Full Face Mask for Noninvasive Positive-Pressure Ventilation in Patients With Acute Respiratory Failure

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Background: Noninvasive positive-pressure ventilation (NPPV) is commonly used to improve ventilation and oxygenation in patients with acute respiratory failure (ARF). Mask leak and intolerance due to facial discomfort or claustrophobia often occur with NPPV and are frequently cited reasons for treatment failure.

Methods: Retrospective review of patient records from a tertiary-care referral hospital.

Results: We report the effectiveness of a full face mask in the application of NPPV for 10 nonambulatory patients (mean [SD], 61 [9] years) who had a combined total of 13 episodes of ARF. After these patients were unable to receive NPPV therapy via the more commonly available nasal or oronasal masks, care was provided using full face masks. Eight of 10 patients had hypercapnic respiratory failure; 2 patients, hypoxemic respiratory failure. All patients were placed on ventilation initially using a bi-level positive airway pressure device. Subsequently, patient ventilation was achieved using a Puritan Bennett 7200a ventilator for on-line respiratory monitoring. The mean (SD) duration of treatment with NPPV was 9.7 (2.7) hours per day for 3.0 (1.6) days. Following NPPV via full face mask, the patients’ PaCO2 decreased (65 [20] vs 82 [27] mm Hg, P=.09) and pH increased significantly (7.36 [0.07] vs 7.26 [0.07], P<.05) in less than 2 hours. Moreover, the patients demonstrated decreased respiratory rate (18 [7] vs 32 [8] breaths/min, P<.01), heart rate (106 [13] vs 124 [16] beats/min, P=.008), and Acute Physiology and Chronic Health Evaluation II scores (12 [3] vs 17 [4], P<.005) after NPPV via full face mask. These cardiorespiratory alterations occurred as early as 1 hour after NPPV initiation and were maintained throughout treatment. Two patients required endotracheal intubation because of copious purulent secretions.

Conclusion: For individuals with hypercapnic respiratory failure who cannot tolerate NPPV using nasal or oronasal masks, use of full face masks may improve outcomes, allowing physicians to avoid ordering endotracheal intubation and mechanical ventilation.

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In carefully selected patients with chronic respiratory failure, noninvasive positive-pressure ventilation (NPPV) has been shown to improve gas exchange, sleep quality, and functional status.1-5 Some studies have found that, in 60% to 80% of patients with acute respiratory failure (ARF), NPPV decreased the need for sedation and invasive mechanical ventilation while also decreasing the incidence of sinusitis and nosocomial pneumonia.6-14 In addition, some investigators15-17 have shown NPPV improves survival in patients with ARF as compared with conventional invasive mechanical ventilation. Reasons that NPPV treatment may be unable to prevent the need for endotracheal intubation include: aerophagia, claustrophobia, facial skin breakdown, inability to handle copious purulent secretions, interruption to deliver nebulized bronchodilators, limitations in achieving adequate ventilation, mask leaks, and mask placement instability.16

Some of the factors that limit the use of NPPV are related to problems with patient-mask interfacing. Previously, Criner and colleagues18 compared the efficacy of NPPV via full face mask versus nasal and oronasal masks in patients with chronic respiratory failure. Their study determined that full face masks could more effectively increase minute ventilation measurements and decrease PaCO2 than other mask types. Moreover, that study found that full face masks decreased mouth and mask leaks, enhanced tolerability, and were more comfortable for patients than other mask types. Similarly, other investigators19,20 have reported a decrease in intubation rates and mask-related complications with the use of a new type of full face mask called the “helmet.”

The present study describes 10 patients who had a combined total of 13 episodes of ARF. After these nonambulatory patients were unable to receive NPPV therapy via more commonly available nasal or oronasal masks, treatment was delivered using full face masks (Total Face Mask [TFM], Respironics Inc, Monroeville, Pa). Using TFM, we explored the need for endotracheal intubation and examined a variety of respiratory and hemodynamic parameters.
Methods

Patient Selection

Ten patients who were admitted to Temple University Hospital in Philadelphia, Pa, for treatment of ARF were selected for participation in the present retrospective study. Two of these patients had chronic obstructive pulmonary disease (COPD) and were later readmitted. All patients were initially treated with NPPV using nasal or oronasal masks but were either unable to tolerate this therapy or their ventilation failed to improve. Their treatment was then converted to NPPV via full face mask.

