Automatic Tube Compensation Versus Pressure Support Ventilation, Continuous Positive Airway Pressure And T-Tube During Spontaneous Breathing Trial

Hala E. Zanfaly
Department of Anesthesia and Intensive Care
Faculty of Medicine, Zagazig University

ABSTRACT

Background: Automatic tube compensation (ATC) is a mode of ventilation that has many advantages to be used during spontaneous breathing trial (SBT) of weaning from mechanical ventilation.

Objective: We compare ATC to pressure support ventilation (PSV), continuous positive airway pressure (CPAP) and a T-tube to determine the optimal approach for performing SBT before extubation.

Design: Prospective, randomized, controlled study.

Methods: 120 mechanically ventilated patients who met criteria for a weaning were randomly assigned into four groups (30 patients each) to undergo 2 hours of SBT as the following: ATC group, PSV group, CPAP group and T-tube group. The following data were collected at the start, after one hour and at the end of the SBT: tidal volume (VT), respiratory rate (RR), minute volume (VE), frequency/tidal volume ratio (f/VT), peak inspiratory pressure (PIP), mean airway pressure, heart rate (HR), mean arterial blood pressure (MAP) and arterial blood gases. Tolerance of SBT and extubation outcome were assessed in all patients.

Results: After 2 hours of SBT, there was a significant increase in the number of patients who tolerate SBT in ATC group when compared to CPAP and T-tube groups, it was 86.7% in ATC group versus 56.7% in CPAP group and 53.3% in T-tube group (P<0.05). Similarly, there was significant increase in the number of patients who were successfully extubated in ATC group when compared with CPAP and T-tube groups, it was 73.3% in ATC versus 46.7% in CPAP group and 40% in T-tube group (P<0.001). There was no significant difference between ATC group and PSV group as regard the tolerance for SBT and extubation outcome (P>0.05).

Conclusion: This study confirms the usefulness of ATC during the weaning from mechanical ventilation and that it can be used as an alternative mode of ventilation.

Keywords: spontaneous breathing trial, Automatic tube compensation.

INTRODUCTION

Patients on mechanical ventilation usually have a significant increase of respiratory resistance[1]. One of the most important cause of weaning failure from mechanical ventilation is an imbalance between the respiratory load and respiratory muscle capability. The endotracheal tube (ETT) increases the respiratory load in spontaneous breathing patients who are receiving mechanical ventilation.[2]

A pressure gradient is produced between the two ends of the ETT during spontaneous inspiration. Greater flow rate in the ETT produces a greater pressure gradient between the two ends and increase the resistance. Artificially created positive pressure is applied to the ETT to decrease its resistance. Optimizing the work of breathing (WOB) is an important factor in successful weaning from mechanical ventilation.[3]. Tolerance of spontaneous breathing trial (SBT) is a predictor of successful weaning from mechanical ventilation. SBT can be achieved while the patient receives varying levels of ventilatory support, including T-tube circuit, automatic tube compensation (ATC), pressure support ventilation (PSV) or continuous positive airway pressure (CPAP).[4]. CPAP may improve lung mechanics and decrease the effort needed by mechanically ventilated patients with airflow obstruction.[5]. A T-tube trial of SBT is a predictor for selecting patients who are ready for
extubation. This trial is associated with a rate of extubation failure (percentage of reintubation ranging from 15 to 19%) [6]. PSV can overcome the additional work of breathing caused by the ETT [7]. However, PSV is unable to compensate for the non-linear, flow-dependent, resistive workload caused by the ETT because it gives constant inspiratory support [5,8]. The result may be either inadequate support (under compensation) when inspiratory flow is high or over assistance (over compensation) when inspiratory flow is low [5].

ATC was designed to deal with this problem. The amount of ventilatory support is continuously modified within the breathing cycle to face both the related pressure drop across the ETT and the changing flow rate [9].

We hypothesized that the use of ATC as a mode of ventilatory support during SBT may improve extubation outcome.

A previous study found that more patients tolerate SBT with ATC than with T-tube or pressure support [10]. Similarly, another study showed that more patients passed SBT with ATC than with CPAP with higher rate of successful extubation in ATC group [5].

