Positive End-Expiratory Pressure vs T-Piece*

**Extubation after Mechanical Ventilation**

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Because T-piece breathing may impair oxygenation, the best airway pressure from which to extubate ventilated patients is controversial. We compared the effects of extubation after 1 h of either CPAP 5 and T-piece/ZEEP. Once weaned from mechanical ventilation and breathing spontaneously, 106 patients were randomized to 1 h CPAP or 1 h T-piece/ZEEP, following which patients were extubated and mask O₂ administered. No significant difference existed between groups in age, sex, Hb, Ht, Fio₂, PaCO₂, or PaO₂. However, P(A-a)O₂ was significantly greater at 120 min in the CPAP group. Within the CPAP group, P(A-a)O₂ was also significantly worse at 120 vs 0 min. Nineteen T-piece patients showed improved P(A-a)O₂ at 120 min compared with only ten CPAP patients. Three CPAP and two T-piece patients subsequently required reintubation. This study demonstrates that use of a T-piece does not impair arterial oxygenation and may in fact be superior to direct extubation from CPAP 5. (Chest 1991; 100:1655-59)

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\text{ABCs} = \text{arterial blood gas values; CPAP 5} = 5 \text{ cm H}_2\text{O continuous positive airway pressure; EPAP} = \text{expiratory positive airway pressure; IMV = intermittent mandatory ventilation; ZEEP} = \text{zero end-expiratory pressure}
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**METHODS**

All mechanically ventilated patients in the medical-surgical ICU of a university teaching hospital were considered for entry into the study. The entry criteria accepted for extubation were an IMV of zero, Fio₂ ≤ 0.5; PaO₂ ≥ 60 mm Hg; PaCO₂ ≤ 45 mm Hg, Vr of ≥ 7.5 ml/kg; VC of ≥ 15 ml/kg; and peak inspiratory pressure greater than −20 cm H₂O.<br>

Randomization was accomplished by means of sequential sealed envelopes containing a data collection sheet and the mode of therapy to be used (either CPAP 5 or T-piece). After randomization, ABCs were measured (0 min) and repeated at 20 and 60 min. Patients were then extubated and additional ABCs were determined 20 and 60 min later (80 and 120 min from beginning of the study). The P(A-a)O₂ was measured by the following standard formula:

\[
\left(\text{P}\left(\text{A-a})O_2\right) = [\text{FIO}_2 \text{(barometric pressure – water vapor pressure)} - \text{PaCO}_2/0.8] \text{ – PaO}_2
\]

at the start of the study (0 min) and at the completion of the study, 60 min following extubation (120 min). To ensure quality control, a two-point calibration was performed prior to each series of ABCs and all Fio₂ values were measured with oxygen meters calibrated to known medical gas standards.

If a patient failed in either mode, mechanical ventilation again was initiated. Aspiration into the tracheobronchial tree required withdrawal from the study.

Statistical analysis was performed on the differences in means of PaO₂ and P(A-a)O₂ at the stated times in the trial. Differences in the frequency of weaning failures and deaths also were examined. Statistical significance was determined by the Student t test with Bonferroni's correction and the Fisher exact test where appropriate.

This study protocol was approved by the Office of Research Administration, University of Toronto, in regard to its ethical content. Statistical calculations were based on standard formulas taken from Ingel Singer et al.²

**RESULTS**

One hundred six patients aged between 19 and 99 years (mean ± SEM = 65.07 ± 15.00 years) were ran-

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Table 1—Pathologic Processes and Reasons for Admission

<table>
<thead>
<tr>
<th>Reasons for Intubation</th>
<th>CPAP</th>
<th>T-Piece</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-operation</td>
<td>20</td>
<td>28</td>
</tr>
<tr>
<td>CHF/pulmonary edema</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td>COPD/asthma</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>Neurologic/sedation</td>
<td>8</td>
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<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

Randomized into two groups. The CPAP group consisted of 54 patients aged between 21 and 99 years (65.58 ± 16.71 years) and the T-piece group was comprised of 52 patients aged between 19 and 81 years (64.60 ± 13.45 years). Age differences between the groups were not significant (p > 0.5), nor was sex distribution (p = 0.173). Fifteen patients in the CPAP group had a history of COPD (as defined by presence of cough, sputum or dyspnea or all three) compared with 16 patients in the T-piece group (p = 0.159). There was, however, a significantly higher number of smokers in the T-piece group (37 of 52) than in the CPAP group (21 of 54; p = 0.0059). The underlying pathologic processes and reasons for admission are listed in Table 1.