All patients received aggressive combination therapy with antibiotics, bronchodilators (albuterol, 5 mg, every 4 hours; ipratropium bromide, 0.5 mg, every 6 hours via small-volume nebulizer), intravenous methylprednisolone, 0.5 mg per kilogram of body weight, every 6 hours, theophylline, and when indicated, supplemental oxygen. Despite aggressive pharmacotherapy, the patients’ worsening respiratory status necessitated the administration of NPPV.

Acute Physiology and Chronic Health Evaluation (APACHE) II scores were used to measure illness severity in all patients receiving NPPV. The following three components were used to determine APACHE II scores:

- acute physiologic score: vital signs, PaO\textsubscript{2}, pH, electrolytes, and complete blood cell count
- Glasgow Coma Scale: eye movement as well as verbal and motor responses
- chronic health points: age and the presence of underlying disorders

In order to determine the total APACHE II score, we combined the values for each of the three components noted.

Mask Selection and Ventilation Targets

All patients were initially treated with NPPV via conventional nasal or oronasal face masks (Respironics Inc, Monroeville, Pa) using a bi-level positive airway pressure device (BiPAP, Respironics Inc, Monroeville, Pa) followed by a conventional intensive care unit (ICU) volume ventilator (Puritan Bennett 7200a, Puritan Bennett, Carlsbad, Calif). A conventional volume ventilator was used because of the need for on-line respiratory monitoring. Figure 1 and Figure 2, respectively, show the nasal and oronasal face masks used in the present study.

Mechanical ventilator settings were chosen while monitoring patients’ respiratory rates, end-inspiratory and end-expiratory airway pressures, and inspiratory and expiratory flows and volumes. The final settings considered optimal were those that improved the patients’ gas exchange, and those that visually decreased labored breathing and improved patient comfort. For the purposes of this study, “labored breathing” and “patient discomfort” were defined as failure to decrease the respiratory rate to less than 30 breaths/min or to achieve a tidal volume greater than 6 mL/kg, and failure to diminish sternocleidomastoid muscle activity as assessed both visually and by palpation.

One of the authors (G.J.C.) conducted all patient evaluations (ie, physical examinations and clinical evaluations) and supervised NPPV initiation. Patients who had extensive mouth or mask leaks, poor mask tolerance, or an inability to increase applied ventilation to target levels so as to stabilize their gas exchange and diminish labored breathing within 1 hour of treatment with nasal or oronasal masks were considered for treatment with NPPV via full face mask (Figure 3). All variables reported were obtained while patients received ventilation via TFM. We received institutional review board approval to use the TFM on a compassionate basis.

Hemodynamic and Respiratory Variables

Hemodynamic (blood pressure, heart rate) and respiratory (respiratory rate) variables were measured for 2 minutes with average values reported. Pulmonary function was tested according to American Thoracic Society guidelines. The baseline forced expiratory volume in 1 second (FEV\textsubscript{1}) was obtained from the most recent spirometry done in our pulmonary function laboratory prior to patient hospitalization for ARF. Patients’ arterial blood gases were measured at least 30 minutes after ventilation or spontaneous breathing trials on the chosen ventilator settings and fraction of inspired oxygen (FiO\textsubscript{2}) levels.

Statistical Analysis

An analysis of variance was used to compare ventilatory variables, arterial blood gas levels, and APACHE II scores on and
off NPPV (SigmaStat Software; Systat Software Inc, Richmond, Calif). The Wilcoxon rank sum test was used for data that are not normally distributed. A \( P \) value of less than .05 was considered statistically significant. Demographic data are reported as mean (SD).