On the other hand, a recent study found that breathing pattern variability measurement during T-tube trial is the best choice for predicting extubation outcome in Intensive Care Unit patients [11].

In spite of these modalities, some doubt is present about the most appropriate method [6].

The aim of this study was conducted to compare ATC with PSV, CPAP and T-tube modes to determine the optimal approach for SBT before extubation.

PATIENTS AND METHODS

After approval from local ethics committee and obtaining a written informed consent from each patient or his legal representatives, this study was performed at the Surgical Intensive Care Unit of Zagazig University Hospitals, including 120 mechanically ventilated patients who met criteria of readiness for weaning. The study population were randomly assigned in a blind fashion to one of four ventilatory modes: ATC, PSV, CPAP or T-tube. Immediately after randomization, the patient's airway was connected to the T-tube within the first 3 minutes, tidal volume and respiratory rate were measured with a spirometer over at least 15 breaths (baseline) (Microspiro HI-198, Manufactured by chest M.I.I NC Tokyo,Japan). In patient with tidal volume above 5 mL/kg and a respiratory rate of less than 35 breaths/minute, the ventilatory mode was then switched to the assigned mode.

ATC group (n=30 pt): In this group, patients breathed through the ventilator circuit with CPAP of 5 cmH2O and the fraction inspired oxygen (FiO2) less than 0.5 with inspiratory ATC set at 100%. ATC was adjusted according to the size of endotracheal tube in use by dialing in the inner diameter of the tube and activating the ATC function implemented in the ventilator. ATC was provided by Galileo, Hamilton Medical AG CH-7403 Rhaézins, Switzerland.

PSV group (n=30 pt): In this group, patients breathed through ventilatory circuit FiO2 less than 0.5 with the addition of 7 cmH2O of pressure support.

CPAP group (n=30 pt): In this group, patients breathed through ventilatory circuit with CPAP of 5 cmH2O.

PSV and CPAP modes were realized with Servo-S, Maquet Critical Care AB, SE-17195 Solna.

T-tube group (n=30 pt): The patient’s airway was connected with the T-tube with fraction of inspired oxygen (FiO2) less than 0.5.

Patients having the following criteria were included in the study:
- Patients on mechanical ventilation for more than 48 hours.
- Availability of informed written consent from the patient's relatives
- Patients who met criteria for readiness of weaning [12]:
  1. Improvement or resolution of the cause for initiating mechanical ventilation.
  2. Oxygen saturation of 92% or more with FiO2 of 50% or less.
  3. Adequate gas exchange as known by a ratio of the partial pressure of arterial oxygen to the fraction of inspired oxygen (PaO2/FiO2) >200 on positive end-expiratory pressure (PEEP) ≤5 cmH2O while breathing on FiO2 <0.5.

4. Rapid shallow breathing index (f/VT): Respiratory rate to tidal volume ratio <105 breaths/minute/L. f/VT was calculated after one minute of spontaneous breathing with PEEP of 5 cmH2O and no mandatory machine breaths supplied from the ventilator (determined from the digital display of the mechanical ventilator).

5. Stable neurological state (Glasgow coma score) "GCS" higher than 8.

6. Core body temperature below 38°C.

7. Hemoglobin level above 10 g/dL.

8. No further need for sedative agents or vasoactive drugs (except dopamine <5 µg/kg/min).

9. Need for bronchial toilet less than twice in the eight hours before the assessment.

10. Level of PEEP less than 8 cmH2O.

11. Systolic blood pressure more than 90 mmHg.

Exclusion criteria:
- Patients need for mechanical ventilation less than 48 hours.
- Patients treated with non-invasive ventilation.
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- Patients on tracheostomy.
- Patients having neuromuscular diseases.

Data collected at the start of SBT:
- Demographic data including: age, sex, admission diagnosis and reason for initiation of mechanical ventilation.
- Severity of disease at the time of admission to ICU using Acute Physiology and Chronic Health Evaluation II (APACHE II) score[13].
- Size of the ETT.

