Original Article

The Effect of Switching from Volume-Controlled to Pressure-Controlled Ventilation on Respiratory Distress and Asynchrony Index Improvement among Mechanically Ventilated Adults

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Abstract

Background: It is important to synchrony the time, intensity, and respiratory signal of the phrenic nerve between the patient and the ventilator. This study aimed to evaluate the effect of switching from volume-controlled to pressure-controlled ventilation on respiratory distress and asynchrony index improvement.

Materials and Methods: In this randomized controlled clinical trial, 70 patients admitted to the intensive care unit under mechanical ventilation were included. Asynchronous evaluation was performed by examining the patient and evaluating and analyzing the graphic flow curve and ventilator pressure, which included trigger and flow asynchronous and asynchronous cycling. In the intervention group, the mode of ventilation was switched to PSIMV such that peak inspiratory pressures would be equivalent to positive end-expiratory pressure (PEEP) in the volume-controlled mode. Finally, again at 60, 75, and 90 min, information about the ventilator and the patient's symptoms, and arterial carbon dioxide levels were sent by arterial gas sample. The asynchronous index was also recorded in both groups.

Results: This study showed that the mean of variables such as height, ideal body weight, tidal volume, set rate; Sense, FiO_2, PEEP did not differ significantly between the two groups. The mean of asynchrony was significantly reduced in both control group (16.51 ± 3.35–14.51 ± 2.90; $P < 0.001$) and intervention group (18.26 ± 6.13–13.32 ± 5.53; $P < 0.001$).

Conclusion: Regardless of the type and severity of the disease, switching the ventilation mode from volume-controlled to pressure-controlled can improve patient adaptation to the ventilator, especially in cases with frequent asynchrony.

Keywords: Asynchrony, mechanical ventilation, pressure-controlled, respiratory distress, volume-controlled

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Introduction

Intensive Care Units (ICUs) require highly experienced medical staff and special equipment to provide critical care to patients who need constant monitoring and support. Today, many hospitals have an ICU, but these units are expensive to operate and maintain.[1] One of the most commonly provided cares in the ICUs is respiratory care. Considering the type of patients usually admitted to ICUs, it is a basic but critical ICU practice to use mechanical ventilation to improve oxygenation and reduce

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the arterial CO_2 pressure of the patients. Typically, the purpose of mechanical ventilation is not to treat lung disease but rather to give patients the artificial ventilation and oxygenation and the respiratory support that they need until the underlying factors are identified and eliminated.[2,3] During mechanical ventilation, ventilator settings are adjusted to synchronize its cycles with the patient's breathing and the phrenic nerve breathing signal. The more synchronized the ventilator with the patient, the more efficient and comfortable the ventilation will be.[4] Mechanical ventilation is designed based on the basic principles and concepts of respiratory physiology, and is typically either pressure-controlled or volume-controlled. The ventilation of each of the pressure-controlled and volume-controlled modes has its own advantages and disadvantages, which would make it difficult to call either one clearly superior to the other.[5] In Volume-Controlled Ventilation (VCV), the flow rate is constant and this may cause patient-ventilator asynchrony (PVA). In this mode of ventilation, the inspiratory flow pattern can be constant (square waveform) or decelerating (descending ramp/sinus waveform), and the inspiratory time is determined by the peak and pattern of the inspiratory flow and the tidal volume (VT). In Pressure-Controlled Ventilation (PCV), the administered pressure to the airway is constant. In this mode of ventilation, the inspiratory flow has a descending pattern and is determined by ventilator settings, airway resistance, and lung compliance. In this mode, VT is also determined by respiratory compliance, airway resistance, the set pressure, and the set rise time. Having variable flow in PCV will improve the patient-ventilator synchrony.[6-8] While patient-ventilator asynchronies are very common, they are highly underdiagnosed. In a study on mechanically ventilated patients in ICUs, the overall frequency of asynchronous breaths was 23% and 93% of the patients had at least one incident of asynchrony. PVA should be treated when the asynchrony index (AI), which shows the ratio of the number of asynchronous breaths to the total number of breaths, rises above 10%. PVAs increase the need for sedatives and decrease the quality of sleep. The signs of these asynchronies appear in the ventilator's respiration graphs.[9,10] PVAs can be detected by aggressive monitoring such as esophageal and gastric pressure monitoring, but clinicians can also identify them by the much less invasive method of observing the flow and pressure curves in ventilator graphics.[11,12] Patient-ventilator synchrony can lead to higher rate of patient's comfort and satisfaction. However, this synchrony is so complicated and can be affected by ventilator settings, the kind of ventilator, patient-ventilator interactions, the medications and the sedative drugs the patient is taking, and the type of disease. Airway pressure measurements and ventilator graphics are reliable methods for determining PVAs. There is also a clear relationship between PVA and diaphragmatic dysfunction, period of mechanical ventilation, and the duration of stay in ICU.[9,13,14] Robinson *et al*. indicated that the incidence of PVA was higher in trauma patients under synchronized intermittent mandatory ventilation (SIMV) than spontaneous ventilation and reported that PVAs can increase the duration of mechanical ventilation.[15] A research by Luo *et al*. reported that SIMV and Assist Control ventilation (AC) improved the oxygenation index but did not change asynchrony and the need for sedation.[16] Chacko *et al*. reported that patients under PCV had lower mortality and morbidity rates than those under VCV and they also had better compliance.[5] Tassaux *et al*. also reported better patient-ventilator synchrony and respiratory drive under Adaptive Support Ventilation (ASV) rather than Pressure Support-SIMV (PS-SIMV).[17] Reviewing and examining the high prevalence of PVA in ICUs and the limited number of studies on the subject, the present study investigated the effect of switching the control mode of ventilator from volume-controlled to pressure-controlled on respiratory distress and AI in mechanically ventilated adults.

