Pressure support ventilation mode versus pressure support ventilation+T-piece trial as a weaning modality in mechanically ventilated patients with chronic obstructive pulmonary disease

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Background Pressure support ventilation (PSV) mode and T-piece trial were used in weaning of mechanically ventilated (MV) patients with chronic obstructive pulmonary disease (COPD). Thus, the objective of study is to assess the value of adding T-piece trial to PSV mode in weaning off patients with COPD.

Patients and methods A total of 80 MV patients with COPD admitted to respiratory ICU were divided into two groups: group I included 40 patients who were weaned off by PSV mode and group II included 40 patients who were weaned off by PSV mode and T-piece trial.

Results The mean age of patients was 62 years. Overall, 73.8% were males and 73.75% were smokers. There were no significant differences between both groups regarding age, sex, BMI, smoking status, Acute Physiology and Chronic Health Evaluation score, exacerbation frequency, and hospital admission. Moreover, there was no significant differences between both groups regarding vital capacity, negative inspiratory force, rapid shallow breathing index, partial arterial oxygen pressure, partial arterial carbon dioxide pressure, and arterial oxygen saturation at the end of PSV mode in both groups. A significant decline in partial arterial oxygen pressure and arterial oxygen saturation and increase in partial arterial carbon dioxide pressure were observed in group II patients after adding T-piece trial. A total of 34 (85%) patients were successfully extubated in group I, whereas 33 (82.5%) patients were successfully extubated in group II. Period of MV, duration of weaning, ICU stay, and mortality were significantly higher in group II patients.

Conclusion T-piece trial after PSV mode has no role in weaning; moreover, it causes more complications and leads to longer duration of weaning.

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Introduction

Chronic obstructive pulmonary disease (COPD) is a major world health problem because of its high percentage, major healthcare problems, and high mortality [1].

Once respiratory failure occurs, the improvement of gas exchange by nonpharmacological treatment is strongly advised, the most important being oxygen therapy. Ventilatory support is a further option to improve alveolar ventilation and decrease mechanical load [2].

Weaning off mechanical ventilation (MV) is defined as withdrawal of ventilator support, resulting in shifting the work of breathing (WOB) to the patient. Approximately 40% of MV time is spent in weaning process [3].

A successful weaning trial was considered when spontaneous breathing is sustained for 48 h without respiratory distress, with pH value more than 7.35 and partial arterial oxygen pressure (PaO_2) more than 60 mmHg at fraction of inspired oxygen less than or equal to 0.6 [4].

In contrast, failure of weaning is considered by one of the following: (i) failed spontaneous breathing trial (SBT), (ii) reintubation and/or resumption of ventilatory support following successful extubation for less than 7 days after weaning, and (iii) death within 48 h following extubation. Extubation failure was defined as reintubation within less than 48 h [5]. Difficult and prolonged weaning cases represent ~46% in respiratory ICU, whereas extubation failure cases represent ~17% [6].

The purpose of this study was to determine the value of combining T-piece trial to pressure support ventilation (PSV) trial in predicting successful weaning in MV patients with COPD. We evaluate the extubation outcome after a SBT with PSV and then T-piece trial and compared it with PSV alone.

Patients and methods

Study design and ethics

This randomized clinical trial study was conducted in respiratory ICU, Chest Department, Faculty of Medicine, Assiut University Hospital, during the period from June 2015 to June 2017. The study design was approved by the Scientific Ethics Committee of Faculty of Medicine of Assiut University.

In this clinical trial, written consent was taken from the patient relatives, and all details were explained to them.

Patients

Among patients with COPD who were admitted to respiratory ICU during this period and supported by either invasive ventilation and/or noninvasive ventilation (NIV), only a subgroup of patients (120 patients) were intubated and fulfilled the inclusion criteria, which included patients with COPD, admitted to respiratory ICU during this period, intubated, and MV. Of them, 80 patients met the criteria of weaning and were involved in the study. Exclusion criteria included age younger than 18 years, previous tracheostomy, central nervous system disorders unrelated to hypercapnic encephalopathy or hypoxemia, neurological, and neuromuscular diseases, patients with self extubation before or during the weaning procedure, and patients with postarrest encephalopathy.

