A Prospective Comparison of IMV and T-Piece Weaning from Mechanical Ventilation

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Two hundred (200) consecutive medical and surgical patients requiring mechanical ventilation were entered into a prospective randomized trial of weaning by either intermittent mandatory ventilation (IMV) or T-piece. Patients in these groups were of similar age and sex and had the same total ventilation time (TVT). The study design provided equal time for each weaning mode after specific criteria for oxygenation and ventilation were satisfied (PaO₂ >55 mm Hg on FIO₂ <0.5, VE <12 L/min and two of the following four parameters: MVV >2 Vₑ, Vr >5 ml/kg, VFC >10 ml/kg, NIF ≤20 cm H₂O). Of the original 200 patients 165 were entered into the weaning phase; 35 patients were withdrawn prior to weaning due to the discretion of the attending physician or protocol error. Weaning time was not different between the IMV (5.3 ± 1.2 h, mean ± SEM) and T-piece groups (5.9 ± 1.4 h, p = NS). Of the 165 patients, 155 (93 percent) were weaned successfully by protocol, 79 in the IMV and 76 in the T-piece group. Of 155 patients, 136 (88 percent) were weaned on the first attempt by protocol. Of the 19 who were not weaned, 11 were weaned successfully on the second and five on the third trial; three patients required three-day weans. We conclude that clinically stable patients who require short-term mechanical ventilation and meet standard bedside weaning criteria can be weaned efficiently by protocol using either IMV or T-piece techniques. (Chest 1989; 96:348-52)

IMV = intermittent mandatory ventilation; TVT = total ventilation time; MVV = maximum voluntary ventilation; NIF = negative inspiratory force; AMV = assisted mandatory ventilation; WT = weaning time

Since the advent of positive pressure ventilation, various methods for elective withdrawal of ventilatory support (weaning) have been proposed. The introduction of intermittent mandatory ventilation (IMV) as a method of weaning has initiated a controversy concerning the optimum weaning mode. Several studies have examined the attributes of T-piece and IMV weaning with inconclusive results. Criticism of these studies has included machine variability in relation to the work of breathing, improper application of the two weaning methods, and the lack of a heterogeneous study population.

We report the results of a prospective, randomized trial of medical and surgical patients who were weaned from mechanical ventilation by either T-piece or IMV.

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To test the hypothesis that patients satisfying specific ventilatory and gas transfer criteria can wean rapidly by either IMV or T-piece, a protocol was developed to ensure equal weaning time for all successful weaning attempts.

METHODS

Patient Population

Over a 16-month period all adult patients requiring mechanical ventilation at the three hospitals in the Medical University of South Carolina system (Medical University Hospital, Charleston Veterans Administration Medical Center, and Charleston Memorial Hospital) were randomized into two groups following informed consent. All patients were ventilated with the same ventilator, a Bennett MA-1 (Puritan-Bennett Corp). IMV was administered with an H valve replacing the 9200 demand valve for the IMV circuit (Air Life-American Pharmaseal Co).

Experimental Design

To eliminate bias during the stabilization period of mechanical ventilation due to possible differences in work of breathing using the two modes of ventilation, the two groups were randomized according to months. During odd months (January, March, May, etc.), patients were assigned to assisted mandatory ventilation (AMV) and during even months (February, April, June, etc.) to the IMV mode. The stabilization period was defined as the time required for
Table 1—Summary of Weaning Steps for IMV and T-Piece

<table>
<thead>
<tr>
<th></th>
<th>Group A (2-h wean)</th>
<th>Group B (7-h wean)</th>
<th>Group C (3-day wean)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stabilization (&lt;72 h)</td>
<td>Stabilization (&gt;72 h)</td>
<td>Never Satisfied Weaning Parameter or failed 3 weaning attempts</td>
</tr>
<tr>
<td>IMV</td>
<td>T-Piece</td>
<td>IMV</td>
<td>T-Piece</td>
</tr>
<tr>
<td>Rate 6:30 min</td>
<td>T-Piece:30 min</td>
<td>Rate 8:2 h</td>
<td>T-Piece:30 min q 2 h x 3</td>
</tr>
<tr>
<td>Rate 4:30 min</td>
<td>Mechanical vent:30 min</td>
<td>Rate 6:2 h</td>
<td>T-Piece:30 min q 4 h x 2</td>
</tr>
<tr>
<td>Rate 0:1 h</td>
<td>T-Piece:1 h</td>
<td>Rate 4:2 h</td>
<td>T-Piece:1 h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rate 0:1 h</td>
<td>T-Piece:2 h q 4 h x 2</td>
</tr>
</tbody>
</table>