Materials and Methods

This haphazard controlled clinical trial was performed on 70 mechanically ventilated adult patients. The sample size of 70 patients (35 patients in each group) was selected by simple random sampling technique from the mentioned population according to the sample size formula for between-group comparisons at 95% confidence interval, 80% test power, and considering the mean of AI (22 ± 7 and 17 ± 3) in previous studies[17] in the two groups. The inclusion criteria: 30–45 years old, being under V-SIMV, and having respiratory distress. The exclusion criteria: needing to switch the mode of ventilation in <1 h, drop in blood pressure and arterial oxygen saturation, hemodynamic instability, endotracheal tube extubation, and patient's dissatisfaction.

The study was begun after getting approval from the ethics committee of Isfahan University of Medical Sciences (IR. MUI. MED. REC.1398.079) and registering the research plan on the Iranian Registry of Clinical Trials (IRCT20190117042390N1). The participants were chosen through using convenience sampling method from the patients admitted to the ICU of Al-Zahra Hospital (Isfahan, Iran). The patients were assigned to two groups of intervention and control by lottery while keeping the groups balanced in terms of disease severity as indicated by the Sequential Organ Failure Assessment (SOFA) score [Figure 1]. Respiratory distress was diagnosed by clinical observation and examination according to the standard definitions (tachypnea, intercostal retraction, cyanosis, nasal flaring, sweating). PVA was diagnosed by examining the patient and checking the ventilator flow and pressure graphics and was classified into four types: auto-triggering, double triggering, ineffective effort, and premature/delayed cycling.

First, ventilation data (peak flow, VT, SR, Sense, FiO_2, and positive end-expiratory pressure [PEEP]) of all the patients were collected. The AI, static compliance, airway resistance, and average airway pressure were also recorded in a checklist designed for this purpose. The heart rate, systolic and diastolic blood pressures, and arterial oxygen saturation were also determined. Furthermore, arterial blood samples were gathered and sent to the laboratory to measure arterial CO_2.

The AI[10] was defined by the number of asynchrony events divided by the total respiratory rate computed as the sum of the number of ventilator cycles (patients-triggered) and of wasted efforts: AI (expressed in percentage) = number of asynchrony events/total respiratory rate (ventilator cycles × ineffective triggering) ×100. As previously reported,[10] a high incidence of asynchrony was defined as an AI >10% [Figure 2].

In the next step, the necessary therapeutic measures for the treatment of respiratory distress and asynchrony, such as sedation (if necessary) and change in ventilation settings (Sense, Rise Time, RR, PEEP, FiO_2), were taken. In the intervention group, the mode of ventilation was switched to PSIMV such that peak inspiratory pressures would be equivalent to P peak-PEEP in the volume-controlled mode. The patient was then monitored for on1 h. Upon observing increased respiratory distress, decreased saturation, or