Baseline patient data

Full history was taken from the patients or their relatives. Full clinical examination also was done on the day of ICU admission. Chest radiography, arterial blood gases (ABGs) at the day of intubation, and at the end of every SBT. Full laboratory assessment was done. Illness severity and expected mortality were measured on the day of ICU admission by Acute Physiology and Chronic Health Evaluation (APACHE) II score [7]. Moreover, the prospectively collected data included amount of sputum, period of MV, and ICU and hospital stay.

Procedures

Initiation of mechanical ventilation

All included patients (80 patients) were intubated using endotracheal tubes (ETTs) with size range from 7.0 to 8.0 mm. Ventilation was performed with the Puritan-Bennett 840 ventilator (Purtian Bennett company, Hazelwood, USA), Engostrom Carestation (Jun air, IDEX corporation 2300M-139, USA) or Hamilton G5 (Hamilton medical company, Switzerland). Patients were adjusted on synchronized intermittent mandatory ventilation, volume controlled mode, or volume controlled plus mode.

The procedure of weaning off MV was considered as early as possible. Patients who were receiving MV more than 24 h underwent a daily screen of subjective and objective indices for assessment of readiness to wean [4].

The beginning of weaning is considered when the patient can resume and maintain spontaneous breathing with other criteria for weaning readiness.

Preparation to spontaneous breathing trial

Usually SBT was conducted early in the morning, when the patient was fully rested and there was a full complement of staff available. It initiated while the patient is awake, cooperative, and not receiving sedative infusions. Before the start of SBT, communication with patient and explanation of the procedure was done.

The process of spontaneous breathing trial

The duration of the trials ranges between 30 and 120 min. The need for a shorter time can be recommended for patients on the ventilator for less than 1 week and when weaning success is expected, whereas longer duration trial in patients with history of failed weaning [8].

Modes of spontaneous breathing trial

The SBT was performed with either PSV or combined PSV+T-piece trial. For patients who were weaned by PSV, initial positive pressure support (PS) is 15 cmH_2O. Patients were extubated at PS of 8 cmH_2O. The first trial was usually conducted by rapid decline of PS, whereas subsequent trials were conducted by rapid or gradual reduction of support [4]. PS was lowered by 2–4 cmH_2O on the basis of respiratory parameters, circulation, and patient response [9]. However, in the PSV+T-piece group, the patient must tolerate at least an additional half an hour trial with T-piece ventilation after passing SBT with PSV before extubation.

Monitoring during spontaneous breathing trial

Close observation, especially during the first few minutes, should be done. The patient should be subjectively observed for dyspnea, fatigue, anxiety, and distress. The criteria of successful SBT include good respiratory rate, adequate gas exchange, hemodynamic stability, and patient comfort [4]. ABGs were done at the end of SBT. Tolerance to SBT was continuously evaluated. Variables monitored during SBT included ventilatory data, which were recorded at the end of SBT, including level of

PEEP, tidal volume, respiratory rate, and ratio of respiratory rate and tidal volume (rapid shallow breathing index) (breaths/min/l). Values were measured by ventilator, and we used the average of three breaths.

The total duration of weaning was measured as the duration between the time of readiness to wean and the time of successful weaning for the last time [10].

Statistical analysis

Data were recorded to statistical package for social science, version 21 (IBM Inc., Armonk, New York, USA). Data were described using mean±SD or frequencies (%) according if they are quantitative or qualitative, respectively. A *P* value was calculated between both PSV and T-piece group, and the value of less than 0.05 was considered significant. Nonparametric tests were used in this study, such as χ^2-test.

