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Original Article

Comparison of respiratory and hemodynamic stability in patients with traumatic brain injury ventilated by two ventilator modes: Pressure regulated volume control versus synchronized intermittent mechanical ventilation

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Abstract

Background: This study aimed to compare pressure regulated volume control (PRVC) and synchronized intermittent mechanical ventilation (SIMV) modes of ventilation according to respiratory and hemodynamic stability in patients with traumatic brain injury (TBI) admitted to Intensive Care Unit (ICU).

Materials and Methods: In a randomized, single-blinded, clinical trial study, 100 patients who hospitalized in ICU due to TBI were selected and randomly divided into two groups. The first and second groups were ventilated by PRVC and SIMV modes, respectively. During mechanical ventilation, arterial blood gas and respiratory and hemodynamic parameters were also recorded and compared between the two groups.

Results: According to the *t*-test, the mean rapid shallow breathing index (RSBI) after the first 8 h of mechanical ventilation was significantly higher in SIMV group compared with PRVC group (107.6 ± 2.75 vs. 102.2 ± 5.2, respectively, $P < 0.0001$). Further, according to ANOVA with repeated measures, the trend of RSBI changes had a significant difference between the two groups ($P < 0.001$). The trend of ratio of partial pressure arterial oxygen and fraction of inspired oxygen was different between the two groups according to Mann–Whitney–Wilcoxon test ($P < 0.001$).

Conclusions: Using PRVC mode might be more desirable than using SIMV mode in patients with TBI due to better stability of ventilation and oxygenating. To ensure for more advantages of PRVC mode, further studies with longer follow-up and more detailed measurements are recommended.

Key Words: Intensive care, mechanical ventilation, traumatic brain injury

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INTRODUCTION

About 10% of patients in Intensive Care Units (ICUs) require prolonged mechanical ventilation, and this group of patients allocates the most human and financial resources of the hospital.[1] Mechanical ventilation is a complex process including interactions

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between pressure, flow, volume, and time. In a simple classification, ventilation modes are classified into pressure control ventilation, volume control ventilation, or both. In volume mode, regardless of the pressure and airway resistance, a certain amount of volume is delivered to the lungs which may cause damages due to pressure or pneumothorax.[1,2] In contrast, pressure mode continues ventilation support to reach the predetermined pressure and prevents injuries caused by pressure; however, in the case of inappropriate volume, lungs may reach to the predetermined pressure too quickly, and the patient suffers from hypoventilation and respiratory acidosis.[3] Each of pressure or volume modes has its own advantages. Accordingly, to take advantage of the benefits of both modes, manufacturing companies have decided to design modes which have two pressure and volume control components in combination.[4,5]

In pressure regulated volume control (PRVC) mode which was introduced by Siemens Company, a certain volume is given to the patient. Thus, the device guarantees this volume by regulating pressure, i.e., the device may increase the pressure to achieve the desired volume. Advantages of this mode compared to the ventilation pattern with volume control are lower maximum inspiratory pressure, flow coordination of ventilation pattern, less manipulation of the device by operator, and automatic decease of ventilator support.[6-10] The clinical outcome of patients who have been treated by this mode has not been well examined. Therefore, this study was designed to compare two PRVC and synchronized intermittent mechanical ventilation (SIMV) modes in terms of sedation, ventilation weaning, and hemodynamic stability in patients with traumatic brain injury (TBI) admitted to ICU.

MATERIALS AND METHODS

After approval of Medical Ethics Committee of the Isfahan University of Medical Sciences (Research Project No: 3940940) and taking patients' family informed consent, this single-blind, random, clinical trial study was conducted. The study population consisted of patients with TBI who required mechanical ventilation. Inclusion criteria included lack of history of chronic obstructive pulmonary disease or addiction to opioids or sedative drugs or alcoholism. Exclusion criteria consisted of patient's death or discharged 24 h before admission to ICU.

Using the formula for estimating the sample size, the sample size was determined as 43 patients in each group to compare the means which have been listed below and by considering the level of confidence of 95%, test power of 80%, standard deviation of sedation score estimated about 1.33, and least significant difference in sedation score in the studied groups considered 0.8; 50 patients were studied in each group. Randomization of patients to each group was done by random allocation software with simple randomization method.

All patients were ventilated by MEDEC ventilator (Medec Benelux NV, Belgium). The parameters of ventilator were adjusted on SIMV mode for the first group and PRVC mode for the second group. Monitoring of patients including pulse oximetry, electrocardiogram monitoring, and noninvasive systolic, diastolic, and mean blood pressure monitoring was checked in the two groups.