Data collected at the start, after one hour and at the end of SBT:
- Hemodynamic parameters including: heart rate (HR) and mean arterial blood pressure (MAP).
- Ventilatory parameters including:
  - Tidal volume (VT), minute volume (VE), respiratory rate (RR), peak inspiratory pressure (PIP) and mean airway pressure.
  - Rapid shallow breathing index (f/VT) frequency (RR) to tidal volume ratio.
- Arterial blood gases.

During the SBT in all groups tolerance of the trial was continuously evaluated. For patients who tolerated SBT, immediate extubation were done and supplemental oxygen was given via a face mask. Patients who did not tolerate the SBT, full ventilatory support was re instituted with the same mode preceding SBT. Signs of poor tolerance of SBT[4]:
1- RR above 35 breaths/min for 5 min or longer.
2- Arterial oxygen saturation less than 90%.
3- Increase in HR above 140 beats/ min.
4- Increase in systolic blood pressure above 180 mmHg or decreased to less than 90 mmHg.
5- Increased anxiety.
6- Diaphoresis or thoraco-abdominal paradox.
7- Cardiac dysrhythmia.

Successful extubation, defined as the ability to maintain spontaneous breathing for 48 hours after discontinuation of mechanical ventilation and extubation[10]. Failure of extubation is defined as the need for reintubation within 48 hours after extubation[10].

Indication for reintubation include:
- Hypoxemia (oxygen saturation below 90% for more than 5 min) while receiving FIO2 more than 0.5.
- Inability to protect airway because of upper airway obstruction (stridor).
- Presence of respiratory acidosis (arterial pH below 7.35) with PaCO2 above 45 mmHg except in COPD patient.
- Evidence of excessive work of breathing (RR >35 breaths/min for more than 5 min).
- Diaphoresis and thoraco-abdominal paradox.

All patients were followed up until discharge from hospital. Length of stay in ICU and in hospital were assessed.

For estimation of sample size, in a study of Haberthur et al[10], the estimated sample size will be 30 patients at 80% power and 95% confidence interval (Epi-Info version 6).

Statistical analysis:
Data were checked, entered and analysed by using SPSS version 15 software computer package. Data were expressed as mean ± SD for quantitative variables, number and percentage for categorical variables. ANOVA (F-test), Chi-squared (X2) paired t-test were used when appropriate. P<0.05 was considered statistically significant.

RESULTS
Patients characteristics are shown in Table (1). There were no significant differences between the four groups regarding age, sex, body weight, endotracheal tube size, APACHE II score at ICU admission, or reasons for mechanical ventilation. Also, there were no significant differences between the groups for the measured respiratory or hemodynamic parameters at the start of the SBT (Table 2).

After one hour of the SBT, in patients breathing with ATC, the tidal volume was significantly increased and the respiratory rate was significantly lower when compared with the other three groups (p<0.05). As regard the RSBI, there was significant decrease in ATC group when compared with other three groups (p<0.05). However minute volume, other respiratory parameters and hemodynamic characteristics didn't show any significant differences among the four groups (p>0.05) (Table 3).

As regard the changes in tidal volume, respiratory rate, minute volume and the ratio of respiratory rate to tidal volume at the end of SBT, there were no significant differences between the groups with a tendency toward a higher tidal volume during automatic tube compensation (P>0.05) (Table 4).

Regarding PIP and mean airway pressure, there were significant decreases in CPAP group when compared with ATC and PSV groups after one hour and at the end of SBT (p<0.05) (Tables 3,4).

HR, MAP and arterial blood gases mean values did not show significant differences between the four groups during the whole period of SBT (Tables 2,3,4).

There were no significant differences between the four groups regarding the duration of mechanical ventilation, length of stay in ICU and in hospital (Table 5).

After 2 hours of SBT, there was a significant increase in the number of patients who tolerate SBT (SBT success) in ATC group when compared with CPAP and T-tube groups, in ATC group 86.7% versus 56.7% in CPAP group and 53.3 % in T-tube group (p<0.05) (Table 6).