Results

No significant difference was found between both groups regarding sex, age, BMI, smoking state, APACHE II score, exacerbation frequency per year, and previous hospital admission. Regarding laboratory data of both groups at the first day of ICU admission, apart from a significant increase in serum bilirubin in group I, no significant differences were recorded between both groups (Table 1).

ABGs of both groups were recorded at initial presentation; they showed a significant increase in partial arterial carbon dioxide pressure ($PaCO_2$) and decrease in oxygen saturation (SaO_2) in group II than group I (Table 2).

Regarding clinical, ventilatory, and gasometric data at the end of SBT, significantly higher heart rate, blood pressure, and rapid shallow breathing index with a significant decrease in SaO_2 in group II than group I were recorded (Table 3).

On comparing ABGs before and after adding T-piece in group II, there was a significant decrease in pH, PaO_2, and SaO_2. Otherwise, a significant increase in the level of $PaCO_2$ was also noted (Table 4).

Duration of MV and the need for NIV were significantly higher in group II than group I. However, there was an insignificant increase in the number of SBTs, extubation failure and weaning duration in group II. Moreover, ICU and hospital

Table 1 Demographic data of both groups

Parameters	Total (*n*=80)	Group I [*n*=40 (50%)]	Group II [*n*=40 (50%)]	*P* value
Sex				
Male	59 (73.8)	32 (80)	27 (67.5)	0.204
Female	21 (26.2)	8 (20)	13 (32.5)	
Age (years)	62.85±7.58	64.3±7.18	61.4±7.77	0.087
BMI (kg/m^2)	27.66±2.59	27.45±2.16	27.88±2.96	0.46
Ever-smoker	59 (73.75)	32 (80)	27 (67.5)	0.204
Nonsmoker	21 (26.25)	8 (20)	13 (32.5)	
Smoking index	30.85±8.05	30.94±7.56	30.74±8.738	0.926
APACHE II score	12.75±3.97	11.98±3.39	13.53±4.39	0.081
Calculated mortality	16.46±9.732	15.05±8.19	17.88±10.98	0.196
Exacerbation/year	3.74±1.23	3.55±1.26	3.93±1.19	0.174
Previous hospital admission	1.29±1.14	1.13±1.14	1.45±1.13	0.204

Continuous data are presented as mean±SD, whereas categorical variables are presented as frequency (%). APACHE II, Acute Physiology and Chronic Health Evaluation; ever-smoker, exsmoker+current smoker; PSV, pressure support ventilation. *P* value is calculated between both PSV and PSV+T-piece groups.

Table 2 Initial arterial blood gases of both groups

Parameters	Total (*n*=80)	Group I [*n*=40 (50%)]	Group II [*n*=40 (50%)]	*P* value
pH	7.25±0.064	7.26±0.059	7.24±0.086	0.132
$PaCO_2$	88.36±16.01	85.8±15.21	90.93±16.55	0.018*
PaO_2	39.79±6.69	39.8±6.75	35.78±6.73	0.987
PaO_2/FiO_2	38.61±9.74	38.93±9.5	38.3±10.09	0.776
SaO_2	62.23±15.55	64.95±14.34	59.5±16.41	0.032*

FiO_2, fraction of inspired oxygen; $PaCO_2$, partial arterial carbon dioxide pressure; PaO_2, partial arterial oxygen pressure; SaO_2, arterial oxygen saturation. *Significant difference.

stay and mortality were insignificantly higher in group II. Regarding weaning categories, no significant difference was found between both groups. Regarding complications, group II had significant higher rates of both ventilator-associated pneumonia and acute respiratory distress syndrome than group I (Table 5).

Discussion

Weaning should be initiated when patient's condition is stable and allows spontaneous breathing. Most of our patients were males and cigarette smokers, which is consistent with the study by Halbert *et al*. [11], which stated that the prevalence of COPD is higher in smokers as compared with nonsmokers.

Regarding age, most of our patients were between the age of 50 and 70 years, and the mean age of them was 62.85±7.58 years which is compatible with the study of van Durme *et al*. [12], which demonstrated the average age of patients with COPD is 70 years.