**Results**

This cohort of 10 patients (age, 61 [9] years) had a combined total of 13 episodes of ARF that required treatment with NPPV. The most common cause of ARF was hypercapnic respiratory failure due to COPD exacerbation (Table 1). The causes of ARF in the other patients were severe kyphoscoliosis, community-acquired pneumonia, and posttransplant lymphoproliferative disorder in a patient who also had COPD. Baseline spirometry was available for the majority of patients. For 1 patient, who was admitted with community-acquired pneumonia, this baseline measure was unavailable. In 12 of 13 episodes, patients had an FEV\(_1\) of 1 L or lower. The remaining patient, who had a single-lung transplant, had an FEV\(_1\) of 1.82 L. The mean FEV\(_1\) of 0.70 (0.4) L reflected severe airflow obstruction in the patients with COPD and severe chest wall restriction in the patient with kyphoscoliosis.

In the 13 episodes of ARF, 11 episodes were due to hypercapnic respiratory failure with an admission PaCO\(_2\) value ranging from 52 to 116 mm Hg (6.9-15.5 kPa). Overall, the mean PaCO\(_2\) value on admission was 71 (28) mm Hg (9.5 [4] kPa). All patients were initially treated with NPPV using conventional nasal or oronasal masks and were either intolerant of the mask or failed to show clinical improvement. In the 7 patients for whom arterial blood gas was measured after NPPV initiation with conventional masks, acute respiratory acidosis failed to improve after 1 hour of treatment as reflected by persistent acidemia (NPPV using conventional masks, 7.26 [0.1] vs baseline, 7.29 [0.07], \( P < .1 \)) and hypercapnia (PaCO\(_2\) with NPPV using conventional masks, 75 [34] mm Hg [10 (5) kPa] vs baseline, 59 [27] mm Hg [7.9 (4) kPa], \( P < .03 \)). All patients were acutely ill as reflected by the moderately high mean APACHE II score of 18 (3).

Following ineffectiveness of conventional masks in this cohort, TFM was applied. The initial inspiratory positive airway pressure was 21 (4) cm H\(_2\)O with baseline continuous positive airway pressure of 3 (3) cm H\(_2\)O (Table 2). The average pressure boost (ie, difference between inspiratory and continuous positive airway pressure levels) was 18 (4) cm H\(_2\)O. All patients were treated with NPPV via the pressure support mode; 6 patients in the pressure support mode with backup 4 to 6 breaths/min of intermittent mandatory ventilation. During NPPV treatment with TFM, all patients received ventilation without difficulty. The average minute ventilation was 12.9 (8.1) L, tidal volume was 585 (100) mL, and respiratory rate was 33 (7) breaths/min. (continued)
### Table 1
**Noninvasive Positive-Pressure Ventilation via Full Face Mask: Patient Characteristics on Admission (N=10)**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age, y</th>
<th>Sex</th>
<th>Disease</th>
<th>FEV, L</th>
<th>APACHE II Score</th>
<th>( P_{aO_2} )</th>
<th>( F_\text{IO}_2 )*</th>
<th>( P_{co_2} )*</th>
<th>pH</th>
</tr>
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<tr>
<td>1</td>
<td>67</td>
<td>M</td>
<td>COPD</td>
<td>0.86</td>
<td>19</td>
<td>176</td>
<td>66</td>
<td>7.28</td>
<td></td>
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<tr>
<td>2</td>
<td>56</td>
<td>F</td>
<td>COPD</td>
<td>0.46</td>
<td>20</td>
<td>196</td>
<td>104</td>
<td>7.27</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>46</td>
<td>F</td>
<td>Kyphoscoliosis</td>
<td>0.70</td>
<td>15</td>
<td>258</td>
<td>116</td>
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<td>4</td>
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<td>COPD</td>
<td>0.58</td>
<td>20</td>
<td>200</td>
<td>57</td>
<td>7.36</td>
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<td>7.34</td>
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<td>59</td>
<td>F</td>
<td>COPD</td>
<td>0.35</td>
<td>9</td>
<td>463</td>
<td>55</td>
<td>7.36</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>53</td>
<td>M</td>
<td>Pneumonia</td>
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<td>17</td>
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<td>19</td>
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<td></td>
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<tr>
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<td>COPD</td>
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<tr>
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<td>55</td>
<td>F</td>
<td>COPD s/p SLT</td>
<td>1.82</td>
<td>17</td>
<td>273</td>
<td>39</td>
<td>7.43</td>
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</tr>
</tbody>
</table>

Mean (SD) | 61 (9) | NA  | NA  | 0.70 (0.4) | 18 (3) | 270 (86) | 71 (28) | 7.29 (0.07) |

* Data are given as mm Hg.