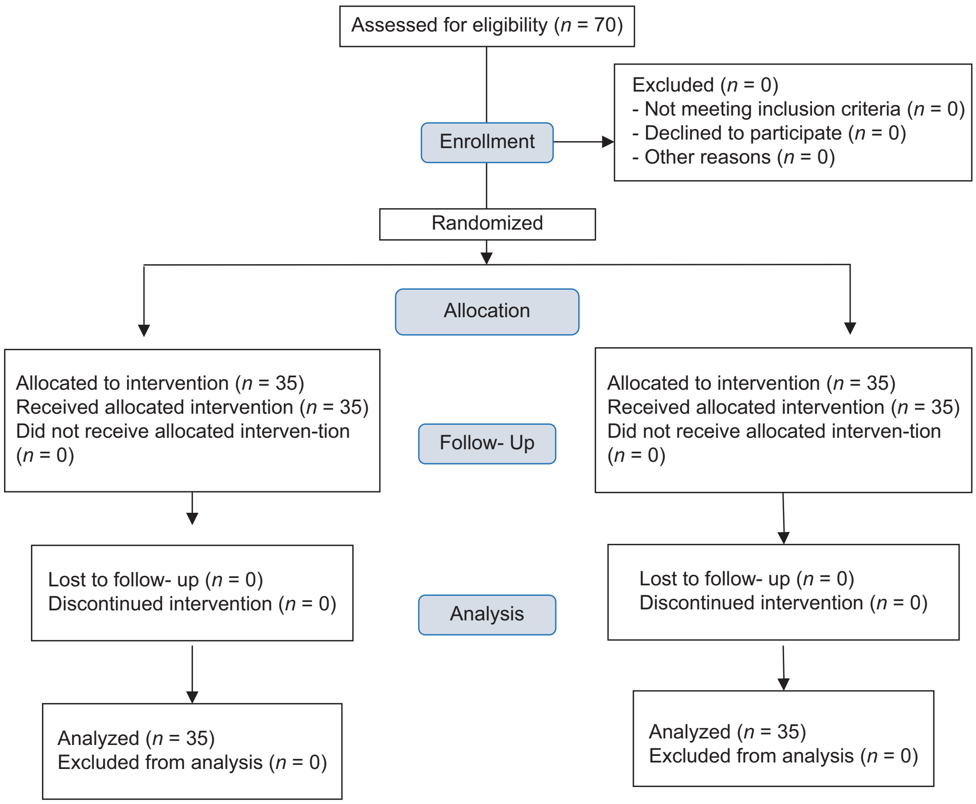

Figure 1: Consort flowchart of patients

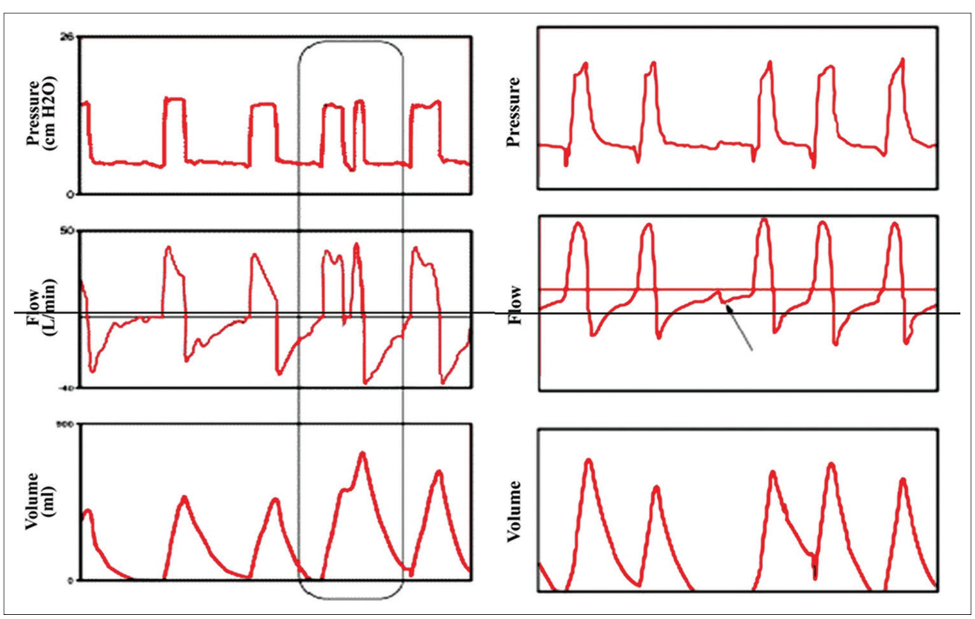

Figure 2: Asynchrony in ventilator algorithm

arrhythmia during this 1-h period, the mode of ventilation was switched back and the patient was excluded from the study. At the end of this period, ventilation data (static compliance, airway resistance, and average airway pressure), vial and essential signs (heart rate, blood pressure, arterial oxygen saturation), and arterial CO_2 were recorded again and the AI was determined. The amount of consumed sedative drugs were also recorded and compared.