As regard the number of patients who did not tolerate the SBT (SBT failure), there was a significant decrease in the number of patients who did not tolerate the SBT in ATC group when compared with CPAP and T-tube groups, it was 13.3% in ATC group versus 43.3% in CPAP group and 46.7% in T-tube group (table 6).

Concerning the extubation outcome, there was a significant increase in the number of patients who were...
Successfully extubated in ATC group when compared to CPAP and T-tube groups, in ATC group 73.3% versus 46.7% in CPAP group and 40% in T-tube group (Table 6).

Of note, the differences between ATC group and PSV group regarding tolerance of SBT, failure of SBT and the number of patients that were successfully extubated did not reach statistically significant values (p>0.05) (Table 6).

As regard the number of patients who required reintubation, there were no significant differences among the four groups (p>0.05). In ATC group 4 patients from 26 patients required reintubation. In PSV group only 3 from 23 patients required reintubation. Meanwhile, the number of patients who required reintubation in both CPAP and T-tube were 3 from 17 and 4 from 16 patients respectively. (Table 6).

**Table (1) : Patients characteristics at the start of spontaneous breathing trial**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>ATC (n=30)</th>
<th>PSV (n=30)</th>
<th>CPAP (n=30)</th>
<th>T-tube (n=30)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (year)</td>
<td>46.2+10.7</td>
<td>47.1+11.5</td>
<td>46.7+12.0</td>
<td>45.7+12.7</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Sex : Male/Female (n)</td>
<td>18/12</td>
<td>15/15</td>
<td>20/10</td>
<td>18/12</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>74.9+7.3</td>
<td>75.2+6.0</td>
<td>73+5.5</td>
<td>74+5.4</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Size of ETT (mm)</td>
<td>7.7+0.4</td>
<td>7.5+0.4</td>
<td>7.8+0.4</td>
<td>7.7+0.4</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>APACHE II score</td>
<td>21.8+5</td>
<td>20.3+7.3</td>
<td>24.4+4.5</td>
<td>21.6+6.6</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Causes for initiating mechanical ventilation (n)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postoperative</td>
<td>10</td>
<td>12</td>
<td>11</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Polytrauma</td>
<td>10</td>
<td>11</td>
<td>10</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>COPD</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Sepsis</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

Values are expressed as mean ± SD or number of patients (n). There were no intergroup differences (p>0.05)

ATC : Automatic tube compensation
PSV : Pressure support ventilation
CPAP : Continuous positive airway pressure
ETT : Endotracheal tube
APACHE II score : Acute physiology and chronic health evaluation score

**Table (2) : Respiratory and hemodynamic characteristics at the start of spontaneous breathing trial**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>ATC Group</th>
<th>PSV Group</th>
<th>CPAP Group</th>
<th>T-tube Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal volume (L)</td>
<td>0.57±0.09</td>
<td>0.55±0.1</td>
<td>0.54±0.06</td>
<td>0.53±0.2</td>
</tr>
<tr>
<td>Respiratory rate (breaths/min)</td>
<td>16.8±3.1</td>
<td>17 ± 4.3</td>
<td>16.9±3.8</td>
<td>16.9±3.9</td>
</tr>
<tr>
<td>Minute volume (L/min)</td>
<td>9.57±2.1</td>
<td>9.35±3.1</td>
<td>9.12±3</td>
<td>8.95±3.2</td>
</tr>
<tr>
<td>f/VT (breaths/min/L)</td>
<td>29.47±19.2</td>
<td>30.9±20.2</td>
<td>29.6±21.8</td>
<td>30.1±20.2</td>
</tr>
<tr>
<td>Peak inspiratory pressure (CmH2O)</td>
<td>12.3±5.1</td>
<td>12.2±4.1</td>
<td>12.5±5.2</td>
<td>-</td>
</tr>
<tr>
<td>Mean airway pressure (CmH2O)</td>
<td>9.1±2.1</td>
<td>9.9±2.3</td>
<td>8.9±1.9</td>
<td>-</td>
</tr>
<tr>
<td>PaO2 (mmHg)</td>
<td>135±24</td>
<td>141 + 31</td>
<td>130 ± 20</td>
<td>129 + 20</td>
</tr>
<tr>
<td>PaCO2 (mmHg)</td>
<td>42.5±3.1</td>
<td>43 + 2.5</td>
<td>43.4 + 4</td>
<td>42.4±3.5</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td>90.1±13.8</td>
<td>91.2±13.0</td>
<td>93±12.5</td>
<td>92.5±11.7</td>
</tr>
<tr>
<td>Mean arterial pressure (mmHg)</td>
<td>88.9±10.1</td>
<td>89±11.1</td>
<td>87.1±8.9</td>
<td>88.1±10.2</td>
</tr>
</tbody>
</table>

