The Comparison of Pressure (PSV) and Volume Support Ventilation (VSV) as a 'Weaning' Mode

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Objective: The purpose of our study is to compare two different ventilation modes-pressure support ventilation (PSV) and volume support ventilation (VSV)-as the means of weaning.

Methods: Sixty patients were enrolled in our study. Patients were randomized in to two groups. For the PSV group, FiO_2 and airway pressure values were adjusted in order to sustain PaCO_2 : 35-45 mm Hg, pH >7.32, 6-8 mL kg^{-1} TV (tidal volume), and saturation >92%. For the VSV group, FiO_2 , TV, respiration frequency (f), and peak pressure were adjusted to obtain PaCO_2 : 35-45 mm Hg, pH >7.32, 6-8 mL kg^{-1} TV, saturation >92%, and PO_2 >60 mm Hg. Every morning, spontaneous breathing was tried in those patients. The patients were extubated after 2 hours of T-piece breathing. The patients who failed spontaneous respiration with the T-piece were returned to mechanical ventilation. Assisted ventilation time (ART), mechanical ventilation time (MRT), total T-piece time (TTT), total weaning time (TWT), and sedation need (SN) values were recorded. "T-test" and "Chi-square" methods were used for statistical analysis.

Results: In our study, the mean ART was 82.60 hours for the PSV group and 56.03 hours for the VSV group ($p<0.041$). TWT was 93.30 hours for the PSV group and 56.03 hours for the VSV group ($p<0.035$). The mean TTT was 7.67 hours for the PSV group and 3.83 hours for the VSV group ($p<0.007$). Nineteen patients in the PSV group and 9 patients in the VSV group required sedation during the weaning process ($p<0.01$).

Conclusion: In the weaning period, VSV seems to be more advantageous than PSV.

Key Words: Weaning, ventilatory support, assisted ventilation modes

Introduction

Mechanical ventilation is currently one of the important practices in the supportive treatment of respiratory failure in intensive care units. It is known that ventilation treatment could be accompanied by unintended and unexpected adverse events. The pathophysiological event that causes these adverse events is reversal of normal physiology of intrathoracic pressure during positive-pressure ventilation. In addition to the risk of developing barotrauma and volutrauma, mechanical ventilation has also unfavourable impacts on cardiovascular system and organ perfusion. Moreover, prolonged mechanical ventilation enhances the risk of nosocomial pneumonia. This condition directs us to the general principle of minimizing the duration of mechanical ventilation and performing extubation as soon as possible. In recent years, development of numerous models of artificial respiration, which could support spontaneous breathing, has made it possible to gradually decrease the mechanical ventilatory support. Existence of a great variety of methods brings into mind the question that by which method for which patient can successful, rapid and effective results be obtained? Demonstrating that 'weaning' phase accounts for 40% of duration of mechanical ventilation in patients undergoing different mechanical ventilation methods highlights the importance of this subject (1).

The aim of the present study was to determine superiority of two different ventilation models, pressure support ventilation (PSV) and volume support ventilation (VSV), to each other as two different means of weaning.

Methods

The present study was approved by Istanbul University Istanbul Medical Faculty Ethics Committee (date: 21.03.2007 and number: 2007/437). The informed consents of the first-degree relatives of the patients were obtained. This study included patients aged between 16-80 years, who were hospitalized at the intensive care unit for any medical or surgical indication, underwent pressure-targeted controlled mechanical ventilation for at least 48 h, and fulfilled the following conditions: 1) Body temperature $<38^{\circ}\text{C}$, 2) Haemoglobin $>8.5\text{ g dL}^{-1}$, 3) $\text{PaO}_2 >60\text{ mmHg}$ ($\text{FiO}_2 <40\%$), 4) PEEP $<6\text{ cmH}_2\text{O}$, 5) Respiratory rate $<35\text{ min}^{-1}$, 6) Spontaneous tidal volume (VT) $>5\text{ mL kg}^{-1}$, 7) Haemodynamically stable (no need for vasopressor or inotropic medication), 8) Discontinuation of sedative drugs 24 hours ago, and 9) No electrolyte or acid-base imbalance.

The patients were randomly divided into equal groups after recording demographic data, APACHE II score, disease leading to intubation (medical, surgical), concomitant disease likely to influence breathing, presence of previous sedation, blood pressure values (systolic/diastolic/mean), heart rate, SpO_2 level measured by pulse oximeter, tidal volume, peak airway pressure (PawP), mean airway pressure (MawP), respiratory rate (f), amount of PEEP applied, $\text{PaO}_2/\text{FiO}_2$ values, f/VT ratio, and static lung compliance.

