RESPIRATORY THERAPY

Bedside Criteria for Discontinuation of Mechanical Ventilation*

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The purpose of this study was to determine bedside criteria for discontinuation of mechanical ventilation. The resting minute ventilation (MV), maximal voluntary ventilation (MVV) and peak negative pressure on maximal inspiration (PNP) were studied in 100 consecutive patients receiving assisted ventilation. Seventy-six patients (Group 1) had MV less than 10 L/min and could double the MV with an MVV maneuver. All Group 1 patients could have mechanical ventilation discontinued. Seventeen patients (Group 2) could not double their resting MV with an MVV maneuver and required further ventilatory assistance. Seven patients (Group 3) could not double their resting MV with an MVV maneuver but did not require further mechanical ventilation. Patients whose PNP was greater than 30 cm H2O less than atmospheric were always able to have mechanical ventilation discontinued. The ease with which these measurements can be performed at the bedside and their high degree of predictability make them useful in acute respiratory care.

Patients requiring mechanical ventilation via an endotracheal tube will either promptly be weaned from the ventilator or necessitate more prolonged ventilatory assistance via a tracheostomy. Those who are able to recover rapidly and have assisted ventilation discontinued are better able to participate in procedures designed to promote their recovery and therefore have the best prognosis. The potential hazards of endotracheal intubation can also be avoided by early extubation.14 Thus, it becomes imperative that the clinician objectively evaluate the need for continued ventilatory assistance.

Determining the appropriate time to discontinue mechanical ventilation is often an arbitrary clinical decision based on judgment and experience. However, some ventilatory measurements have been suggested as useful guidelines to aid the clinician. Bendixen6 is of the opinion that the average patient is unable to be without mechanical ventilation for an appreciable length of time if his vital capacity is less than 10 ml/kg body weight, which is approximately twice the normal resting tidal volume. Safar and Kunkel8 feel that if the average adult patient's vital capacity is less than 1.0 liter, ventilatory assistance should not be discontinued due to the increased chance of progressive atelectasis. Stetson7 recommends that for an adult patient to be extubated, the resting minute ventilation should be below 10 L/min and he should be able to at least double the resting minute ventilation with a maximal voluntary effort.

This study was designed to establish some simple bedside criteria to determine when ventilatory assistance could be discontinued. We decided to evaluate the criteria proposed by Stetson and a measurement of inspiratory force in 100 consecutive patients and correlate these with the ability to discontinue mechanical ventilation.

MATERIALS AND METHODS

One hundred consecutive patients receiving mechanical ventilatory assistance in intensive care units of three hospitals (Colorado General Hospital, Denver Veterans Administration Hospital and Denver General Hospital) were studied. The resting minute ventilation (MV), maximal voluntary ventilation (MVV) and peak negative pressure on maximum in-
spiration (PNP) were measured. The MV and MVV were measured with a dry Wright respirometer which was calibrated with a Tissot spirometer. The PNP was measured with an aneroid manometer. Patients who were not alert or were unconscious had to be eliminated from the study as they were not able to perform an MVV maneuver. Patients were measured as soon as their oxygen transport was adequate (\(P_{\text{ErO}_2} > 55 \text{ mm Hg}\)), with an inspired oxygen fraction of 40 percent and their clinical condition stable.

The MV and MVV measurements were performed with the patient breathing nonhumidified air with an inspired oxygen fraction of 40 percent via a Puritan all purpose nebulizer in a "closed" system. The system consisted of two low resistance one-way flutter valves to ensure a non-rebreathing system and an 18-in reservoir tube to minimize entraining of room air (Fig 1). The flow meter was calibrated, and the accuracy of the air mix system was checked by sampling at the inspiratory end of the tubing. Prior to the measurement of the MV and MVV the patient was allowed sufficient time to become familiar with the equipment. The MV was measured over a full minute with the patient at 45°. The MVV was measured in a similar position over a 15-sec period.

The instantaneous PNP was measured during maximal inspiration following a maximal expiratory effort. Figure 2 shows the simple aneroid manometer used in the PNP measurements. One end of the Y-connector was placed in the adaptor of the endotracheal tube so as to occlude the lumen. After a maximal expiration, the other end of the Y-connector was occluded and the peak negative pressure generated during the ensuing inspiratory effort was recorded.

Following the measurements the patients were placed on a T-tube apparatus with an approximate inspired oxygen fraction of 40 percent. All patients were observed by at least one of the authors and arterial blood gases (ABG) were obtained at 30 minutes after mechanical ventilation was discontinued. If the ABG at 30 minutes showed a significant deterioration (ie, a decrease in \(P_{\text{ErO}_2}\) or an increase in \(P_{\text{ErCO}_2}\) of greater than 10 mm Hg) or the patient's clinical condition worsened (ie, arrhythmia, blood pressure instability, agitation, diaphoresis, tachypnea), then it was decided to reinstitute mechanical ventilation. However, if the ABG and clinical condition were stable, the patient was continued on the T-tube apparatus for an additional period (two to eight hours) with serial ABG measurements. At the end of this period of observation, if the clinical condition and ABG were satisfactory then the patients were extubated. All patients were followed until transfer from the intensive care unit.

**RESULTS**

Sixty men, with an average age of 52.4 years, and 40 women, with an average age of 43.7 years, were studied. The patients had received assisted ventilation for an average duration of 37 hours, with a range of 12 to 144 hours.

The reasons for mechanical ventilation are listed

**FIGURE 1.** Diagramatic representation of system used for MV and MVV measurements. Note two one-way flutter valves which ensured nonrebreathing system.