Values are expressed as mean ± SD

PaO2 : Partial Pressure of arterial oxygen
PaCO2 : Partial pressure of arterial carbon dioxide
f/VT : Respiratory rate to tidal volume ratio (rapid shallow breathing index)

**Table (3) : Respiratory and hemodynamic characteristics after one hour of spontaneous breathing trial**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>ATC Group</th>
<th>PSV Group</th>
<th>CPAP Group</th>
<th>T-tube Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal volume (L)</td>
<td>0.57±0.2*</td>
<td>0.45 ±0.1</td>
<td>0.43±0.1</td>
<td>0.42±0.2</td>
</tr>
<tr>
<td>Respiratory rate (breaths/min)</td>
<td>17.9±4.3*</td>
<td>20.6 ±6.3</td>
<td>22.4 ±6.2</td>
<td>23.5±5.2</td>
</tr>
</tbody>
</table>
Table (4): Respiratory and hemodynamic characteristics at the end of spontaneous breathing trial

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>ATC group</th>
<th>PSV Group</th>
<th>CPAP group</th>
<th>T-tube Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal volume (L)</td>
<td>0.54±0.16</td>
<td>0.50±0.19</td>
<td>0.48±0.15</td>
<td>0.47±0.15</td>
</tr>
<tr>
<td>Respiratory rate (breaths/min)</td>
<td>18.9±4.1</td>
<td>20.8±5.2</td>
<td>20±4.6</td>
<td>18.5±5.9</td>
</tr>
<tr>
<td>Minute volume (L/min)</td>
<td>10.20±4</td>
<td>10.4±4.5</td>
<td>9.6±4</td>
<td>8.69±2.1</td>
</tr>
<tr>
<td>f/VT (breaths/min/L)</td>
<td>35±10.5</td>
<td>41.8±11.1</td>
<td>41.66±10.1</td>
<td>39.36±12.1</td>
</tr>
<tr>
<td>Peak inspiratory pressure (CmH2O)</td>
<td>14±2.1</td>
<td>12±3.1</td>
<td>8±1.1#</td>
<td>-</td>
</tr>
<tr>
<td>Mean airway pressure (CmH2O)</td>
<td>8.4±1.2</td>
<td>8.3±1.1</td>
<td>6.7±1.0#</td>
<td>-</td>
</tr>
<tr>
<td>PaO2 (mmHg)</td>
<td>130±24</td>
<td>142±32</td>
<td>130±21</td>
<td>132±20</td>
</tr>
<tr>
<td>PaCO2 (mmHg)</td>
<td>46±3.1</td>
<td>46±3.3</td>
<td>45±3.9</td>
<td>44±3.5</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td>91.4±17.2</td>
<td>93.5±16.2</td>
<td>92.7±18.2</td>
<td>89.9±19.2</td>
</tr>
<tr>
<td>Mean arterial pressure (mmHg)</td>
<td>91.3±10.5</td>
<td>92.3±11.3</td>
<td>91.9±11.7</td>
<td>93.1±12.3</td>
</tr>
</tbody>
</table>

Values are expressed as mean± SD
*p<0.05 compared to the other groups
#p<0.05 compared with ATC and PSV groups

Table (5): Duration of mechanical ventilation, length of stay in ICU and in hospital