**Abbreviations:** APACHE II, Acute Physiology and Chronic Health Evaluation; COPD, chronic obstructive pulmonary disease; FEV\(_1\), forced expiratory volume in one second (most recent data recorded on the patient's chart); \( F_\text{IO}_2 \), partial pressure of oxygen; NA, not available; \( P_{aO_2} \), arterial oxygen tension; \( P_{co_2} \), arterial carbon dioxide tension; SLT, single lung transplant; s/p, status post.

### Table 2
**Noninvasive Positive-Pressure Ventilation via Full Face Mask: Patient Ventilation and Respiratory Values on Admission (N=10)**

<table>
<thead>
<tr>
<th>Patient</th>
<th>IPAP*</th>
<th>CPAP*</th>
<th>Mode</th>
<th>( V_\text{T} ), mL</th>
<th>RR, bpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22</td>
<td>2</td>
<td>PS</td>
<td>0.27</td>
<td>600</td>
</tr>
<tr>
<td>2</td>
<td>22</td>
<td>4</td>
<td>PS/IMV</td>
<td>0.21</td>
<td>650</td>
</tr>
<tr>
<td>3</td>
<td>18</td>
<td>2</td>
<td>PS</td>
<td>0.27</td>
<td>560</td>
</tr>
<tr>
<td>4</td>
<td>20</td>
<td>3</td>
<td>PS</td>
<td>0.27</td>
<td>600</td>
</tr>
<tr>
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<td>26</td>
<td>2</td>
<td>PS</td>
<td>0.21</td>
<td>800</td>
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<tr>
<td>6</td>
<td>15</td>
<td>3</td>
<td>PS</td>
<td>0.28</td>
<td>500</td>
</tr>
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<td>700</td>
</tr>
<tr>
<td>8</td>
<td>22</td>
<td>2</td>
<td>PS/IMV</td>
<td>0.27</td>
<td>500</td>
</tr>
<tr>
<td>9</td>
<td>18</td>
<td>3</td>
<td>PS/IMV</td>
<td>0.27</td>
<td>580</td>
</tr>
<tr>
<td>10</td>
<td>15</td>
<td>3</td>
<td>PS</td>
<td>0.40</td>
<td>400</td>
</tr>
</tbody>
</table>

Mean (SD) | 21 (4) | 3 (3) | NA  | 0.27 (0.05) | 585 (100) | 33 (7) |

* Data are given as cm H\(_2\)O.

**Abbreviations:** CPAP, continuous positive airway pressure; \( F_\text{IO}_2 \), partial pressure of oxygen; IMV, intermittent mandatory ventilation; IPAP, inspiratory positive airway pressure; NA, not applicable; \( V_\text{T} \), tidal volume.
Figure 4. Daily mean arterial pressure (MAP), heart rate, and respiratory rate on admission (day 0), during noninvasive positive-pressure ventilation (NPPV) via full face mask (Total Face Mask [TFM], Respironics Inc, Monroeville, Pa), and while breathing spontaneously with supplemental oxygen. The MAP tended to be higher during NPPV treatment. Heart rate and respiratory rate were lower during therapy when compared with spontaneous breathing on supplemental oxygen alone. *Statistically significant (P<.05) when compared with baseline data on hospital admission (day 0).