Throughout the study period, all patients remained hemodynamically stable. There were no significant differences in HR between the groups at any time or within either group at any time. Likewise, systolic and diastolic blood pressures (Fig 1) were stable throughout the study (p > 0.2). Mean PaCO₂ did not vary either within (p > 0.5) or between groups (p > 0.3) (Fig 2).

The initial mean PaO₂ in the T-piece group (103.16 ± 23.47 mm Hg) was higher than that in the CPAP group (92.93 ± 21.04 mm Hg; p = 0.021 [Fig 3]), but this did not achieve statistical significance. (Bonferroni's correction required p < 0.01 for statistical significance.) During the hour prior to extubation, PaO₂ in the CPAP group declined by 2.5 percent while PaO₂ in the T-piece group decreased by 8.3 percent such that at the time of extubation, PaO₂ in the T-piece group was 94.64 ± 24.93 mm Hg, while that in the CPAP group was 90.59 ± 23.08 mm Hg (p > 0.3). Following extubation, PaO₂ in the T-piece group declined by 1.6 percent while PaO₂ in the CPAP group decreased by 6.2 percent, so that 60 min following extubation, PaO₂ in the T-piece group was 93.16 ± 19.89 mm Hg and that in the CPAP group was 84.94 ± 22.24 mm Hg (p = 0.05).

The FiO₂ was comparable in both groups, as shown in Figure 4, up to the point of extubation (CPAP group FiO₂ = 0.36 ± 0.06; T-piece group FiO₂ = 0.36 ± 0.06; p > 0.05). Following extubation, however, there was a slight decline in FiO₂ in the T-piece group (0.35 ± 0.06), while that in the CPAP group increased to 0.38 ± 0.09 (p > 0.05). Although this increase was not significant, it led us to examine the PaO₂/FiO₂ ratios in both groups (Fig 5). During the first 20 min, the T-piece group showed a sharp decline of 8.5 percent which was followed by a more gradual decrease such that at the time of extubation, a 10.9 percent decline had occurred. Following extubation, an immediate and sustained increase of 1.7 percent was observed so that 60 min after extubation the PaO₂/FiO₂ ratio showed an overall decline of 9.2 percent.
from initial values \((p>0.1)\). In contrast, the CPAP group manifested a moderate constant decline throughout the first 60 min and at the point of extubation, a 2.5 percent decline in the \(\text{PaO}_2/\text{FiO}_2\) ratio was noted. Following extubation, however, a rapid constant decline of 10.8 percent occurred so that 60 min after extubation the CPAP group showed an overall decrease of 13.3 percent in the \(\text{PaO}_2/\text{FiO}_2\) ratio \((0<0.001)\).

The \(\text{P(A-a)}_2\) (Fig 6) at 0 min in the T-piece group was \(105.97 \pm 68.36\) mm Hg compared with \(112.60 \pm 45.54\) mm Hg in the CPAP group \((p>0.5)\). At the conclusion of the study (60 min following extubation), \(\text{P(A-a)}_2\) in the T-piece group remained unchanged at \(109.20 \pm 66.54\) mm Hg compared with the initial value \((p>0.5)\). The \(\text{P(A-a)}_2\) in the CPAP group at 120 min had increased to \(142.25 \pm 70.32\) mm Hg and was significantly different from both the CPAP group value at 0 min \((p=0.0116)\) and the T-piece group value at 120 min \((p=0.0158)\). Because of the larger number of patients with CHF/pulmonary edema in the CPAP group, comparisons of the baseline \(\text{P(A-a)}_2\) between these patients and those with asthma/COPD revealed no significant differences \((p>0.5)\).

A review of \(\text{P(A-a)}_2\) on an individual basis showed that 19 patients in the T-piece group showed an

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**Figures:**

**Figure 2.** Mean \(\text{PaCO}_2\) vs time.

**Figure 3.** Mean \(\text{PaO}_2\) vs time.

**Figure 4.** Percent change in \(\text{PaO}_2/\text{FiO}_2\) ratio vs time.
improved P(A-a)O₂ compared with only ten patients in the CPAP group (Fisher exact test, p = 0.021).

Overall, five patients failed extubation and ventilation had to be resumed. In all cases, failure was due to inadequate cough, secretions and progressive hypoxemia. Three patients were from the CPAP group and 2 patients were from the T-piece group; the difference was not significant (Fisher exact test, p = 0.318).