<table>
<thead>
<tr>
<th>Duration of:</th>
<th>ATC</th>
<th>PSV</th>
<th>CPAP</th>
<th>T-tube</th>
</tr>
</thead>
<tbody>
<tr>
<td>MV (days)</td>
<td>5.9±3.9</td>
<td>5.2±2.5</td>
<td>5.1±2.9</td>
<td>4.9±2.9</td>
</tr>
<tr>
<td>ICU stay (days)</td>
<td>9±7.7</td>
<td>10.1±4.1</td>
<td>9.8±3.5</td>
<td>9±3.0</td>
</tr>
<tr>
<td>Hospital stay (days)</td>
<td>10.9±4.0</td>
<td>11.1±4.0</td>
<td>10±5.7</td>
<td>10.7±6.6</td>
</tr>
</tbody>
</table>

MV: Mechanical ventilation
ICU: Intensive Care Unit

Table (6): Extubation outcome for patients in ATC versus PSV, CPAP and a T-tube.

<table>
<thead>
<tr>
<th>After 2 hours of SBT</th>
<th>ATC group (n=30)</th>
<th>PSV group (n=30)</th>
<th>CPAP group (n=30)</th>
<th>T-tube group (n=30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBT success</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>26*</td>
<td>23</td>
<td>17</td>
<td>16</td>
</tr>
<tr>
<td>%</td>
<td>86.7</td>
<td>76.7</td>
<td>56.7</td>
<td>53.3</td>
</tr>
<tr>
<td>SBT failure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>4*</td>
<td>7</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>%</td>
<td>13.3</td>
<td>23.3</td>
<td>43.3</td>
<td>46.7</td>
</tr>
</tbody>
</table>
**DISCUSSION**

The goal of SBT is to simulate respiratory condition that will be present after extubation[14].

SBT most commonly done with PSV, CPAP or T-tube. An important role during such trials is decreasing respiratory work[15]. ATC has been made to face the work load of respiration due to ETT. ATC gives dynamic ventilatory support of each spontaneous breath by giving the exact amount of pressure necessary to overcome the resistive load of the ETT[4]. ATC resemble spontaneous breathing without ETT. So, it has been made as an electronic extubation. Thus, ATC is suitable for use during period of weaning[5].

Our hypothesis was that the use of ATC as a mode of ventilatory support during SBT may improve extubation outcome. However in this study, no major differences between the four groups were observed hence all investigated modalities can be used to assess a trial of spontaneous breathing.

The possible explanation for this finding could be that the ATC simply did not make an accurate compensation for the workload imposed by the tube. In the prototype ventilator, the pressure drop across the ETT was the sum of a linear and non-linear flow dependence according to the original description of the tube resistance[9]. However, in the standard ventilator used in this study, only the non linear co-efficiencies were used.

Furthermore, the tube coefficient used for the regulation of ATC were given when new tubes without obstruction or kinking were assessed. As the tube was remained for several days in the patients, this may result in decrease in the inner diameter of the tube due to the presence of secretion[16].

For feasibility in this study we used a commercial implementation of ATC. As this commercial ventilators based on a simplified formula, this resulted in a slightly inadequate tube compensation. Therefore, when using ATC on this standard ventilators which cannot deal with the new workload imposed by the obstructed or kinked tube, this might reflect a problem[17].

After one hour the SBT, there were a significant differences between the four groups as regard the tidal volume, respiratory rate and the ratio of respiratory rate to tidal volume. This is in agreement with the results of Haberthur et al.[10].

As regard the changes in VT, RR and VE at the end of SBT, there were no significant differences between the four modes of weaning.

This is in agreement with a study performed by Kuhlen et al.[17] who found no significant differences in VT between PSV groups and ATC group.

This is also in agreement with a study performed by Ferreya et al.[18] who studied the breathing pattern and work of breathing in spontaneously breathing patient during CPAP and PSV with and without ATC and found that there was no significant difference in breathing pattern in any mode.

As regard the changes in peak inspiratory pressure (PIP) and mean airway pressure in our study, we found that PIP and mean airway pressure mean values tended to be higher in ATC group than during the use of PSV and CPAP.

Our results also agreed with the study performed by Ferreya et al.[18] who found that PIP was significantly higher in ATC than PSV without ATC. Also, PIP in CPAP with ATC is higher than CPAP without ATC.

