

Clinical Comparison of Volume Support Ventilation With Pressure Support Ventilation in Patients Admitted at Intensive Care Unit

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Abstract- Mechanical ventilation (MV) is among the main basics of supportive treatment for respiratory failure in the intensive care unit (ICU). This supportive treatment may cause undesirable complications that led to the introduction of various MV modes. The current study was aimed to assess and compare outcomes of volume support ventilation (VSV) and pressure support ventilation (PSV) regarding spontaneous breath return, weaning and hemodynamic changes among patients admitted at ICU following surgical procedures. This single-blinded randomized-clinical-trial (RCT) was conducted on 100 patients admitted at ICU in 2018-2019. Patients were randomly divided into two fifty-member groups treated with PSV and VSV modes. Oxygen saturation, systolic (SBP) and diastolic blood pressure (DBP), mean arterial pressure (MAP), arterial blood gas (ABG), extubation and MV time and sedation based on RAMSY criteria were recorded and compared. Mean age ($P=0.79$) and gender distribution ($P=0.57$) were not statistically different in the two groups. Time has no effect on patients' hemodynamic ($P>0.05$) while hemodynamic stability was superior in VSV ($P<0.05$). ABG showed no statistical difference between groups ($P>0.05$) except for arterial oxygen pressure that was higher in the VSV group ($P<0.001$). The duration of MV, extubation time and duration of ICU admission was significantly lower in the VSV group. Furthermore, sedation based on RAMSY criteria showed the superiority of VSV ($P<0.05$). Use of VSV mode was accompanied with superior outcomes in four entities including earlier and easier weaning, shorter duration of ICU admission, least hemodynamic instabilities and least sedation requirement in comparison to PSV mode.

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Introduction

Mechanical ventilation is currently one of the main basic supportive treatments of respiratory failure in the intensive care unit (ICU), which most of the financial resources are allocated to this section because of special nutritional needs, chest physiotherapy and intensive care to prevent the effects of mechanical ventilation. This is while reducing mortality in the ICU is considerably due to advances in respiratory support by mechanical ventilation using a variety of methods (1,2).

This supportive treatment, along with all the benefits, can lead to unwanted side-effects. One of these unwanted effects is the natural physiology reversal of Intra-abdominal Pressure (IAP) during positive-pressure ventilation (3). Furthermore, mechanical ventilation can lead to barotrauma and volutrauma which, regardless of

the type of injury, can also have negative effects on the cardiovascular system, hemodynamic status and tissue perfusion of organs (4). On the other hand, long-term mechanical ventilation may lead to nosocomial infection or ventilator-associated pneumonia (VAP) (5).

In recent years, there has been a lot of change in the care of patients under mechanical ventilation in order to minimize the complications. Alongside developments in sedation techniques, are the introduction of mechanical ventilation techniques and newer ventilation modes. Advances in studies have shown that early weaning from mechanical ventilation can reduce the need for sedation and subsequently reduce costs while minimizing the complications. These methods have somehow affected the duration of intubation, shortening the length of stay in the intensive care unit, reduced the need for intubation and sedation, as well as reduced complications and costs

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(6-8).

In Volume Support Ventilation (VSV), a certain amount of volume, regardless of the volume and airway resistance, enters into the lungs. This can lead to complications such as barotrauma and pneumothorax (9). On the other side, there is Pressure Support Ventilation (PSV) that continues support ventilation until reaching the preset pressure and prevents injuries sustained by pressure, but in case of inappropriate velocity, the lungs may be too quick to reach the preset pressure and the patient sustains hypotension and respiratory acidosis (10). Regarding what has been said, each of the modes has advantages and disadvantages, but studies designed to compare the hemodynamic and weaning effects of the use of these two modes are limited and contradictory (11).

The purpose of this study was to evaluate and compare Volume Support Ventilation (VSV) and Pressure Support Ventilation (PSV) in terms of spontaneous return of breathing and weaning as well as hemodynamic changes.

Materials and Methods

This study was a single-blind randomized clinical trial (RCT) on 100 patients admitted to the intensive care unit

of Al-Zahra hospital in Isfahan University of Medical Sciences from May 2018 to April 2019.

Patients aged 18 to 70 years following a surgical procedure hospitalized in the intensive care unit of Al-Zahra hospital, with the indication of treatment by mechanical ventilation using Volume Support Ventilation (VSV) and pressure support ventilation (PSV) were included in the study.

Patients discharged within 24 hours of admission to ICU, or those who died in the ICU for any reason were excluded from the study.

After approval by the ethics committee of Isfahan University of Medical Sciences (IR.MUI.MED.REV.1397.3.318), the study process was explained to the patient (if possible) and their legal guardian, and they were asked to sign an informed consent form to participate in the study.

