Intermittent Volume Cycled Mechanical Ventilation Via Nasal Mask in Patients With Respiratory Failure Due to COPD*

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Intermittent mechanical ventilation via nasal CPAP mask was provided to 13 patients admitted to this institution for exacerbation of chronic respiratory failure. Ten suffered from COPD, two suffered from obesity hypoventilation syndrome (OHS), and one from severe hypothyroidism. All except one presented with dyspnea and hypercapnia due solely to progression of their underlying disease processes. Six of the patients with COPD and the patient with hypothyroidism responded to positive pressure ventilation by mask with improvements in blood gas values and clinical status. The remaining two patients with COPD and the two patients with OHS were unable to use the system. Four of the patients with COPD and chronic respiratory failure have been subsequently maintained on daily volume ventilation via nasal mask for about 20 months with persistent clinical and physiologic improvements. Application of volume ventilation through the nasal CPAP mask is a feasible strategy for providing long-term mechanical ventilation to selected patients with COPD and respiratory failure.

(Chest 1991; 99:681-84)

OHS = obesity hypoventilation syndrome

Long-term intermittent mechanical ventilatory support has been shown to have beneficial effects in individuals with chronic respiratory failure due to various diseases of the lungs, chest wall, and nervous system. Patients with COPD have been shown to have improvements in respiratory muscle function, both acutely after single treatments with the cuirass ventilator, and chronically, after long-term intermittent use of cuirass or positive pressure ventilation via tracheostomy. Hemodynamic improvements have also been reported after treatment of chronic respiratory failure with body ventilators. More recently, improvement in ventilation has been reported in patients with neuromuscular diseases and kyphoscoliosis treated either chronically with volume cycled positive pressure ventilation delivered via close fitting nasal CPAP mask, or on a short-term basis with positive pressure ventilation via full face CPAP mask for acute respiratory failure.

We have applied positive pressure mechanical ventilation by mask acutely by mask to selected patients with either acute respiratory failure overlying chronic pulmonary disease or chronic respiratory insufficiency which had progressed far enough to require hospitalization. We have further provided long-term intermittent mechanical ventilation via mask where indicated. This report addresses the utility and efficiency of this modality of mechanical ventilation.

Materials and Methods

Patient Selection

Thirteen patients admitted to Our Lady of Mercy Medical Center with respiratory failure were provided with volume cycled positive pressure ventilation via CPAP mask. Ten had COPD, two had obesity hypoventilation syndrome, and one had severe hypothyroidism. The mean age was 71 years (40 to 80). There were six men and seven women. One of the patients with COPD was the only one with an acute illness (pneumonia). All others had well-documented progressive respiratory failure for periods ranging from one to five years without significant acute deterioration prior to admission.

Mask Fitting

Patients were fitted with CPAP masks on initial presentation in respiratory failure. Nine used nasal CPAP masks, and the other four were given full face CPAP masks after being unable to ventilate on the nasal masks.

Ventilation

Volume cycled mechanical ventilation was provided with ventilators (Bear II) set to deliver a tidal volume of 10 ml/kg, an inspiratory flow rate of 60 L/min, a respiratory rate of 18, and an FiO2 initially of 0.4, which was subsequently adjusted to provide a P02 of 60 to 70 mm Hg. Those patients requiring and desiring long-term intermittent mechanical ventilatory support were subsequently provided with portable volume cycled ventilators, which were used for 6 to 10 hours daily in the home. These patients (four
Table 1—Physiologic Parameters Before and After Mechanical Ventilation During Acute Respiratory Failure in Nine Patients

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Pulse, beats/min</th>
<th>RR, breaths/min</th>
<th>Pco₂, mm Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before therapy</td>
<td>111 ± 15</td>
<td>29 ± 4</td>
<td>67 ± 8</td>
<td></td>
</tr>
<tr>
<td>After therapy</td>
<td>81 ± 10</td>
<td>20 ± 4</td>
<td>49 ± 9</td>
<td></td>
</tr>
<tr>
<td>p</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
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</table>

of the original group) were reevaluated after six to ten months on daily volume cycled ventilation via nasal CPAP masks. All four have recently been contacted and asked about their current state of health, at 20 months after the initiation of intermittent positive pressure mechanical ventilation support.

**Evaluation**

Patients were evaluated with arterial blood gas and clinical status classification before and after the acute therapeutic intervention. In addition, patients continuing with prolonged therapy were evaluated initially after two weeks and after six to ten months with full PFTs, blood gases, and functional status evaluation by the classification system of Haas and Haas.*

**Statistics**

Results of testing before and after acute and chronic mechanical ventilatory interventions were computed using Student's t-test for paired values. Alpha probabilities of less than 0.05 were considered statistically significant.