Mechanical ventilation before the primary physician decided that the patient was "clinically stable." During the stabilization period, the primary physicians specified the rate, Vt, FIO2, and level of PEEP. Only the ventilatory mode was predetermined by protocol; the patient remained on the initial mode of ventilation until weaning was initiated. All patients had a ±7.00 mm endotracheal tube in place before weaning was initiated. The weaning phase of the protocol was started when the patient was stable clinically and specific gas transfer and acid-base parameters were satisfied: (1) a PaO2 of >55 mm Hg on a FIO2 of <0.50; (2) a pH ≥7.30 and ≤7.50; (3) PEEP ≤5 cm H2O; and (4) respiratory rate ≤36/min.

Weaning parameters (spontaneous ventilatory measurements) were obtained by the respiratory therapist at the beginning of each 8-h shift. Acceptable weaning parameters included: (1) minute ventilation (Ve) <12 L/min, and two of the following four parameters: (2) maximum voluntary ventilation (MVV) > two times Ve; (3) tidal volume (Vt) >5 ml/kg body weight; (4) forced vital capacity (FVC) >10 ml/kg body weight; and (5) negative inspiratory force (NIF) ≤-20 cm H2O. When weaning parameters were satisfied, the patient was randomized immediately, according to hospital number, into either an IMV (even) or T-piece weaning mode (odd). The time from having acceptable weaning parameters to completion of a successful wean was recorded as weaning time (WT). Total weaning time (TWT) was defined as the time from initiation of mechanical ventilation to completion of a successful wean. A successful wean was defined as discontinuation of mechanical ventilation for more than 48 h. The decision to extubate the patient was made by the attending physicians.

During the weaning trials acceptable blood gases had to be maintained using a fixed FIO2 (≤0.45): (1) PaO2 ≥55 mm Hg; (2) PaCO2 increase of ≤10 mm Hg; and (3) pH between 7.28 and 7.55. The following vital sign criteria had to be maintained during weaning: (1) respiratory rate (RR) ≤40 or no increase above 50 percent of the baseline RR; (2) heart rate (HR) ≤140 beats/min or no increase above 30 percent of the baseline HR; and (3) a systolic blood pressure above 90 mm Hg or no decrease below 20 percent of baseline.

If the patient failed to meet the above blood gas or vital sign criteria during weaning, the patient was removed from protocol, returned to mechanical ventilation on the original ventilator settings, and the primary physician notified. If the patient was stable clinically by the beginning of the next 8-h shift, weaning parameters were measured again and, if acceptable, the patient was assigned to a second or third trial of the protocol.

Patients were placed into three study groups: (1) group A patients required mechanical ventilation in a stabilization mode for <72 h; (2) group B patients required mechanical ventilation in a stabilization mode for ≥72 h; and (3) group C patients either never met proposed weaning criteria and were stable clinically after seven days or had failed three weaning attempts at 2-h and 7-h wean. To maintain the same potential weaning time, the following weaning protocols were assigned to each of the three groups (Table 1).

**Group A (Mechanical Ventilation <72 h): 2-H Wean**

**IMV:** The IMV rate was progressively decreased over 2 h. This consisted of 30 minutes of an IMV rate of 6, 30 minutes of an IMV rate of 4, and 1 h of an IMV rate of 0. Blood gas levels were measured 30 minutes after each ventilator change, and the patient was changed to the next step in the protocol if clinically stable while blood gas results were pending.

**T-Piece:** A 30-minute T-piece trial was followed by 30 minutes on the original ventilator settings, and then with a 1-h T-piece trial (total, 2 h). At the end of each T-piece trial, a blood gas analysis was obtained.

**Group B (Mechanical Ventilation ≥ 72 h): 7-H Wean**

**IMV:** The IMV rate was progressively decreased over 7 h, the rate being decreased every 2 h from a rate of 8 to 6 to 4; this was followed by 1 h at an IMV of 0. Blood gas values were measured 30 minutes after IMV rate changes were instituted.