Sedation of patients in ICU was done by intravenous (IV) administration of 2 mg morphine and 2 mg midazolam, and then 2 mg/IV/PRN as morphine and midazolam, based on Richmond agitation-sedation scale of 2 or more. During ventilation, arterial blood gas was controlled and recorded at admission to ICU and then once daily or PRN in other situations. Respiratory parameters which were measured included spontaneous tidal volume (TV), respiratory rate (RR), rapid shallow breathing index (RSBI), and ratio of partial pressure arterial oxygen and fraction of inspired oxygen (PaO_2/FiO_2 ratio). All respiratory and hemodynamic parameters were recorded at every 8 h by the anesthesia assistant from admission to ICU until 80 h and registered in the questionnaire.

Data were analyzed by SPSS software (version 22.0, IBM Corp., Armonk, NY, USA) using the Chi-square, *t*-test, Mann–Whitney U-test, and ANOVA with repeated measures.

RESULTS

In this study, 106 patients with TBI who required mechanical ventilation and admitted to ICU were randomized into two groups of SIMV and PRVC modes. Six patients were excluded due to death at first 24 h in ICU [Figure 1].

In Table 1, the distribution of demographic variables of patients in both groups has been shown. According to Table 1, the distribution of age and sex had no significant difference in the two groups. In Figures 2-7, the mean hemodynamic and respiratory parameters in the two groups have been shown. According to ANOVA with repeated measures, systolic, diastolic, and mean blood pressure, RR, and SPO_2 had a significant difference in the two groups; however, the heart rate was not different between the two groups.

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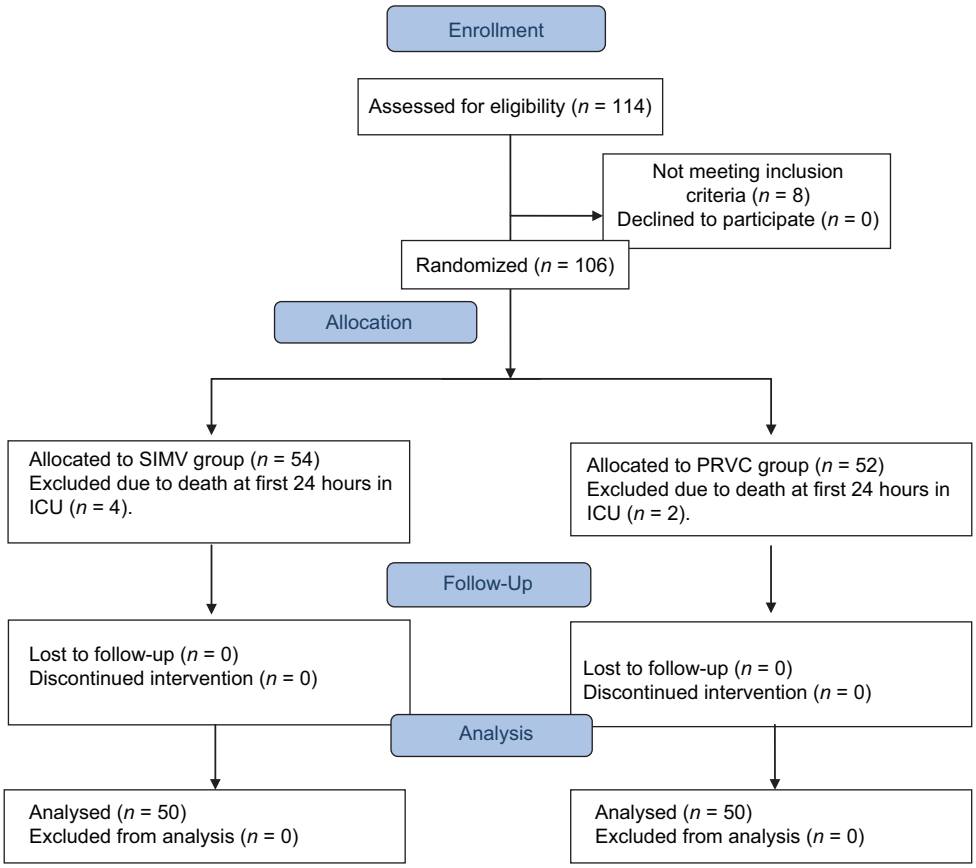

Figure 1: CONSORT flow diagram

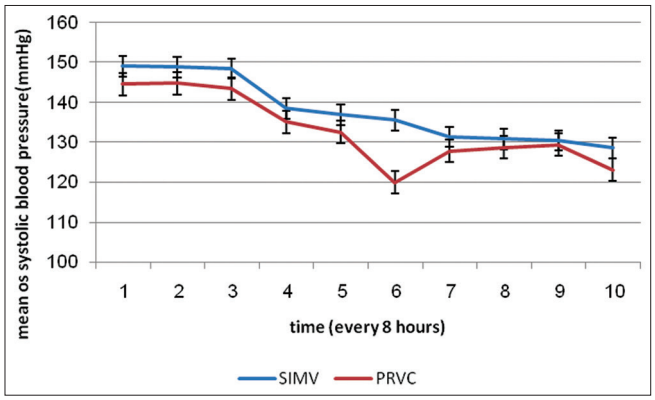

Figure 2: Mean systolic blood pressure per 8 h in both groups ($P = 0.018$)

The results of the respiratory parameters during the study period have been shown in Table 2. According to the *t*-test, the mean RSBI after the first 8 h of mechanical ventilation was significantly higher in SIMV group at different times. Further, according to ANOVA with repeated measures, the trend of RSBI changes was significantly different in the two groups ($P < 0.001$).