**RESULTS**

**Acute Utility**

Of the 13 patients, nine showed substantial acute improvement over one to three days on a continuous regimen of 2- to 3-h periods of mechanical ventilation separated by 1 h of rest. This was shown by statistically significant decreases in respiratory rate, Pco₂, and heart rate (Table 1). The four remaining patients (two with COPD and two with obesity hypventilation syndrome) failed to improve their ventilation, blood gas levels, or clinical status. One of the patients with COPD had a severely congested nose and could not tolerate a full face mask. This patient subsequently responded well to ventilation with a cuirass respirator. The patient with bullous emphysema and acute pneumonia needed intubation for both toilette and ventilation. This patient also did well with a cuirass respirator subsequent to extubation. Neither patient with OHS and sleep apnea improved significantly on positive pressure ventilation by mask, but both improved gradually after being provided with a mask system providing 5 cm of nasal CPAP alone during sleep.

**Acceptance After Acute Therapy**

Nine patients with chronic respiratory failure responded acutely to mechanical ventilation by mask; eight had COPD and one had severe hypothyroidism. Among these nine, the patient with hypothyroidism required no further mechanical assistance after thyroid replacement; four of the patients with COPD found the system so uncomfortable that they did not wish to continue; and the remaining four with COPD have continued with daily periods of 6 to 10 h of volume ventilation for a mean of 20 months, finding it comfortable and acceptable, particularly in view of their improved physical capacity.

**Results of Long-Term Therapy**

After two weeks of therapy, the patients who continued on prolonged therapy with intermittent volume ventilation by mask showed improvements in blood gases (specifically Pco₂) with small improvements in pulmonary function and functional status. Subsequently, after six to ten months of daily therapy, they showed uniform and substantial improvements in spirometry, MVV, blood gases, and functional status (Table 2). All had been in chronic progressive respiratory failure for several years, and their hospitalizations were occasioned by decompensation due to well-documented progression of their disease processes rather than to any acute event. During the period of longterm therapy vital capacity, MVV, and peak inspiratory pressure increased significantly, without change in airway function as assessed by FEV₁/FEV₁/VC. Since the patients were uniformly using supplemental oxygen prior to the institution of mechanical ventilation, there was a significant decrease in arterial carbon

Table 2—Spirometric, Blood Gas, and Functional Class Evaluation Prior to and After Therapy in Four Patients

<table>
<thead>
<tr>
<th></th>
<th>VC, % Pred</th>
<th>FEV₁, % Pred</th>
<th>MVV, % Pred</th>
<th>Pi max</th>
<th>PE max</th>
<th>Pco₂</th>
<th>Po₂</th>
<th>Functional Class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>FEV₁/VC</td>
<td>Mean ± SD</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before Rx</td>
<td>1.0 ± 0.2 L</td>
<td>0.52 ± 0.3 L</td>
<td>52 ± 4%</td>
<td>26 ± 6 cm H₂O</td>
<td>52 ± 6 cm H₂O</td>
<td>61 ± 3 mm Hg</td>
<td>63 ± 5 mm Hg</td>
<td>E</td>
</tr>
<tr>
<td>(31 ± 8%)</td>
<td>(29 ± 12%)</td>
<td>(22 ± 12%)</td>
<td>(21 ± 3%)</td>
<td>(20 ± 11%)</td>
<td>(19 ± 11%)</td>
<td>(18 ± 3%)</td>
<td>(20 ± 3%)</td>
<td></td>
</tr>
<tr>
<td>After Rx 2 wk</td>
<td>1.2 ± 0.4 L</td>
<td>0.67 ± 0.2 L</td>
<td>55 ± 5%</td>
<td>30 ± 7 cm H₂O</td>
<td>55 ± 7 cm H₂O</td>
<td>52 ± 2 mm Hg</td>
<td>65 ± 5 mm Hg</td>
<td>D-E</td>
</tr>
<tr>
<td>(36 ± 12%)</td>
<td>(29 ± 6%)</td>
<td>(24 ± 3%)</td>
<td>(23 ± 3%)</td>
<td>(22 ± 2%)</td>
<td>(21 ± 2%)</td>
<td>(20 ± 3%)</td>
<td>(22 ± 3%)</td>
<td></td>
</tr>
<tr>
<td>p*</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>&lt;0.05</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>After Rx 8 mo</td>
<td>1.5 ± 0.3 L</td>
<td>0.67 ± 0.3 L</td>
<td>46 ± 5%</td>
<td>44 ± 8 cm H₂O</td>
<td>60 ± 7 cm H₂O</td>
<td>44 ± 6 mm Hg</td>
<td>65 ± 3 mm Hg</td>
<td>C</td>
</tr>
<tr>
<td>(46 ± 9%)</td>
<td>(28 ± 8%)</td>
<td>(27 ± 3%)</td>
<td>(27 ± 3%)</td>
<td>(26 ± 3%)</td>
<td>(26 ± 3%)</td>
<td>(26 ± 3%)</td>
<td>(26 ± 3%)</td>
<td></td>
</tr>
<tr>
<td>p*</td>
<td>&lt;0.05</td>
<td>NS</td>
<td>&lt;0.05</td>
<td>&lt;0.04</td>
<td>NS</td>
<td>&lt;0.03</td>
<td>NS</td>
<td>&lt;0.04</td>
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</table>

*p value refers to comparison of the specified posttreatment data set with pretreatment values.
dioxide tension without a change in oxygen tension. Presently, all four patients have gone from bed or chair bound (class E) to being able to go out and even climb a few stairs (classes B-D). This improvement in daily activity level continues at the present time, 20 months after the initiation of intermittent positive pressure ventilatory support.