**FIGURE 2.** Aneroid manometer and Y-connector used for PNP measurements.
Table 1—Diagnosis or Surgical Procedure Performed on the Patients Studied

<table>
<thead>
<tr>
<th>Diagnosis or Procedure</th>
<th>Patients, No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac surgery</td>
<td>32</td>
</tr>
<tr>
<td>Thoracic surgery</td>
<td>9</td>
</tr>
<tr>
<td>Upper abdominal surgery</td>
<td>26</td>
</tr>
<tr>
<td>Chronic airway obstruction</td>
<td>16</td>
</tr>
<tr>
<td>Drug overdose</td>
<td>8</td>
</tr>
<tr>
<td>Pulmonary edema, nonecardiac (ARDS)*</td>
<td>6</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>5</td>
</tr>
<tr>
<td>Pulmonary edema, cardiac</td>
<td>3</td>
</tr>
<tr>
<td>CNS pathology</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
</tbody>
</table>

in Table I. Sixty-one patients received postoperative ventilatory assistance, while 39 had a variety of nonsurgical disorders. There were 15 patients with chronic airway obstruction.

Three different groups emerged from the study (Table 2). Group 1 consisted of 76 patients who met the proposed criteria and required no further ventilatory assistance. Seventeen patients, in Group 2, did not meet the proposed criteria and required further assisted ventilation. The third group of seven patients did not meet the proposed criteria, but no further ventilatory assistance was required.

There were 76 patients in Group 1 who had an MV of less than 10 liters/min and at least doubled the MV with an MVV maneuver. The mean MV in this group was 7.1 L/min and the mean MVV was 25.1 L/min. The PNP was 30 cm H2O or greater, less than atmospheric in all patients, with the mean being 31.5 cm H2O. Mechanical ventilation was discontinued and extubation was accomplished within two hours in all patients. No patients in this group required reinstitution of mechanical ventilation.

None of the 17 patients in Group 2 could double their resting MV with an MVV maneuver. The mean MV was 9.8 L/min, and the mean MVV was 14.1 L/min. Nine patients had MV less than 10 L/min, while eight patients had MV greater than 10 L/min. The PNP was 22 cm H2O or lower, less than atmospheric in all patients, with the mean being 17.2 cm H2O. All required further ventilatory assistance within an average 2.6 hours.

None of the seven patients in Group 3 could double their resting MV with an MVV maneuver. The mean MV was 10.2 L/min, and the mean MVV was 18.9 L/min. Four patients had MV less than 10 L/min, while three were greater than 10 L/min. The PNP was 25 cm H2O or greater, less than atmospheric, with a mean of 28.4 cm H2O. Mechanical ventilation was discontinued and extubation was accomplished within eight hours. None of the patients in this group required reinstitution of mechanical ventilation. Measurement of the MV and MVV after extubation revealed a mean MV of 10.6 L/min (a 3.9 percent increase over pre-extubation values) and a mean MVV of 28.6 L/min (a 51.3 percent increase over pre-extubation values).

DISCUSSION

The 76 patients (Group 1) who met the proposed criteria were able to have ventilatory assistance discontinued and were extubated within two hours. The need for further ventilatory assistance in patients meeting the proposed criteria would appear to be minimal unless other complications ensue. No patients who met these criteria required further mechanical ventilatory assistance ("false positives").

All 17 patients (Group 2) who did not meet the proposed criteria needed further ventilatory assistance within four hours. This group of patients demonstrated increased resting ventilatory demands and limited reserve.

The seven patients (Group 3) who did not meet the criteria but were able to be without ventilatory assistance fall into a "false negative" group. Further evaluation of the data from these patients revealed that in four the MVV was 1.0 L or less from being twice the resting MV. In two patients the gap was between 1.0 and 2.0 liters and only one patient missed doubling the resting MV by 4.0 liters. Furthermore, postextubation measurements of the MV and MVV in these patients showed that all could easily double the MV. It is possible that in these patients with borderline values, the increased resistance to airflow imposed by the narrow caliber of the endotracheal tube may be a significant factor in the low MVV measurements and may actually diminish the ventilatory reserve of the patient.

Analysis of the values of the PNP measurements revealed that if they exceeded 30 cm H2O, less than atmospheric the patients could have ventilatory assistance discontinued. However, if the PNP value was less than 20 cm H2O below atmospheric, then the patients could not maintain adequate ventilation without assistance. Values between 20 and 30 cm H2O less than atmospheric did not allow accurate predictability. As a number of the patients...
had had cardiac surgery, we did not feel that it was advisable to measure a sustained inspiratory pressure due to possibility of acute hemodynamic changes.

Analysis of the 15 patients with chronic airway obstruction revealed a distribution in all three groups. The seven chronic airway obstruction patients in Group 1 were no different from their 69 counterparts. It was not surprising that seven of the 17 patients in Group 2 had chronic airway obstruction. These patients are certainly the most difficult single group to remove from assisted ventilation. One of the seven patients in Group 3 ("false negatives") had chronic airway obstruction.

Measurement of the resting MV and MVV are useful guides in deciding when to discontinue mechanical ventilation. If the resting MV is less than 10 L/min and the patient can at least double the MV with a maximal voluntary effort (MVV), then mechanical ventilation can almost always be safely discontinued. In marginal patients extubation may be a key factor in the ability to ventilate without mechanical support. A PNP value of greater than 30 cm H2O less than atmospheric also correlated well with the ability to discontinue mechanical ventilation. The ease with which these measurements can be performed at the bedside with a simple respirometer and aneroid manometer make them a useful procedure in acute respiratory care.

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REFERENCES