/FiO₂</td>
<td>215±38</td>
<td>221±41</td>
<td>0.38</td>
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</table>

*f/VT = ratio of respiratory frequency to tidal volume
Table 3. Post extubation complications of critically ill morbidly obese patients

<table>
<thead>
<tr>
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<th>NIV N=62</th>
<th>Conventional therapy N=62</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory failure</td>
<td>6 (10)</td>
<td>16 (26)</td>
<td>0.03</td>
</tr>
<tr>
<td>Reintubation</td>
<td>6 (10)</td>
<td>13 (21)</td>
<td>0.14</td>
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Causes of respiratory failure

<table>
<thead>
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<th></th>
<th>NIV</th>
<th>Conventional therapy</th>
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<tbody>
<tr>
<td>Hypoxia</td>
<td>2 (3)</td>
<td>3 (5)</td>
<td></td>
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<tr>
<td>Hypercarbia</td>
<td>2 (3)</td>
<td>9 (15)</td>
<td></td>
</tr>
<tr>
<td>Respiratory muscle fatigue</td>
<td>1 (2)</td>
<td>2 (3)</td>
<td></td>
</tr>
<tr>
<td>Hemodynamic instability</td>
<td>0</td>
<td>1 (2)</td>
<td></td>
</tr>
<tr>
<td>Inability to clear secretions</td>
<td>0</td>
<td>1 (2)</td>
<td></td>
</tr>
<tr>
<td>Delirium</td>
<td>1 (2)</td>
<td>0</td>
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<tr>
<th></th>
<th>NIV</th>
<th>Conventional therapy</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital-acquired pneumonia</td>
<td>3 (5)</td>
<td>9 (15)</td>
<td>0.13</td>
</tr>
<tr>
<td>Blood stream infection</td>
<td>2 (3)</td>
<td>5 (8)</td>
<td>0.44</td>
</tr>
<tr>
<td>ICU stay, days</td>
<td>11.8±7.9</td>
<td>18.2±11.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hospital stay, days</td>
<td>20.6±10.6</td>
<td>26.0±11.3</td>
<td>0.007</td>
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<tr>
<td>Hospital mortality</td>
<td>8 (13)</td>
<td>15 (24)</td>
<td>0.17</td>
</tr>
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</table>

NIV = Noninvasive ventilation
Table 4. Characteristics of patients with hypercarbia during spontaneous breathing trial

<table>
<thead>
<tr>
<th></th>
<th>NIV</th>
<th>Conventional therapy</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PaCO₂, mmHg</td>
<td>55.6±6.6</td>
<td>52.9±5.7</td>
<td>0.19</td>
</tr>
<tr>
<td>Respiratory failure</td>
<td>3 (12)</td>
<td>10 (45)</td>
<td>0.03</td>
</tr>
<tr>
<td>Reintubation</td>
<td>3 (12)</td>
<td>8 (36)</td>
<td>0.10</td>
</tr>
<tr>
<td>ICU length of stay, days</td>
<td>14.5±9.8</td>
<td>22.1±14.6</td>
<td>0.04</td>
</tr>
<tr>
<td>Hospital mortality</td>
<td>4 (16)</td>
<td>11 (50)</td>
<td>0.03</td>
</tr>
</tbody>
</table>