The patients were included in the study non-randomly and using a convenience sampling method, and then, they were randomly assigned to two groups of treatment with Pressure Support Ventilation (PSV) and Volumetric Support Ventilation (VSV). Randomizing the patients was performed using Random Allocation software in which each case in the study was given a number, and they were assigned to each of the experimental groups according to the numbers (Figure 1).

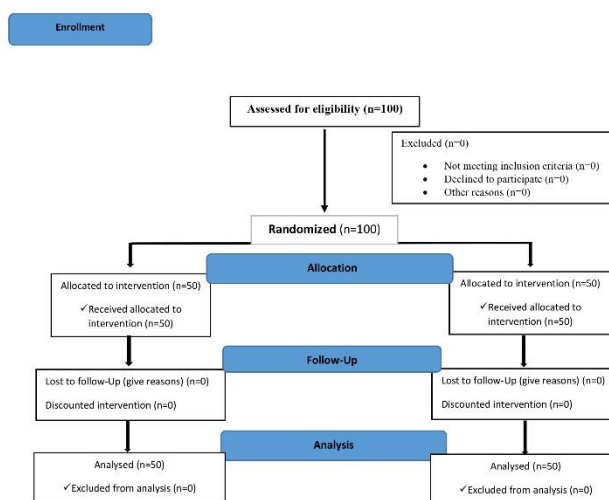


Figure 1. Study flow diagram

In this single-blind study, patients were unaware of the mode used for pulmonary ventilation.

All patients in the study were under ventilation with BENET840 (Altern up Medical, Germany) to minimize the potential bias affected by the type of device.

All patients were monitored and parameters such as

oxygen saturation (O_2 Sat), electrocardiographic monitoring, systolic and diastolic blood pressure and mean arterial pressure was measured in the initial 6 hours of attachment to mechanical ventilation.

For all patients, sedation was administered using 2 mg of morphine and 2 mg of midazolam intravenously and a

dose of 2 mg of morphine plus 2 mg of midazolam as needed based on the Richmond method (12). In addition, scoring the amount of sedation based on the RAMSY sedation scale was performed at 1-6 hours of mechanical ventilation and then every 6 hours for 24 hours (13).

During the ventilation, arterial blood gas (ABG) was measured and recorded at the time of entry and then on a daily basis. Moreover, the duration of weaning, as well as the mechanical ventilation time, were recorded in the study checklist. In addition, hemodynamic parameters including systolic and diastolic blood pressure, mean arterial pressure, heart rate and oxygen saturation were recorded.

In this study, high blood pressure (hypertension) was defined as systolic blood pressure higher than 140 mmHg and diastolic blood pressure higher than 90 mmHg, and low blood pressure (hypotension) was defined as more than 20% decrease in arterial blood pressure compared to baseline blood pressure. Furthermore, mean arterial pressure (MAP) was calculated based on the formula of $MAP = 2DBP + SBP / 3$ (MAP: Mean Arterial Pressure, SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure). Heart rate above 100 beats per minute was defined as tachycardia, and heart rate less than 60 beats per minute was defined as bradycardia.

Natural parameters of arterial blood gas (ABG) analysis were considered in the natural pH range between 7.35 to 7.45, partial pressure of carbon dioxide (PCO₂) between 35-45 mmHg, partial pressure of oxygen (PO₂) more than 70 mmHg and mean concentrations of bicarbonate (HCO₃) about 24 mEq/L for arterial blood. Therefore, arterial hypoxemia means a decrease in the partial pressure of arterial blood oxygen levels PO₂ below

60 mmHg, and hypercapnia means an increase in the partial pressure of arterial blood carbon dioxide above 45 mmHg. In addition, pH values lower than 7.35 mmHg were considered as acidosis and pH higher than 7.45 mmHg was considered as alkalosis.

In addition, Sequential Organ Failure Assessment (SOFA) was used as the scoring system to measure the risk of death after surgery, based on which 0 to 24 scores were assigned; where between 0 and 7 was considered low intensity with the mortality risk up to 2.4%, moderate-intensity was considered between 8 and 15 with a mortality risk higher than 2.4%, and severe intensity score was considered above 16 with mortality risk higher than 10.4%.

The data was entered in the SPSS-24 software (IBM Chicago, USA), and it was analyzed. Descriptive data were reported as mean and percent while for analytical information statistical tests including Chi-square, *t*-test and analysis of repeated measures ANOVA were used.