Patients who successfully completed spontaneous breathing trial at a trigger level of $-2\text{ cmH}_2\text{O}$ were assigned to the PSV or VSV. In the PSV group, FiO_2 and airway pressure were adjusted providing that PaCO_2 to be $35\text{--}45\text{ mmHg}$, pH to be >7.32 , VT to be $6\text{--}8\text{ mL kg}^{-1}$, saturation to be $>92\%$, and PaO_2 to be $>60\text{ mmHg}$. In the VSV group, VT of $6\text{--}8\text{ mL kg}^{-1}$, FiO_2 , and the peak pressure level were adjusted providing that PaCO_2 to be $35\text{--}45\text{ mmHg}$, pH to be >7.32 , saturation to be $>92\%$, and PaO_2 to be $>60\text{ mmHg}$. Spontaneous breathing trial was performed every morning using a T-piece in the patients fulfilling the following criteria: 1) Improvement of underlying disease causing acute respiratory failure, 2) Discontinuation of vasoactive and sedative agents, 3) $\text{PaO}_2 >60\text{ mmHg}$, 4) $\text{FiO}_2 <0.5$, 5) PEEP $<6\text{ cmH}_2\text{O}$, 6) $\text{VT} >6\text{ mL kg}^{-1}$, and 7) $\text{f/VT} <105$.

Patients without any problem according to the below-mentioned criteria while breathing through a T-piece were extubated following 2-h spontaneous breathing period through a T-piece. Again, spontaneous breathing through a T-piece was discontinued and mechanical ventilation restarted in the patients who were considered unsuccessful based on the below-mentioned criteria.

Criteria for failure in the patients monitored during spontaneous breathing were as follows: 1) Respiratory rate $>35\text{ min}^{-1}$, 2) $\text{SpO}_2 <90\%$, 3) Heart rate $>140\text{ min}^{-1}$ (or higher than 20% of the baseline), 4) Systolic arterial pressure $<80\text{ mmHg}$ or $>200\text{ mmHg}$, 5) Agitation, 6) Anxiety, and 7) Perspiration.

Similar practices were performed daily in these patients and a T-piece was used at certain intervals until all criteria were fulfilled. During the study, the following parameters were re-recorded: need for sedation in the PSV and VSV groups (if sedation was performed, whether the dose increased or not), need for controlled ventilation in the patients on assisted ventilation, requirement of intervention for mechanical ventilation parameters due to impaired gas exchange, f/VT ratios, static lung compliance, VT, respiratory rate (presence or absence of tachypnea), airway pressures, $\text{PaO}_2/\text{FiO}_2$ ratios, SpO_2 level measured by pulse oximeter, heart rate, blood pressure values, presence or absence of atelectasis (chest X-ray repeated every morning was evaluated by a radiologist), need for non-invasive ventilation after extubation, whether the patients who could not tolerate extubation were re-intubated, total duration of mechanical ventilation, total 'weaning' time, total assisted ventilation time, and total T-piece time.

Direct radiological findings of atelectasis included displacement of interlobar fissures and crowding of vascular structures and bronchi. Indirect radiological findings of atelectasis included local enhancement in opacity, elevation of the hemidiaphragm, mediastinal shift, compensatory overinflation, hilar displacement, approximation of the ribs, absence of air bronchograms (only in resorption atelectasis), disappearance of visibility of interlobar arteries (only in inferior lobe atelectasis).

Extubated patients were monitored for 48 h unless they exhibited the criteria of failure. Patients who exhibited the criteria of failure either were re-intubated or underwent non-invasive mechanical ventilation depending on clinical symptoms and respiratory parameters. Patients who did not require re-intubation for 48 h were considered successful. Recorded parameters of 30 patients with 'weaning' success with PSV and 30 patients with 'weaning' success with VSV were compared. All patients were followed-up until death or discharge from the intensive care unit.

Statistical analysis

Statistical Package for the Social Sciences (SPSS, Inc. Chicago, IL, USA) version 16 for Windows was used for statistical analyses. Quantitative data were expressed as mean $\pm$ standard deviation. Intergroup comparisons of the normally distributed data were performed by Student's t-test, whereas

categorical data were evaluated by chi-square test. A p value smaller than 0.05 was considered statistically significant.

Results

The present study included 60 patients hospitalized in the intensive care unit. No significant difference was found between the groups in terms of age and APACHE II score ($p=0.397$). Both the PSV and VSV groups included 16 (53.33%) males and 14 (46.66%) females. The primary diseases and comorbidities of the patients are demonstrated in Tables 1 and 2.