Figure 5. Mean PaO$_2$/FiO$_2$, Paco$_2$, and pH values on admission (day 0), during noninvasive positive-pressure ventilation (NPPV) via full face mask (Total Face Mask [TFM], Respironics Inc, Monroeville, Pa), and while breathing spontaneously with supplemental oxygen alone. Following treatment initiation, mean PaO$_2$/FiO$_2$ was higher and Paco$_2$ was lower than on admission, but the values were not statistically significant. The pH value increased when patients were on NPPV via full face mask and while spontaneously breathing when compared with admission values. *Statistically significant (P<.05) when compared with baseline data on hospital admission (day 0).
On ICU admission, each patient’s mean arterial pressure (MAP), respiratory rate, and heart rate were measured hourly after NPPV initiation and during spontaneous breathing with supplemental oxygen (Figure 4). Data recorded for patients’ MAP showed a trend to increase from day 2 through day 4 (95 [7] vs 100 [13] mm Hg, P = .35). After placement on NPPV, heart rate (122 [16] vs 103 [16] beats/min, P < .05) and respiratory rate (33 [7] vs 18 [7] breaths/min, P < .05) decreased when compared with spontaneous breathing on supplemental oxygen alone. During the 4-day observation period, the reductions in heart rate and respiratory rate seen with NPPV via TFM remained stable.

When compared with breathing supplemental oxygen alone, \(\text{PaO}_2/\text{FiO}_2\) values tended to be higher and \(\text{PaCO}_2\) values tended to be lower in patients with NPPV via TFM, but these values did not reach statistical significance (Figure 5). On days 2 and 3 of treatment, however, pH values during NPPV (7.32 [0.05] vs 7.40 [0.05]) and while spontaneous breathing (7.32 [0.12] vs 7.37 [0.04]) were significantly greater when compared with ICU admission values (7.29 [0.06], P < .05).

Expired minute ventilation and tidal volume were measured daily in all patients during NPPV treatment (Figure 6). During the first 3 days of NPPV application, mean (SD) minute ventilation was 12.6 (7.1) L and tidal volume was 647 (147) mL, with a range of 400 to 1000 mL. These values remained stable during treatment.

Before NPPV initiation, APACHE II scores were determined. Researchers continued to monitor these scores daily (Figure 7). After treatment initiation, APACHE II scores were significantly lower in patients while on NPPV and during spontaneous breathing. Lower scores were the result of reductions in acute physiologic scores reflecting improvements in gas exchange as well as hemodynamic and respiratory data. That is, patients had higher blood pressure, lower respiratory rates, and a lower incidence of hypercapnia.

In the first full day of treatment, patients averaged 13.5 (1.9) hrs/day (Figure 8). The number of patients using NPPV and the duration of use decreased subsequently, in days 2 and 3 of therapy. In those patients still requiring treatment on days 4 and 5 after initiation, the average duration of use was 7.8 (2.7) hrs/day.

There were some complications as a result of NPPV via TFM (Table 3). Of the 10 patients, 2 required endotracheal intubation. One of these patients required intubation because of excessive purulent secretions and mask leak; the other patient, because of recurrent mask leaks, respiratory distress, and aerophagia complicated by the presence of underlying organic brain disease. Minor mask leaks (<50 mL) were a limitation in 5 of 13 episodes of ARF. Several patients had aerophagia, but this condition did not inhibit NPPV therapy. Three patients required face mask adjustment throughout treatment. As a result of a change in mental status, 1 patient had the hoop-and-loop fastening strap dislodged from the mask. None of the patients had evidence of facial skin breakdown. Overall, the complications most frequently seen were mask leak and aerophagia, neither of which inhibited the continued use of NPPV via TFM.

Comment
Our data show that in 11 of 13 episodes of ARF, therapy with NPPV was successfully accomplished via full face mask in patients who were previously unable to tolerate this treatment modality with conventional nasal or oronasal masks. By initiating NPPV via full face mask, hemodynamic parameters (ie, blood pressure, heart rate) and breathing patterns improved. Noninvasive positive-pressure ventilation also improved gas exchange abnormalities with increased arterial pH, improved oxygenation levels, and decreased incidence of hypercapnia. Moreover, APACHE II scores were significantly reduced with NPPV therapy via TFM. In most patients, the increased ven-
The ventilation associated with NPPV therapy was well tolerated without dislodgment of the face mask or significant need for readjustment. Complications from treatment were minimal and generally did not lead to an interruption in therapy.