**DISCUSSION**

Several recent papers have recommended that patients be extubated directly from low levels of CPAP and that use of a T-piece be abandoned as unnecessary, too rigorous a trial and potentially harmful. These authors have suggested that the use of low levels of CPAP instead of a T-piece with spontaneous ventilation improves the patient's ability to wean by preventing alveolar collapse and hypoxemia. These recommendations are largely based on the results of three studies, the conclusions of which are open to criticism.

Feeley et al. showed that low levels of CPAP resulted in improved VC and lower P(A-a)O₂ than did T-piece breathing. To ensure that P(A-a)O₂ differences were due to intrapulmonary shunt, he utilized an FIO₂ of 1.0. However, breathing 100 percent oxygen for even short periods of time may result in atelectasis and increased intrapulmonary shunt with a higher P(A-a)O₂. The conclusions of this study have been criticized on the basis that CPAP may have prevented atelectasis and that the decrease observed in P(A-a)O₂ cannot be attributed solely to the use of a T-piece.

Quan and co-workers studied extubation from EPAP 5 vs ambient airway pressure in 12 patients. Several flaws exist in this study, the greatest of which is the use of a crossover design. Annest et al. in a study of 17 patients, showed that patients on CPAP had higher FRC values and PaO₂ levels, and lower shunt fractions than patients on a T-piece. However, following extubation, there was no difference in these variables between both patient groups. While this study has many excellent features, there is also a design flaw in that patients were transferred directly from CPAP to T-piece and vice versa. Loss of CPAP alone will result in a decrease in oxygenation and the simultaneous addition of a T-piece may cause values to decline further. There are therefore two elements contributing to the observed decline in oxygenation when a crossover design is used and in both of the aforementioned studies this decline was ascribed to the use of a T-piece alone. Furthermore, removal of a T-piece alone results in improved oxygenation and
addition of CPAP will cause further improvement. In the study by Annest et al., the observed improvement was attributed to the effects of CPAP alone and one must therefore question the validity of the conclusions drawn from this study.

It would therefore appear that the recent literature in favor of direct extubation from CPAP rather than the use of a T-piece has serious design flaws.

Much has been written about the importance of naturally occurring glottic mechanisms which tend to maintain airway pressures and preserve FRC. An endotracheal tube overcomes the natural function of the glottis and inhibits the grunting mechanism which has been shown to be of importance in children. The increase in the PaO2 and the PaO2/FIO2 ratio observed following extubation from a T-piece in this study does not support the existence of a clinically important role for the glottis in maintaining airway pressure and oxygenation in adults.

In this study, the P(A-a)O2 was similar in both groups at the start of the study, but by the conclusion of the study it had increased in the CPAP patients while remaining virtually unchanged in T-piece patients. The increase in the CPAP group may be in part due to the small increase in FIO2 recorded in these patients, but may also be due to atelectasis following withdrawal of CPAP. It is of interest to note that only 10 of 54 patients in the CPAP group showed an improvement in (or decreased) P(A-a)O2 as compared with 19 of 52 patients in the T-piece group.

Another aspect to be considered is the timing of the P(A-a)O2 measurement. Had we elected to measure P(A-a)O2 at 15 or 30 min following extubation we might not have demonstrated a significant difference between the groups. In the T-piece group, post-extubation PaO2 and the PaO2/FIO2 ratio remained relatively stable while those of the CPAP group showed a steady decline. We did not continue observations for longer than 60 min so we cannot say what the lowest PaO2 or PaO2/FIO2 ratios were or at which point in time following extubation they occurred. One point that can be made in favor of the use of a T-piece is that the lowest observed values of PaO2 occurred prior to extubation and that use of this method may help avoid extubation in patients who might fail, thus also avoiding the trauma and risks of reintubation for such patients.

In summary, the results of this study do not agree with previous findings on the use of a T-piece. Patients extubated from a T-piece compared favorably with patients extubated directly from CPAP in terms of hemodynamic stability and ABGs. Oxygenation and, in particular, the PaO2/FIO2 ratios showed two distinct patterns: the T-piece patients manifested a decline prior to extubation and a slight increase following extubation. The CPAP patients had a slight decline in values prior to extubation and a larger, more sustained decrease following extubation. The P(A-a)O2 was better in T-piece patients, but there was no difference in the overall success rate of weaning and extubation.

In conclusion, this study has shown that use of a T-piece does not impair arterial oxygenation; extubation from a T-piece may be superior to extubation from CPAP in this regard.

References

5. Quan SF, Fallrick RT, Schlobohm RM. Extubation from ambient or expiratory positive airway pressure in adults. Anaesthesiology 1981; 55:53-56