**T-Piece:** A T-piece trial of 30 minutes q 2 h × 3 with blood gas values obtained after the first and third T-piece trial was followed by a 1-h T-piece trial with a blood gas analyses obtained at the end of the trial (total, 7 h).

**Group C (Never Satisfied Weaning Criteria After Seven Days or Failed Three Attempts at Weaning (2- and 7-H Wean)): 3-Day Wean**

**IMV:** The IMV rate was decreased each morning; on day one the rate was set at 8, day 2 the rate was decreased to 6, and on day 3 the rate was set at 4. A blood gas analysis was obtained 30 minutes after each ventilator change was instituted. At the beginning of day 4, the ventilator rate was decreased to 0 for 1 h and blood gas values obtained.

**T-Piece:** (3-Day progressive T-piece trial): On day 1 there was a 15-minute T-piece trial q 4 h × 2 followed by a 30 minute T-piece trial q 4 h × 2; for the remaining 8 h the patient was maintained on the original ventilator settings. On day 2 there was a 15-minute T-piece trial q 2 h × 4 for the first 8 h, then T-piece trials of 30 minutes. This was again followed by an 8-hour rest period. On day 3, there was a 1-h T-piece trial q 2 h × 4 followed by a 2 h T-piece trial q 4 h × 2, with blood gas values obtained after the first and third T-piece trial in each of the first two 8-h periods. At the beginning of the fourth day, the patient was given a T-piece trial for 1 h and a blood gas analysis obtained. If blood gases and vital signs were acceptable, the patient progressed to potential extubation by the primary physician. If the patient failed all three or four attempts, then one trial in the opposite mode (IMV or T-piece) was attempted.
Table 2—Indications for Mechanical Ventilation (n = 200)

<table>
<thead>
<tr>
<th></th>
<th>Surgical (n = 133)</th>
<th>Medical (n = 67)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CABG</td>
<td>73</td>
<td>24</td>
</tr>
<tr>
<td>Valve replacement</td>
<td>19</td>
<td>14</td>
</tr>
<tr>
<td>Trauma/general surgery</td>
<td>17</td>
<td>12</td>
</tr>
<tr>
<td>Neurosurgery</td>
<td>14</td>
<td>10</td>
</tr>
<tr>
<td>Thoracic surgery</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>COPD</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Near-drowning</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Statistical Analysis

All data between groups were analyzed by both parametric and nonparametric methods. Parametric analysis consisted of a t test matrix for analysis of variance. Non-parametric analysis employed the Kruskal-Wallis analysis of variance using Χ² distribution with one degree of freedom (1 df). A significant p value was <0.05.

RESULTS

Two hundred (200) patients were initially enrolled in the study. The mean age was 53 years (range, 18 to 87) with 134 males and 66 females. Of the 200 patients, 133 were ventilated following surgery or trauma and 67 patients were ventilated for medical diseases (Table 2). There was no difference in age between patients in the IMV and T-piece groups.

One hundred sixty-five (82 percent) of the patients were maintained in the study until the weaning phase was initiated, and 155 of the 165 (93 percent) were weaned successfully by protocol. Of the 35 patients withdrawn from the study before the weaning phase was initiated, 20 were ventilated by AMV and 15 by IMV. Twenty-four of the 35 (69 percent) patients were withdrawn from protocol because of attending physician preference; four patients were withdrawn because of procedural problems, four because of death, and three because of self-extubation. Twenty-seven of the 35 (77 percent) were surgical patients. In three patients withdrawn due to attending preference, the stabilization mode was changed from AMV to IMV because of respiratory alkalosis. However, in each instance, the change in ventilatory mode did not correct the alkalemia. All surgical patients were weaned on 5 cm H₂O PEEP, while all medical patients were weaned on 0 PEEP.

Table 3 lists the variables that were analyzed in the three groups and in all 200 patients. Group C (three-day wean) was combined with group B (7-h wean) for statistical purposes since only five patients required an attempt on the three-day wean. There was no difference in total ventilation time (TVT) or weaning time (WT) between the IMV or T-piece groups comparing the total, 2-h weans or combined 7-h and three-day weans.