The investigation of PaO_2/FiO_2 ratio in most of measurement times did not show significant difference between the two groups according to the *t*-test.

Table 1: Distribution of demographic variables in both groups

Variables	Group		
	SIMV*	PRVC#	*P*
Age (year)	36.8±12.4	38.5±14.4	0.52
Sex			
Male	31 (62)	33 (66)	0.68
Female	19 (38)	17 (34)	

Data are shown as mean±SD or number (%). *SIMV: Synchronized intermittent mandatory ventilation, #PRVC: Pressure regulated volume control, SD: Standard deviation

However, the trend of changes indicated that the overall level of PaO_2/FiO_2 ratio was higher in PRVC group according to Mann–Whitney–Wilcoxon test ($P < 0.001$) [Figure 8].

DISCUSSION

No single mechanical ventilation mode has ideally been established for ventilating patients with TBI. In this study, we evaluated the respiratory and hemodynamic parameters in 100 patients with TBI who required mechanical ventilation. According to the results of our study, 80 h control of the most important respiratory parameters including RSBI and PaO_2/FiO_2 ratio showed that the overall level of PaO_2/FiO_2 ratio was superior with PRVC mode of ventilation compared

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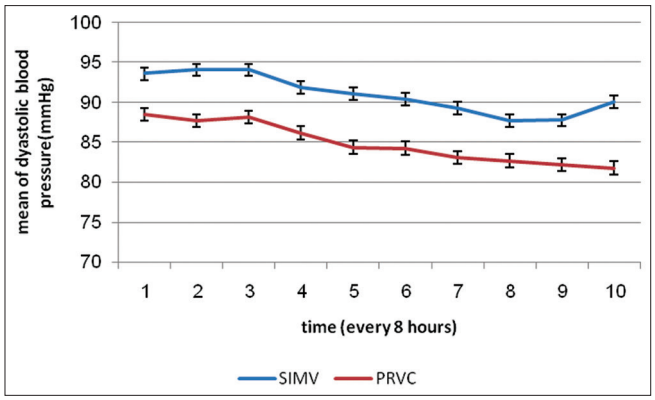

Figure 3: Mean diastolic blood pressure per 8 h in both groups ($P < 0.001$)

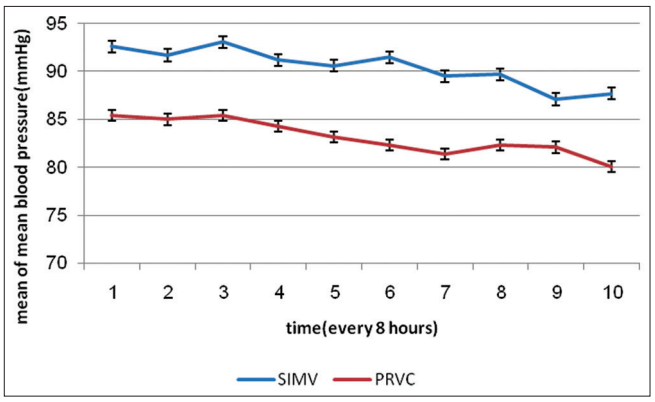

Figure 4: Mean arterial pressure per 8 h in both groups ($P < 0.001$)

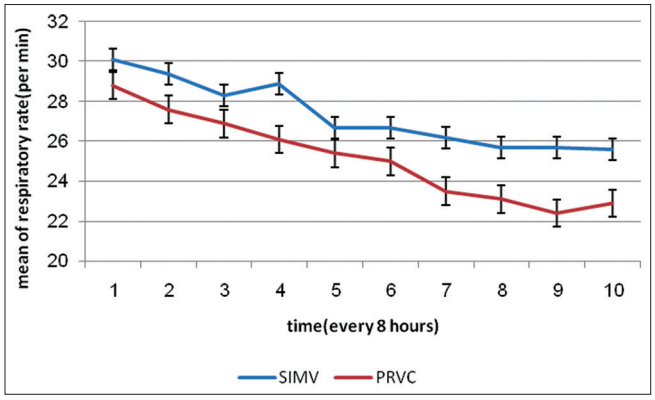

Figure 5: Mean respiration rate per 8 h in both groups ($P < 0.001$)