Baseline data documented no significant difference between both groups regarding demographic, laboratory, and gasometric parameters apart from the baseline bilirubin, $PaCO_2$, and SaO_2. The determined statistical significance was of minimal clinical importance as all other parameters had no significant difference between both groups, including APACHE II score. So, we can propose that both modes of weaning can be conveniently compared with each other in term of weaning course and outcome and also regarding fate of extubation, duration of hospital stay, occurrence of complications, and mortality.

A significant decrease in pH, PaO_2, and SaO_2 and a significant increase in $PaCO_2$ were recorded after T-piece trial in group II patients. This is because during T-piece breathing, patient WOB is increased owing to increased ETT resistance [13].

PSV is used to overcome the WOB added by ETTs and ventilator circuits. This helps in weaning, as the patient who is comfortable at the compensatory level of PS will be able to maintain ventilation after weaning. However, the level of PS required to overcome the work added by ETTs and ventilator circuits varies (from 3 to 14 cm of water) [14,15].

We found that both length of MV and ICU stay were longer in group II patients than group I. This is comparable with the study of Matić *et al*. [16], who studied the outcomes of T-tube and PSV weaning procedures and demonstrated that PSV is better than T-tube regarding duration of MV.

Table 3 Clinical, ventilatory, and gasometric parameters at the end of pressure support ventilation trial in both groups

Parameters	Total (*n*=80)	Group I [*n*=40 (50%)]	Group II [*n*=40 (50%)]	*P* value
Heart rate	99.38±18.44	98.65±14.68	105.1±21.72	0.042*
Blood pressure (mmHg)	93.58±15.82	89.78±14.46	97.38±16.38	0.031*
Respiratory rate (breaths/min)	24.5±6	24.78±5.9	24.25±6.15	0.698
Tidal volume (ml/kg)	5.31±0.96	5.37±0.89	5.25±1.03	0.644
RR/V_T	105.71±70.43	101.58±66.82	109.85±74.49	0.033*
ABG after PSV				
pH	7.44±0.038	7.43±0.034	7.44±0.042	0.139
$PaCO_2$	56.38±10.23	57.23±10.46	55.53±10.05	0.461
PaO_2	81.15±14.56	81.08±13.61	81.23±15.63	0.964
HCO_3	36.73±7.79	37.05±8.05	36.4±7.61	0.712
SaO_2	95.38±2.45	95.5±2.54	93.25±2.37	0.017*

ABG, arterial blood gas; FiO_2, fraction of inspired oxygen; HCO_3, bicarbonate; $PaCO_2$, partial arterial carbon dioxide pressure; PaO_2, partial arterial oxygen pressure; PSV, pressure support ventilation; RR/V_T, ratio of respiratory rate and tidal volume (rapid shallow breathing index) ; SaO_2, arterial oxygen saturation. *Significant difference.

Table 4 Arterial blood gases before and after T-piece trial in group II patients

Arterial blood gases	Before T-piece [*n*=40 (50%)]	After T-piece [*n*=40 (50%)]	*P* value
pH	7.44±0.04	7.38±0.06	0.029*
$PaCO_2$	55.53±10.05	64.13±12.66	0.000*
PaO_2	81.23±15.63	71.08±13.54	0.007*
HCO_3	36.4±7.61	36.2±7.96	0.827
SaO_2	95.25±2.37	92.88±3.93	0.004*

FiO_2, fraction of inspired oxygen; HCO_3, bicarbonate; $PaCO_2$, partial arterial carbon dioxide pressure; PaO_2, partial arterial oxygen pressure; SaO_2, arterial oxygen saturation. *Significant difference.