**DISCUSSION**

Long-term mechanical ventilation, applied either intermittently or continuously, has been shown to benefit numerous patients with chronic respiratory failure due to various disease processes. The majority of patients so treated without tracheostomy have previously been ventilated with cuirass or tank respirator. Positive pressure ventilation has been administered via the lipseal device, but this is rather uncomfortable. The advent of the availability of tight sealing full face CPAP masks led some physicians to attempt positive pressure ventilation with these. However, despite one case series reporting on the treatment of acute respiratory failure using volume ventilation via full face CPAP masks, and the successful acute treatment of one patient in the series reported here, the full face mask seldom fits adequately in the buccal area to contain adequate pressures (15 to 25 cm H₂O) for volume ventilation. On the other hand, the nasal CPAP mask, which has become generally available for the treatment of obstructive sleep apnea, avoids the buccal face. Such masks are able to provide adequate seals for the delivery of volume ventilation so long as the mouth remains closed either spontaneously or with the aid of an elastic chin strap. The utility of such nasal CPAP masks in the delivery of positive pressure ventilation has accordingly been evaluated in recent studies. Positive pressure mechanical ventilation via the nasal CPAP mask seems to be useful in the treatment of acute respiratory failure and has been shown to be effective in the long-term treatment of respiratory failure due to neuromuscular diseases and kyphoscoliosis.

In this series, 30 percent (four) of the patients could not be ventilated by mask. In one, the confounding factor was copious sputum production due to pneumonia, and in another, nasal congestion with an inability to tolerate the full face mask. Both of these patients had COPD and have subsequently responded well to chronic cuirass therapy. The other two patients who could not be ventilated by mask had OHS. Although the masks fit well and contained as much as 30 cm H₂O pressure, both of these patients fell asleep and developed prolonged central apnea on positive pressure ventilation. While apneic, it was not possible to obtain adequate tidal volumes even when their mouths remained closed. These two, whose muscle function was adequate, responded well to 5 cm of nasal CPAP.

Of the nine who responded well to acute ventilatory support with mask delivered volume ventilation, one (with hypothyroidism) ceased to require any mechanical ventilation after adequate thyroid replacement. Of the remaining eight, all of whom had COPD with respiratory failure, four (30 percent of the original group) refused any form of prolonged mechanical ventilation and are now either bed-bound (three patients) or dead (one patient).

In contrast, the four patients using mechanical positive pressure ventilatory assistance experienced short-term (two weeks) improvement in PCO₂ with small improvements in respiratory function and capacity for activities of daily living. Subsequently, they have all shown substantial improvement in all parameters measured. This is similar to previously reported findings in patients treated with cuirass respirators and volume ventilation via tracheostomy.

Some of the improvements noted in this study could be attributed to an increase in compliance or to a decrease in PCO₂, as hypercapnea is known to adversely affect diaphragmatic function. However, the progressive nature of the improvement suggests that it is not simply the result of an acute effect of mechanical ventilation. Rather, although blood gases and compliance no doubt contribute to the changes noted, a more long-term effect seems to be involved, as well. Specifically, the phenomenon of a progressive, long-term increase in ventilatory capacity would seem to suggest resting of a chronically fatigued respiratory muscle system. Other phenomena known to occur over long periods may also contribute to the measured increases in respiratory function. Nutritional status, for instance, has been noted to improve in patients whose breathlessness has been treated with intermittent mechanical ventilation.

The fact that the improvement noted in this study is similar to that described in patients with similarly conceived therapy described in the past is interesting from another point of view, as well. None of the four patients using long-term ventilation was closely followed by a pulmonary subspecialist. They were trained in the use of their equipment, and subsequently followed by either the general medical clinic of this institution or by their private internist, returning to the laboratory for testing only. Thus, in this series, the potential for study bias based on intensive follow-up of highly motivated patients which has been suggested in criticism of previous studies does not exist here.

Long-term positive pressure ventilation by mask is not a panacea for all chronic respiratory failure. However, it seems to be an effective therapy for selected patients with chronic obstructive lung disease, as well as for the previously studied patients.
with neuromuscular disease and kyphoscoliosis.

REFERENCES
1 Braun NMT, Marino WD. Effect of daily intermittent rest of the respiratory muscles in patients with severe chronic airflow limitation (CAL). Chest 1984; 85:59
2 Marino WD. Acute effects of negative pressure ventilation on patients with chronic respiratory insufficiency. Am Rev Respir Dis 1986; 133:167