Results

In this study, 100 patients who underwent surgery were evaluated in two groups of 50 cases of mechanical ventilation using VSV and PSV. The mean age of patients in the VSV group was 45±18.2 years (range: 20-78 years), and in the PSV group, the mean age was 46.4±19.3 years (range: 18-76 years) (*P*=0.79). In addition, male/female demographic distribution was 24/26 in the VSV group and 20/30 in the PSV group (*P*=0.57) (Table 1).

Table 1. Comparison of Demographic characteristic of patients between two groups

Variables	PSV(n = 50)	VSV(n = 50)	P
Gender (male/female)	30:20	26:24	0.57
Age (yrs.)	46.4± 19.3	45.0 ±18.2	0.79

PSV, pressure support mode; VSV, volume support mode

In Table 2, the variables of systolic blood pressure, diastolic blood pressure, mean arterial pressure, oxygen saturation and ABG findings during the hours 1 to 6 connected to the ventilator and at 12, 18 and 24 hours after connection to mechanical ventilation were compared in the two groups. Repeated Measures ANOVA showed that the effect of time (*P*=0.60) and group (*P*=0.21) on systolic blood pressure were not significant. The effect of time on diastolic blood pressure was not significant (*P*=0.68) but the effect of group on diastolic blood pressure was significant (*P*=0.01) so that

the average diastolic blood pressure in the VSV group had increased over time, but in the PSV group, there was no significant change. ANOVA test with repeated observations showed that the effect of time on mean arterial blood pressure was not significant (*P*=0.61) but the effect of group was significant on the mean arterial blood pressure (*P*=0.04) as the mean of arterial blood pressure in the VSV group had increased over time, but in the PSV group, there was no significant change. The effect of time on the mean arterial blood pressure was not significant (*P*=0.61) but the effect of group was

significant on the mean arterial blood pressure ($P=0.04$) as the mean arterial blood pressure in the VSV group had increased with time, but in the PSV group, there was no significant change. ANOVA test with repeated observations showed that the effect of time ($P=0.005$) and group ($P=0.03$) on arterial blood pressure ($P=0.04$) was significant, as the mean arterial blood pressure decreased

in two groups over time. This decrease was more in the PSV group than in the VSV group. The effect of time ($P=0.005$) and group ($P<0.001$) was significant on oxygen saturation. In other words, the average oxygen saturation changed over time, but this change in the PSV group was significantly more than the VSV group (Table 2).

Table 2. Comparison of hemodynamic changes over time in both groups

Time(hr.)	VSV(Mean±SD)	PSV(Mean±SD)		P	
Systolic Blood Pressure					
1	126.4	21.7	123.3	19.9	0.21
2	127.0	20.8	120.7	20.6	
3	128.3	20.3	121.8	21.9	
4	129.2	20.0	121.5	22.2	
5	129.9	18.5	118.3	19.6	
6	129.8	18.4	122.4	20.9	
12	129.2	17.9	123.1	23.3	
18	128.7	17.5	123.7	24.1	
24	128.8	17.4	121.6	23.1	
diastolic blood pressure					
1	83.6	9.5	79.6	15.3	0.01
2	84.9	10.1	77.6	16.7	
3	84.6	10.2	78.1	17.6	
4	85.1	9.4	77.1	16.3	
5	86.7	9.1	74.8	14.5	
6	87.9	8.1	77.4	14.6	
12	88.2	7.4	78.2	15.6	
18	87.8	7.5	79.2	17.3	
24	87.3	7.9	77.8	15.5	
Mean arterial blood pressure					
1	97.9	14.9	94.1	16.5	0.04
2	98.9	12.8	91.9	17.8	
3	99.2	12.7	92.7	18.7	
4	99.8	12.2	91.9	17.9	
5	101.1	11.3	89.3	16.4	
6	101.9	10.7	92.4	16.2	
12	101.9	10.1	93.3	17.8	
18	104.1	9.9	94.0	19.2	
24	101.1	10.1	92.4	17.7	
Heart rate					
1	101.8	8.6	101.9	16.9	0.03
2	100.8	7.2	100.1	15.6	
3	99.7	6.8	102.1	15.1	
4	98.7	6.4	97.6	15.3	
5	98.3	6.5	96.7	16.3	
6	99.3	16.3	94.1	18.9	
12	98.4	16.7	90.6	18.9	
18	97.5	17.0	83.4	24.7	
24	98.2	16.4	84.2	17.3	
oxygen saturation					
1	97.3	1.9	94.8	3.8	<0/001
2	97.5	1.3	94.8	3.7	
3	97.4	1.5	94.6	3.1	
4	97.6	1.5	94.8	2.8	
5	97.7	1.1	93.9	2.8	
6	97.8	0.8	93.4	3.1	
12	97.7	0.8	93.4	2.9	
18	97.8	1.1	94.1	3.1	
24	97.9	0.7	94.9	3.3	

PSV, pressure support mode; VSV, volume support mode.