One hundred fifty-five (93 percent) of the 165 patients were weaned successfully by protocol (Table 4). One hundred thirty-six (136) of 155 (88 percent) weaned on the first attempt, while 19 (12 percent) patients required more than one trial to wean successfully. One hundred twenty-three (123) of the 155 (79 percent) successful weans by protocol were in patients who required less than 72 h of mechanical ventilation. Eighty-three (83) of 128 (65 percent) patients who weaned successfully in group A (mechanical ventilation <72 h) were surgical patients, while 27 of the 32 (84 percent) patients that were weaned in groups B (mechanical ventilation ≥72 h) or C were medical patients.

Ten patients did not wean by protocol; six were weaned by T-piece and four by IMV. Two of the nine patients were extubated immediately despite unacceptable weaning parameters, and both required reintubation within 2 h. Four had acceptable weaning parameters and failed a 2-h wean (one hypcapnia, one tachypnea, one hypotension, and one hypoxemia); all were weaned successfully over the following 4 to 16 h on a higher FIO₂ (0.5 to 0.6). The remaining three patients were weaned by IMV, although their initial weaning parameters had been unacceptable. Only one patient failed to wean after completing all steps of the protocol; he weighed 200 kg, had a history of asthma and sleep apnea syndrome, and was intubated with a 7.5-mm endotracheal tube. He developed acute hypercapnia during both weaning modes.

Of 160 patients who satisfied weaning criteria, 159 (99 percent) weaned either on the first trial (136), second trial (11), third trial (5), or three-day wean (3), or off protocol (4). Of the five of the 165 patients who...
argue that an IMV wean begins immediately and needs no weaning parameter measurements, that the patient is continually challenged to wean and, therefore, may have been weaned successfully prior to being identified by specific criteria (although possibly requiring more blood gas determinations). 34 Most of the patients in group A could not have initiated weaning sooner, because they were still under the influence of anesthesia.

Bedside spontaneous ventilation parameters are used to assist the clinician in identifying patients who should be able to be weaned from mechanical ventilation. 35 In the present study, the criteria chosen were those commonly used by clinicians caring for patients receiving mechanical ventilation and were set conservatively to maintain a high sensitivity and avoid the false positive wean/extubation. Only three patients were weaned successfully despite inadequate weaning parameters (false negatives).

The majority of patients removed from protocol were weaned by IMV with a longer total ventilation time and weaning time. There was a significant difference in TVT between patients in the IMV and T-piece groups who were withdrawn from protocol because two patients (arbitrarily assigned to the IMV group) required longer stabilization, and the number of patients was small. In general, the patients on the medical service required longer mechanical ventilation (stabilization) because of preexisting lung disease and multiorgan system failure.

This study demonstrates that properly executed weaning by either IMV or T-piece can be carried out successfully and rapidly in a similar time frame when simple bedside criteria for ventilation are met. The strengths of this study are in the design (prospective, same ventilator, same IMV system, large number of medical and surgical patients, randomization to stabilization and weaning mode, strict criteria to start and fail wean). The study did evaluate weaning modes in patients with short-term mechanical ventilation. Unfortunately, there were not enough patients who had required long-term mechanical ventilation or difficult to wean patients, especially with COPD. The issue of which weaning mode is preferable for a specific type of acute respiratory failure and for long-term mechanical ventilation still remains unanswered. Simple bedside spontaneous ventilatory measurements have been confirmed to be excellent predictors of a successful wean for most patients. 15, 33

The study was not designed to evaluate the prediction of weaning. However, it was observed that of five patients who did not satisfy weaning criteria and were removed from the protocol, two failed and three were weaned successfully.

Patients who do not satisfy criteria can be given a short T-piece trial or IMV rate reduction with careful
observation. As shown previously, some of these patients can be weaned, yet most cannot.\textsuperscript{15} It is exactly these patients who have to be observed constantly during a weaning trial. Patients who are clinically stable and need weaning parameters should be able to be weaned rapidly by either T-piece or IMV. The use of a weaning protocol, after satisfying specific weaning criteria, can facilitate a short wean with a minimum of personnel. Rapid weaning should be an important cost-containment measure by reducing patient stay in the ICU.

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