Although several studies have now reported in prospective and controlled fashions the beneficial effects of NPPV therapy in ARF, the reasons that treatment fails in 30% to 40% of patients has not been well documented. Commonly cited reasons for failure of NPPV are inability to meet increased ventilation targets and patient mask-intolerance, including problems associated with the mask’s being frequently dislodged (eg, nursing care required to ensure mask placement). In a prospective, randomized controlled trial comparing the efficacy of NPPV versus conventional mechanical ventilation in patients with ARF, 10 (31%) of 32 patients treated with NPPV eventually required endotracheal intubation. The reasons for NPPV failure in that study were inability to improve oxygenation (4 patients), intolerance of NPPV (2 patients), hemodynamic instability (2 patients), persistent dyspnea (1 patient), and excessive purulent secretions (1 patient). In a survey of 42 ICUs on the type of ventilatory support used in patients with ARF (N=689), NPPV was initially used as first-line treatment in 108 (16%) patients. Most of the patients who were treated with NPPV had hypercapnic respiratory failure (50%), with 27% having pulmonary edema, and 14% hypoxemic respiratory failure. In 52 (48%) of these 108 patients, NPPV therapy was terminated early because of a lack of clinical response, patients’ inability to handle purulent secretions, patient intolerance of NPPV, and full dependence on ventilatory support. Forty-three of these patients ultimately required endotracheal intubation. Multiple regression analysis revealed that the Simplified Acute Physiology Score II and intolerance to NPPV were two independent predictors of the need for mechanical ventilation. Indeed, when patients with ARF are unable to tolerate NPPV therapy because of poor mask interface, the result often is interrupted therapy leading to a decrease in treatment efficacy.

The ventilation targets achieved in our patient population were relatively high with little mask adjustment requirements and no incidents of facial skin breakdown. Moreover, mask leaks noted in 5 patients were minimal and were not a limitation in achieving high ventilation targets. We believe that these three factors (ie, lack of mask adjustment, skin breakdown, and minimal mask leaks) were instrumental in the success of using full face masks over the other two types of masks that failed in the same patient population. Because the full face mask is large and is designed to cover the entire face, it

**Figure 7.** Mean Acute Physiology and Chronic Health Evaluation (APACHE II) scores before initiation (day 0) of noninvasive positive-pressure ventilation (NPPV), daily during treatment with NPPV via full face mask, and while spontaneously breathing with supplemental oxygen. Mean scores were significantly lower for patients while on NPPV and during spontaneous breathing with supplemental oxygen. *Statistically significant (P<.05) when compared with baseline data on hospital admission (day 0).

**Figure 8.** Mean (13.5 [1.9] SE) hours of therapy per day with noninvasive positive-pressure ventilation via full face mask (Total Face Mask [TFM], Respironics Inc, Monroeville, Pa). Use and the duration of use decreased in days 2 and 3 of treatment.
patients in whom NPPV therapy had previously failed with conventional masks, and who had a high likelihood of undergoing intubation as a result of ARF.

Conclusion

The present study suggests that in patients with acute hypercapnic respiratory failure who could not tolerate NPPV using nasal or oronasal masks, full face masks could be used to improve patient acceptance of NPPV therapy and possibly improve gas exchange and respiratory mechanics, also avoiding endotracheal intubation and mechanical ventilation. These data further substantiate the importance of choosing the proper patient-mask interface for patients undergoing NPPV.

References


4. Elliott MW, Simonds AK, Carroll MP, Wędzińska JA, Branthwaite MA. Domi-


Table 3

Noninvasive Positive-Pressure Ventilation via Full Face Mask: Patient Complications (N=10)*

<table>
<thead>
<tr>
<th>Patient</th>
<th>Intubation</th>
<th>Purulent Secretions</th>
<th>Mask Leak</th>
<th>Aerophagia</th>
<th>Mask Adjustment</th>
<th>Broken Mask</th>
<th>Mental Status Change</th>
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<td>X</td>
<td>X</td>
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</tbody>
</table>

* X indicates the presence of complication noted as a result of noninvasive positive-pressure ventilation. There were no incidents of facial skin breakdown in this patient population. Patient 10 had no complications.

† Patients 1 and 2 were readmitted to the hospital with acute respiratory failure. Patient 1 had no complications on readmission. Patient 2 had no complications on second readmission.