VSV vs. PSV in patients admitted to ICU

The results of Table 3 shows the changes in ABG results. The analysis of variance with repeated observations showed that the effect of time ($P=0.50$) and group ($P=0.61$) on pH were not significant. In other words, there was no significant change in the average pH in neither of the two groups over time. Analysis of variance with repeated observations showed that the effect of time ($P=0.43$) and group ($P=0.61$) on PCO₂ were not significant. Analysis of variance with repeated observations showed that the effect of time on PAO₂ was

not significant ($P=0.32$), but the effect of group on PAO₂ was significant ($P<0.001$) as average PAO₂ in the VSV group had increased over time, but in the PSV group, there was no change at all, and the increases and decreases were sinusoids in this group. Analysis of variance with repeated observations showed that the effect of time ($P=0.44$) and group ($P=0.91$) on HCO₃ were not significant. In other words, the average HCO₃ in neither of the two groups had significant changes over time. These changes are also shown in (Table 3).

Table 3. Comparison of Arterial pressure changes over time in two groups

Time(hr.)	VSV(Mean±SD)	PSV(Mean±SD)	P		
Mean of PH					
1	7.40	0.05	7.38	0.07	
2	7.27	0.59	7.37	0.06	
3	7.39	0.05	7.36	0.07	
4	7.29	0.61	7.36	0.05	
5	7.30	0.61	7.36	0.05	0.61
6	7.30	0.61	7.37	0.06	
12	7.31	0.61	7.36	0.06	
18	7.30	0.61	7.36	0.07	
24	7.40	0.05	7.37	0.07	
Mean of PCO₂					
1	42.2	4.8	41.8	6.2	
2	42.3	4.6	41.1	5.5	
3	42.2	4.1	41.5	6.7	
4	42.2	4.4	42.9	7.8	
5	41.0	4.4	41.6	6.9	0.61
6	41.5	4.3	41.9	9.3	
12	41.8	4.2	43.6	8.3	
18	41.4	4.1	42.6	9.3	
24	40.9	4.3	44.1	8.1	
Mean of PAO₂					
1	83.4	12.6	99.2	20.1	
2	82.6	11.1	98.1	17.3	
3	82.6	10.7	97.3	18.3	
4	83.8	9.3	102.4	16.2	
5	83.2	8.8	101.2	15.1	<0.001
6	84.9	13.6	101.2	26.4	
12	86.4	15.1	95.1	14.8	
18	85.9	15.3	103.6	18.4	
24	86.5	16.2	99.7	15.2	
Mean of HCO₃					
1	23.2	3.2	23.2	2.8	
2	22.9	3.1	23.2	2.8	
3	22.8	2.9	23.1	3.1	
4	23.6	2.4	22.4	3.4	
5	23.3	2.4	22.4	3.5	0.91
6	23.5	2.5	23.3	4.1	
12	23.4	2.4	23.1	4.6	
18	23.4	2.4	22.9	4.7	
24	22.1	2.9	23.5	4.2	

PSV, pressure support mode; VSV, volume support mode

Table 4 shows that there was no significant difference between the two groups in terms of SOFA score and doses

of sedation required ($P>0.05$). This is while the duration of connection to the ventilator, the duration of intubation, and the duration of hospitalization in the VSV group was significantly lower ($P<0.05$). (Table 4).

In addition, the assessment of sedation based on the RAMSY scale showed a more desirable condition in the volume support mode compared with the pressure support mode at all evaluated times ($P<0.05$) (Table 5).

Table 4. Comparison of two modes of VSV and PSV in terms of SOFA, the dose of sedative drugs used and the index related to the duration of MV use

Variable		VSV(Mean±SD)		PSV(Mean±SD)		P
SOFA		13.1	4.8	12.9	3.9	0.89
Doses of sedative	Morphine	9.8	4.9	11.1	1.7	0.31
	Midazolam	9.1	5.1	10.5	1.9	0.24
Duration of connection to ventilator(day)		4.9	2.9	7.4	5.1	0.035
Intubation duration (day)		3.8	2.5	7.9	5.4	0.001
Hospitalization Duration (day)		7.7	3.9	10.7	6.7	0.03

PSV, pressure support mode; VSV, volume support mode; SOFA, Sequential Organ Failure Assessment; MV, Mechanical Ventilation

Table 5. Frequency Distribution of RAMSY sedation scale each hour in the first 6 hours in the two groups