Similarly, a study by Cohen et al.[4] showed that PIP was higher in ATC than PSV but no significant difference was found in RR, VT and VE and they explained this by fixed gas flow in PSV leading to either over- or under-compensation. In contrast to ATC where continuous adjustment is present, according to change in gas flow and size of ETT, the ventilator measures flow and airway pressure and continuously calculate the Pressure Drops across the ETT (DPETT). The ventilator raises airway pressure during inspiration and lowers it during expiration according to DPETT[19]. Farias et al.[20] found that ATC increases airway pressure during inspiration and decreases it during expiration, while tracheal pressure amplitude remained unchanged.

As regard the change in blood gases in this study, there were no significant differences between the four modes at the start, after one hour and at the end of SBT. This is in agreement with study by Kuhlen et al.[17].

IN contrast to our results, Farias et al.[20] found that mechanical ventilation decreases carbon dioxide tension...
without affecting arterial oxygenation or cardiovascular function and they concluded that ATC markedly unloads the inspiratory muscle and increases alveolar ventilation without compromising cardiopulmonary function. Also, a study by Fletcher et al.[21] showed that the highest decrease in pH and PaO2 and increased in PaCO2 was found in PSV than with ATC and CPAP.

In this study, we found that the values of RSBI using ATC was lower than when using PSV, CPAP or T-tube. Cohen et al.[22] found that the addition of ATC would result in a resistance-free f/VT which might more closely mimic the status after extubation and they added that ATC assisted f/VT has more predictive value for successful extubation than did the unassisted f/VT.

In another study, Cohen et al.[4], revealed that the value of f/VT between 50 and 75 breaths/min/L was associated with higher rate of extubation than values more than 75 breaths/min/L and this means that patients who failed to wean develop more rapid shallow breathing.

In a study by Chao and Scheinha [23] to determine the best threshold of rapid shallow breathing index, they found that RSBI ≤80 breaths/min/L was associated with more tolerance of the patients to SBT.

In the present study, there were significant differences between the four groups in the SBT success and extubation outcome. More patients in ATC group passed SBT successfully and underwent extubation than in other groups. However, ATC appeared to be nearly as effective as PSV with no statistically significant difference between both groups.

This in agreement with Cohen et al.[4] who found that the use of ATC was at least as effective as PSV in predicting successful extubation outcome after SBT.

This also in accordance with EL-Beleidy et al. [24] who reported that ATC was similar to PSV in predicting patients with successful extubation.

Another study by Cohen et al.[5] compared extubation outcome between ATC and CPAP, they found that more patient in ATC group tolerate SBT and undergo extubation (98% versus 85%) and rate of reintubation was 14% in ATC versus 24% in CPAP.

Haberthur et al.[10] reported that more patients passed the SBT with ATC than with T-piece or pressure support. Similarly, Figueroa et al.[26] showed less failure of SBT with ATC compared to CPAP (3% versus 13%) with no difference in duration of weaning or duration of mechanical ventilation. The authors added that ATC is safe, but did not hasten liberation from mechanical ventilation when compared with CPAP.

In contrast to our study Bien et al.[11] found that 100% inspiratory ATC with 5 CmH2O positive end-expiratory pressure and 5 CmH2O pressure support ventilation with 5 CmH2O positive end-expiratory pressure reduced the predictive performance of breathing pattern variability, while breathing pattern variability measurement during the T-piece trial was the best choice for predicting extubation outcome in ICU patients.

Finally, this study showed no significant differences between the four modes as regard duration of mechanical ventilation, ICU and hospital stay. These results are in agreement with the results of Figueroa et al.[25] and Aggarwal et al.[26].

The main limitation of this study is related to the small number of patients. Other limitation is the using of the standard ventilators for feasibility not the prototype and so it affect the performance of the ATC mode as the standard (commercially) ventilators didn't provide the accurate compensation.

Conclusion:
This study confirms the usefulness of ATC during the weaning from mechanical ventilation and that it can be used as an alternative mode of ventilation.

We recommend further studies to compare the efficacy of ATC performance on different ventilators because of different degrees of compensation of tube resistance and different ventilator algorithms used.

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