Among patients who received mechanical ventilation for more than 48 h, the assisted ventilation time was shorter in the VSV group than in the PSV group (56.03 ± 41.24 h vs. 82.60 ± 56.09 h; $p=0.041$). Total “weaning” time was significantly shorter in the VSV group than in the PSV group (61.53 ± 47.10 h vs. 95.30 ± 71.41 h; $p=0.035$; Table 3).

While 19 patients in the PSV group required sedation during the ‘weaning’ process, the number of patients who required sedation was 9 in the VSV group ($p=0.01$). No significant differences were found between the PSV and VSV groups in terms of need for non-invasive ventilation and re-intubation. No significant difference was found between the study groups during the ‘weaning’ process in terms of haemodynamic monitoring parameters. Moreover, no significant differences were found between the study groups in terms of f/V_T ratios, PaO_2/FiO_2 ratios, and static lung compliance during transition to assisted ventilation model.

There were no differences between the groups in terms of re-adjustment of mechanical ventilation parameters due to impaired gas exchange and need again for a controlled ventilation in the patients on assisted ventilation. Atelectasis development showed no difference between the groups. Total mechanical ventilation time was similar in the PSV and VSV groups.

Discussion

In the present study, which compared two different models of ventilation, we concluded that “weaning” process was shorter in the patients undergoing VSV and the need for sedation was lower in the patients undergoing PSV. It is known that mortality and morbidity increase with prolonged mechanical ventilation in patients undergoing invasive mechanical ventilation (2, 3).

‘Weaning’ time accounts for the substantial proportion (40%) of mechanical ventilation time (1). Prolongation of this period increases mortality. Penuelas et al. (4) also emphasized an increase in mortality in patients for whom weaning from mechanical ventilation lasted more than seven days. This pe-

Table 1. Primary diseases and comorbidities of the patients in the PSV group

PSV (n=30)	Primary disease	Comorbidity
2	HELLP syndrome	
1	Chronic renal insufficiency	Hypertension
2	Hypertension	
4	Trauma (excluding cervical trauma)	
2	Pneumonia	Hypertension+ Diabetes Mellitus
1	Pneumonia	Oesophagus Tm
4	Pneumonia	
1	Sepsis-Crohn	
1	Sepsis-Cholangitis	Diabetes Mellitus
2	Eclampsia	
1	Wegener’s granulomatosis	
1	Sepsis	Ovarian cancer- acute renal insufficiency
1	Uterine atony bleeding	
1	Ovarian cancer	Acute renal insufficiency
1	Breast cancer	Hypertension
2	Diabetes Mellitus	Hypertension
1	Insulinoma	
1	Hepatic insufficiency	
1	Pneumonia-sepsis	
PSV: pressure support ventilation		

riod is also important since it accounts for significant proportion of workload in intensive care units. Many factors that influence “weaning” time have been investigated; age, underlying disease, course of the disease at the onset of “weaning”, mechanical ventilation time, psychological factors, adequacy of equipment and personnel, experience and habits of clinician, and technique used are among these factors.

Superiority of ventilation models used for ‘weaning’ to each other is an important issue. Many different artificial ventilation models are used for ‘weaning’ (5). VSV and PSV are assisted ventilation models used for “weaning”. In the present study, we intended to investigate whether these two different models of ventilation were superior to each other during weaning period.

In the VSV model used in the present study, we considered that likely atelectasis might be prevented by keeping V_T within a certain range despite intraalveolar pressure changes. Besides, it has been reported that VSV may cause an uncontrollable pressure increase and related volutrauma (6). Considering working principles of two different models of

Table 2. Primary diseases and comorbidities of the patients in the VSV group

VSV (n=30)	Primary disease	Comorbidity
1	Pneumonia	Chronic renal insufficiency+Hypertension
1	Pneumonia	Diabetes Mellitus+Hypertension
1	Pneumonia	Diabetes Mellitus
5	Pneumonia	
1	Oesophagus cancer	
1	Trauma (excluding cervical trauma)	
1	Acute renal insufficiency	Systemic lupus erythematosus
2	HELLP syndrome	
1	Acute renal insufficiency	Hypertension
1	Chronic renal insufficiency	Diabetes Mellitus
1	Hypertension	
1	Diabetes Mellitus	Hypertension
1	Gastrointestinal system bleeding	Peptic ulcer
1	Waldenström's macroglobulinemia	
1	Sepsis-cholangitis	
1	Sepsis-urinary infection	Diabetes Mellitus
1	Sepsis-colon cancer	
5	Sepsis-pneumonia	
2	Diabetic ketoacidosis	
1	Basedow-graves	Hypertension
VSV: volume support ventilation		