The collected data were analyzed using SPSS software (version 25; SPSS Inc., Chicago, Ill., USA). The quantitative and qualitative data were indicated as mean ± standard deviation and frequency (percentage), respectively. Statistical analyses were carried out using independent t-test, paired t-test, and Cohen's effect size. In all analyses, the level of statistical significance was considered to be < 0.05.

Results

From the 70 studied subjects in two groups, 40 (57.1%) were male and 30 (42.9%) were female. The mean age in the intervention group was 55.26 ± 21.62 years and in the control group was 62.63 ± 15.83 years ($P = 0.112$). The mean of SOFA score in the treatment group was 12.74 ± 2.09 and in the control group was 12.00 ± 1.88 ($P = 0.123$).

Independent *t*-test showed that there was no significant difference between the two groups in terms of mean of ideal body weight ($P = 0.323$), height ($P = 0.278$), VT ($P = 0.743$), SR ($P = 0.390$), Sense ($P = 0.737$), FiO2 ($P = 0.510$), and PEEP ($P = 1.00$) [Table 1].

Before the intervention, the mean of asynchrony in the intervention group was 18.26 ± 6.13 and in the control group was 16.51 ± 3.35. However, the mean of asynchrony in the intervention group was higher than the control group, the independent *t*-test indicated that the difference was not statistically significant ($P = 0.144$). After the intervention, the mean of asynchrony in the intervention group was 13.32 ± 5.53 and in the control group was 14.51 ± 2.90. Again, independent *T*-test showed that although the mean of asynchrony in the intervention group was greater than the control group, the difference was meaningless ($P = 0.265$). In the control group, the mean of asynchrony was changed from 16.51 ± 3.35 in the first stage to 14.51 ± 2.90 in the second stage; paired *t*-test indicated that the difference was significant ($P < 0.001$, Cohen's effect size = 0.638). In the intervention group, the change in the mean of asynchrony from 18.26 ± 6.13 in the first stage to 13.32 ± 5.53 in the second stage was statistically significant too ($P < 0.001$, Cohen's effect size = 0.846). The change in the AI of the treatment group was higher than the control group ($P < 0.265$) [Table 2].

Table 1: The mean of age, height, sequential organ failure assessment score, ideal body weight, tidal volume, set rate, sense, FiO_2, and positive end-expiratory pressure in the two groups of control and intervention

Variable	Intervention group (*n*=35)	Control group (*n*=35)	*P**
Age (years)	55.26±21.62	62.63±15.83	0.112
Height (cm)	170.26±6.72	168.23±8.59	0.278
SOFA score	12.74±2.09	12.0±1.88	0.123
IBW (kg)	63.09±6.55	61.20±8.85	0.323
VT (cc/kg)	433.14±57.23	428.29±66.04	0.743
SR	10.60±2.17	11.06±2.25	0.390
Sense	2.40±0.64	2.46±0.77	0.737
Fio_2	50.09±9.76	50.00±14.05	0.510
PEEP (cm H2O)	6.00±1.61	6.00±1.91	1.00

*Independent *t*-test. SOFA: Sequential organ failure assessment, VT: Tidal volume, IBW: Ideal body weight, SR: Set rate, PEEP: Positive end-expiratory pressure

Discussion

This study was aimed to examine the effect of switching the control mode of ventilation from volume-controlled to pressure-controlled on the improvement of respiratory distress and AI in mechanically ventilated adults. The results of the present study showed that, in both the intervention and the control groups, AI was decreased significantly between the two stages of measurement, but the decrease was greater in the intervention group than the control group. In a study conducted by Robinson *et al*. on the incidence of PVA and its types in trauma patients, they found that asynchrony is more common in trauma patients under SIMV and could increase the duration of mechanical ventilation.[15] In another study, Luo *et al*. compared the effectiveness of SIMV and AC ventilation in patients with ARDS, ultimately finding that SIMV improved the oxygenation index but made no change in the need for sedation and the incidence of PVA.[16] In a study by Chacko *et al*. where they compared the effects of volume-controlled and pressure-controlled modes of ventilation in ARDS patients, the results showed lower mortality and morbidity rates and better compliance in patients under pressure-controlled ventilation.[5] Tassaux *et al*. compared the effects of PS-SIMV and ASV on asynchrony and found that the patients under ASV had better patient-ventilator synchrony and respiratory drive.[17]