Table 5 Outcome of weaning, weaning categories, and complications in both groups

Parameters	Total (*n*=80) [*n* (%)]	Group I [*n*=40 (50%)] [*n* (%)]	Group II [*n*=40 (50%)] [*n* (%)]	*P* value
Duration of MV (days)	7.28±5.53	6.33±3.27	8.23±3.56	0.015*
Duration of weaning (h)	19.28±31.18	18.7±32.1	19.85±31.85	0.873
Number of SBT	1.54±0.763	1.51±0.82	1.57±0.72	0.585
Successful extubation	67 (83.8)	34 (85)	33 (82.5)	0.762
Failed extubation	13 (16.3)	6 (15)	7 (17.5)	
Need of NIV	48 (60)	21 (52.5)	27 (67.5)	0.028*
Duration of NIV (h)	16.68±13.03	15.48±12.11	17.88±13.98	0.029*
ICU stay (days)	11.2±5.03	10.28±4.83	12.13±5.11	0.1
Hospital stay (days)	14.48±6.18	13.5±5.99	15.45±6.29	0.16
ICU mortality	7 (8.8)	3 (7.5)	4 (10)	0.692
Hospital morality	12 (15)	5 (12.5)	7 (17.5)	0.531
Weaning categories				
Simple weaning	50 (62.5)	26 (65)	24 (60)	0.86
Difficult weaning	18 (22.5)	8 (20)	10 (25)	
Prolonged weaning	12 (15)	6 (15)	6 (15)	
Complications				
VAP	32 (40)	14 (35)	18 (45)	0.023*
ARDS	12 (10)	4 (10)	8 (20)	0.033*
Electrolyte disturbance	33 (41.3)	16 (40)	17 (42.5)	0.82

ARDS, acute respiratory distress syndrome; MV, mechanical ventilation; NIV, noninvasive ventilation; SBT, spontaneous breathing trial; VAP, ventilator-associated pneumonia. *Significant difference.

With respect to the duration of weaning in our study, it showed no significant difference between both groups. However, it was longer with patients of group II than patients of group I (19.85±31.85 vs. 18.7±32.1). This is compatible with the study of Matić *et al.* [16], which stated that 43% of the total MV duration was spent in weaning in T-tube group, whereas 36% in PSV group.

Regarding the type of weaning in our study, patients were classified according to weaning category into simple, difficult, and prolonged weaning. A total of 50 (62.5%) patients had simple weaning, whereas 18 (22.5%) of them had difficult weaning, and 12 (15%) had prolonged weaning. This was consistent with Brochard [17] classification during the International Consensus Conference who classified patients in his study into three groups according to the difficulty and duration of the weaning process into simple, difficult, and prolonged weaning. Moreover, weaning was classified into three weaning categories according to the current statement of the ERS, ATS, ESICM, SCCM, and SRL on the basis of difficulty and duration of weaning [4].

Regarding complications such as electrolyte disturbance, we found that there were 33 (41.3%) patients who had electrolyte disturbance but without significant difference between both groups. This is comparable with Ouf *et al.* [18], who documented that imbalance in serum electrolytes has been proved in patients with COPD, both in acute exacerbation and during stable disease.

The number of patients with successful weaning in group I was more (34, 85%) than in group II (33, 82.5%). This is comparable with the results of Esteban *et al.* [19] which documented that patients with successful extubation after SBT was 10% higher with PS of 7 cmH_2O than with T-tube trial.

Our study revealed that weaning by PSV method is more successful than weaning by PSV+T-piece method. This was confirmed by the study of Matić *et al.* [16], which reported that both spontaneous breathing using T-tube and PSV are successful methods of weaning of patients with COPD; however, PSV is more successful.

Conclusion

Finally, in respiratory ICU patients, PSV was safe, reliable, and can be used for weaning trials. The addition of T-piece after PSV provides no benefits in weaning off patients with COPD but is associated with significant deterioration in all gasometric parameters. Moreover, the duration of MV, occurrence of complications, and the need of NIV after extubation are significantly increased. PSV adds a benefit in duration of weaning, number of SBTs, length of ICU stay, and mortality rate.

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Conflicts of interest
There are no conflicts of interest.

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