assisted ventilation used in the present study during 'weaning' process, atelectasis was an important monitoring parameter. Preserving lung compliance by constant pressure in PSV and preserving minute ventilation volume in VSV raised the question that whether they make difference in terms of development of atelectasis. We concluded that there was no difference between the two groups in terms of atelectasis. Accordingly, there were no significant differences between the study groups in terms of need to change the respiratory parameters due to the factors like atelectasis and impaired gas change or need again for controlled ventilation models. In fact, the absence of a difference between two groups in terms of atelectasis was a surprising outcome. Development of atelectasis in the PSV group could have appropriately explained the shorter "weaning" time in the VSV group. No doubt, it is likely that weakness in the precision of radiological detection of atelectasis with the present methodology might have resulted in overlooking an existing difference.

Table 3. Evaluation of the study groups in terms of weaning time and T-piece time before extubation

	Group	N	Mean	Standard deviation	p value
Weaning time (h)	VS	30	61.53	47.10	0.035
	PSV	30	95.30	71.41	
Total T-piece time (h)	VS	30	3.83	2.47	0.007
	PSV	30	7.67	7.13	
VSV: volume support ventilation; PSV: pressure support ventilation					

PSV is beneficial to meet the work imposed by respiratory and trigger system and endotracheal tube via a ventilator circuit. Although the range to compensate this work has been determined to be 3-15 cmH₂O in various studies, a pressure support of 7 cmH₂O may be enough (7, 8). In their study concerning spontaneous breathing trials via PSV at this level, Brochard et al. (9) demonstrated that PSV shortened the 'weaning' time. In another study, three models (VC, SIM-V±PS and PRVC) were compared and none of them was associated with mortality (10). The researchers attributed this to the alveolar pressure's (plateau pressure), which actually reflects hyperinflation of alveoli, remaining at acceptable levels despite high peak inspiration pressure. However, VSV was not among the ventilation models compared in those studies. In the present study, we concluded that, compared to PSV, VSV shortened the 'weaning' time and the total T-piece time in all repetitions. Some studies have concluded that spontaneous breathing trial before extubation is the best technique (11, 12).

The second factor that contributes to shortened 'weaning' time is the short total T-piece time. In the present study, T-piece time was shorter in the VSV group, which could be weaned from mechanical ventilation in a shorter time.

In the evaluation of compliance of patients to the assisted ventilation model, sedation was one of the monitoring parameters. Need again for sedation during transition to the assisted ventilation model was also evaluated. It was found that the need for sedation was lower in the VSV group than in the PSV. Lower need for sedation contributed to the decrease in total mechanical ventilation time in the VSV group as well as it was an indicator that this process was more comfortable.

The incidence of re-intubation after extubation has generally found to be 3%-19% in the studies (9, 13-16). In another study, 217 patients were evaluated and the incidence was found to be 31.8% (17). A multivariable study including patients with unsuccessful extubation demonstrated that mortality rate was seven times lower in the patients with successful extubation. Another study revealed that mortality rate of re-intubated patients in the intensive care unit was higher

as compared to the patients who were successfully extubated (34.8% vs. 5.6%) (18). In a similar study, mortality rate was found to be higher in re-intubated patients as compared to the patients without need for re-intubation (38.9% vs. 5.3%) (19). In this case, importance of the method that would provide successful extubation is increased. The question here is whether re-intubation alone can be the reason for increased mortality, or whether poor outcomes obtained from re-intubated patients are associated with the clinical event that initially cause the need for mechanical ventilation, or whether the 'weaning' model contributes to mortality by enhancing or reducing the need for re-intubation. There has yet been no study demonstrating the correlation between any of the assisted ventilation models used for 'weaning' and re-intubation or mortality. In the present study as well, no significant difference was found between the study group in terms of the need for non-invasive mechanical ventilation and need for re-intubation.

In the present study, development of atelectasis was assessed radiologically by chest X-ray. However, adequacy of this method in definite detection of atelectasis development is limited. Using also computed tomography in the study might be illuminating for the results.

Conclusion

Volume support ventilation used for 'weaning' process shortened total 'weaning' time as compared to PSV. In addition to 'weaning' time, assisted ventilation and T-piece times were also shortened. This condition was accompanied by reduced need for sedation. The assisted ventilation processes of both groups were similar in other aspects. Here, the most important factor that shortened 'weaning' time appeared to be reduced need for sedation. Moreover, microatelectasis, which could not be detected, being higher in PSV might also have a role. Further studies are needed to clarify all of these points.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of İstanbul University İstanbul Faculty of Medicine.

Informed Consent: Written informed consent was obtained from the parents of the patients who participated in this study.

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