PVA is a usual phenomenon in critically ill patients admitted to ICUs. It can be defined as incoordination between the patient's respiratory demands and the ventilator settings and functional characteristics.[18] Recently, a new classification of PVA has been introduced as high respiratory drive or low respiratory drive.[19,20]

Dres *et al*. explained that in case of high respiratory drive, it is essential to determine whether asynchronies (flow starvation, premature cycling, double triggering/breath stacking) are due to inadequate ventilator aids and unmatched needs or caused by the patient's acute illness and should therefore be treated with additional sedation.[19] In extreme cases, PVA related to decreased respiratory drive (reverse triggering phenomenon and resultant double cycling, delayed cycling, ineffective efforts) may be attributable to separate mechanisms like sedation or over-assistance.[20] Before each breath, the ventilator needs to create a particular pattern of control and phase variables. The

Table 2: Comparing the asynchrony index between the intervention and the control groups in the pre- and postintervention stages

Variable	Group	Before	After	Mean difference	Cohen effect	*P***
Asynchrony index	Control	16.51±3.35	14.51±2.90	2.00±1.51	0.638	<0.001
	Intervention	18.26±6.13	13.32±5.53	4.79±4.09	0.846	<0.001
*P**		0.144	0.265			

*Independent *t*-test, **Paired sample *t*-test

conditional variables determine what decisions make about the pattern or specification to be used. In ventilation modes such as CMV and PCV, this pattern is kept constant, and therefore, all breaths are based on the same control variable. But unlike CSV (continuous spontaneous ventilation), in which we can only control pressure (as it is spontaneous ventilation and breathing cycle trigger with patient effort), in CMV, we can choose between pressure control and volume control. Also, since SIMV is a combination of forced and spontaneous breathing, the ventilator must decide when to offer a different pattern for each one. Hence, in SIMV, we have to choose a control variable for forced breathing (pressure or volume), whereas the controlled variable in spontaneous breathing will always be the pressure. This shows that inconsistent control variables may be applied in SIMV (for example, volume in forced respiration and pressure in spontaneous respiration, or pressure for both types of respiration).[21] According to the results of another study, the best approach to managing asynchronies was by adjusting ventilator settings. Proportional modes improved patient-ventilator coupling, resulting in greater comfort and less dyspnea.[22]

At present, there is not sufficient evidence to claim or confirm that one method is superior to the others. The benefits of each method rely on the kind and clinical condition of the patient, the accessible equipment, and the preferences and proficiency of the medical and nursing staff. In general, it may be acknowledged that PCV is especially beneficial in two conditions: (1) when a patient needs a protective ventilation plan with specific pressure limitation, and (2) when a patient has poor compatibility with the ventilator. However, the decision must always be made on based on the cased and the mentioned factors. Epidemiological research studies of mechanical ventilation around the world have indicated that VCV is used more frequently than other modes of ventilation (60% of total mechanical ventilation time). Furthermore, it is claimed that this frequency of use is independent of the type of disease (whether COPD or ARDS).[23] Nevertheless, contemporary suggestions for optimal mechanical ventilation are to use a lung protection strategy by limiting VT to < 6 ml/kg of ideal body weight, plateau pressure of < 30, and early and aggressive PEEP to maintain lung volume at the end of exhalation.[24] The aim of this strategy is to make sure adequate (if not necessarily normal) gas exchange, minimize barotrauma and volutrauma to the lungs, prevent hemodynamic deterioration and preserve right ventricular function, avoid biotrauma and spread of lung damage, and help to minimize the need for sedation.[25,26] These goals can be achieved by using pressure-controlled method or at least using slow and variable flow patterns.[21]

Therefore, although the small sample size of the study is among the limitations of this study, comparison of AI between VCV to PCV modes, regardless of the type and severity of the disease, can be considered as one of the strengths and innovations of this study.

Conclusion

The results of the present study recommend that regardless of the type and severity of the disease, switching the ventilation mode from volume-controlled to pressure-controlled can improve patient adaptation to the ventilator, especially in cases with frequent asynchrony.

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Conflicts of interest

There are no conflicts of interest.

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