Time(hr.)	score	VSV n (%)		PSV n (%)		P
1	1	14	56	2	8	<0.001
	2	7	28	12	48	
	3	4	16	6	24	
	4	0	0	5	20	
2	1	17	68	3	12	<0.001
	2	6	24	11	44	
	3	2	8	6	24	
	4	0	0	5	20	
3	1	16	64	3	12	<0.001
	2	8	32	14	56	
	3	1	4	5	20	
	4	0	0	3	12	
4	1	20	80	9	36	<0.001
	2	5	20	8	32	
	3	0	0	6	24	
	4	0	0	2	8	
5	1	21	84	10	40	<0.001
	2	4	16	8	32	
	3	0	0	6	24	
	4	0	0	1	4	
6	1	23	92	8	32	<0.001
	2	2	8	10	40	
	3	0	0	6	24	
	4	0	0	1	4	
12	1	22	88	12	48	0.002
	2	3	12	9	36	
	3	0	0	4	16	
	4	0	0	0	0	
18	1	23	92	16	64	0.02
	2	2	8	7	28	
	3	0	0	1	4	
	4	0	0	1	4	
24	1	23	92	18	72	0.03
	2	2	8	6	24	
	3	0	0	1	4	
	4	0	0	0	0	

PSV, pressure support mode; VSV, volume support mode

Discussion

Although mechanical ventilation in recent decades has resulted in improved outcome in ICU patients and a significant reduction in mortality of hospitalized patients in the ICU, anesthesiologists have been encountered with new issues associated with mechanical ventilation. One of these complications includes ventilator-associated pneumonia, excessive need for sedatives, and finding the right time for weaning from a ventilator. In this regard, a variety of ventilation modes have been introduced, which have both advantages and disadvantages, and studies to evaluate and compare these modes such as VSV and PSV are continued.

In this study, patients requiring ICU hospitalization after surgery with the indications of the use of both VSV and PSV modes were evaluated. The two groups did not have a significant statistical difference in terms of demographic information. Thus the likely confounding role of age and sex factors were eliminated. Comparison of the two groups in terms of hemodynamic changes showed the significant advantage of VSV mode while comparing the two groups in terms of ABG showed that there was no significant difference between the two, and even the difference observed in the PAO_2 was in normal range, which means that both modes showed patients' normal status. Other benefits of VSV over PSV include time indexes including intubation duration, mechanical ventilation length and hospitalization in the ICU. Although the two groups were the same in terms of receiving the sedative dose of morphine and midazolam, in terms of the RAMSY scale, VSV showed a better measure of the need for sedation.

Sancar *et al.*, conducted a study consistent with the findings in this study. They indicated that variables related to time indicators in patients ventilated by VSV were better than PSV. According to this study, weaning in VSV was significantly earlier and easier than PSV. In addition, the number of people who needed sedation during mechanical ventilation in VSV was less than PSV (11).

The findings were emphasized in the study by Fathi *et al.*, as patients with chronic obstructive pulmonary disease (COPD) who underwent coronary artery bypass under VSV ventilation, were weaned significantly earlier than the group under PSV ventilation (14).

Cassina *et al.*, in a study conducted in 2003, showed that during open-heart surgery (CABG), 86% of patients under VSV ventilation were successfully weaned within 6 hours with an average of 3.6 hours (15).

In two separate studies, Petter *et al.*, (16) and Sulzer *et al.*, (17) compared volume and pressure modes; they also produced similar results based on earlier weaning in VSV.

The certain fact in relation to the duration of ventilation is increased mortality after long-term ventilation (18) and since approximately 40% of the time of mechanical ventilation is allocated to weaning, finding ways to minimize the period required for mechanical ventilation and easiest approach to weaning have the highest value (18,19). In the VSV mode, you can create a constant tidal volume (TV) despite intermittent changes in alveolar pressure to prevent atelectasis. This is while in this method, volutrauma may occur due to increased pressure (20).

Another important factor was to evaluate the use of sedation, which was significantly less needed in patients ventilated with VSV. Other studies have shown that this is significantly related to weaning duration (11). The hypothesis may also be true in the case of the present study. The significant point that must be considered, on the other hand, is the relationship between sedation and weaning; since the use of painkillers and sedatives makes weaning from the ventilator difficult (21). Chanques *et al.*, reported this in their study of mechanical ventilation with PSV mode (22). Moreover, Strom *et al.*, in their study on critically ill patients, made the statement that the use of sedation in these patients led to faster and easier weaning (23).

Use of VSV mode showed better results in four dimensions: faster and easier weaning, shorter length of hospital stay, minimal hemodynamic changes, and less need for sedation in comparison with PSV mode.

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