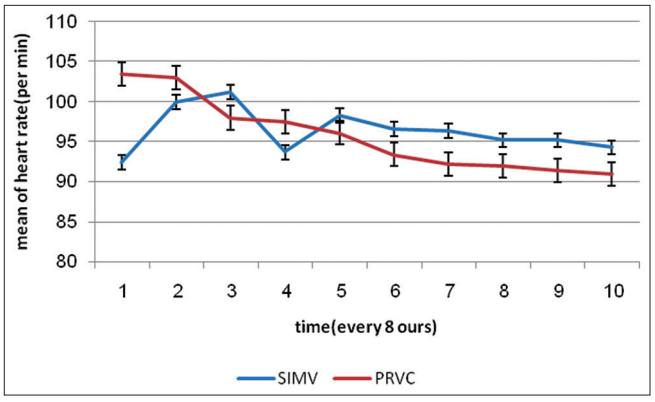

Figure 6: Mean heart rate per 8 h in both groups ($P = 0.53$)

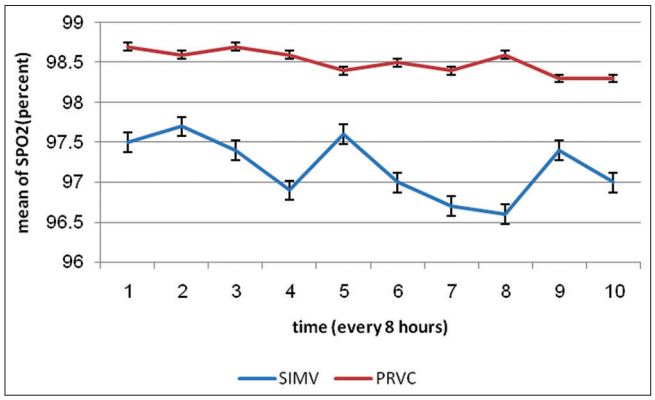

Figure 7: Mean SPO_2 per 8 h in both groups ($P < 0.001$)

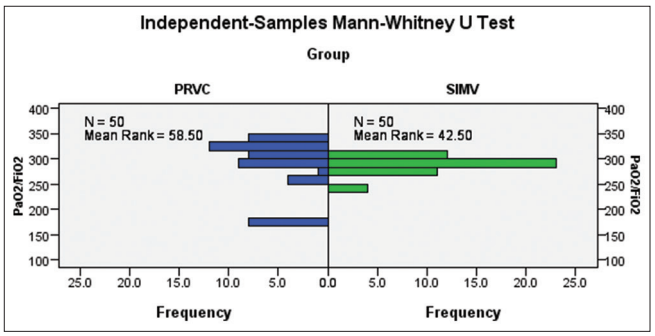

Figure 8: Overall level of partial pressure arterial oxygen and fraction of inspired oxygen ratio in the two study groups (the overall level was higher in pressure regulated volume control group compared to synchronized intermittent mandatory ventilation group according to Mann–Whitney–Wilcoxon test, $P < 0.001$)

to SIMV mode. In addition, respiratory effort and hemodynamic stability were in a better situation in PRVC mode.

Some studies have so far been conducted on the advantages of PRVC mode compared to other modes of mechanical ventilation. In the study by Schirmer-Mikalsen *et al*., patients with TBI ventilated by PRVC mode had less fluctuation in intracranial pressure (ICP) and $PaCO_2$ compared to pressure control mode. However, mean ICP and $PaCO_2$ were not different between the two groups.[11] Although in an experimental work using ventilation simulations, using PRVC mode was not considered to provide appropriate TVs for severely obstructed patients;[12] in other situations such as postcardiac surgical patients, oxygenation index has been superior in PRVC mode of ventilation in recovery period.[13] Other pressure modes of mechanical ventilation may have better patient-ventilator synchrony and adequate gas exchange and less ventilator-induced lung injury.[5,14-16]

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Table 2: Comparison rapid shallow breathing index and PaO_2/FiO_2 ratio in synchronized intermittent mandatory ventilation and pressure regulated volume control groups at different times

Time*	Groups					
	RSBI			PaO_2/FiO_2 ratio		
	SIMV	PRVC	*P*	SIMV	PRVC	*P*
1	123±6.1	123±15.1	0.97	271.8±52.7	273.6±43.1	0.85
2	121.3±9.8	115.7±12.9	0.016	262.6±39.9	279±41.4	0.046
3	119±6.9	109.9±8.4	<0.001	267.2±39.4	277.9±52.6	0.25
4	113.1±11.2	105.7±8.8	<0.001	300.4±36.5	277.7±56.9	0.018
5	105.7±7.7	102.4±8.1	0.038	296.4±26.3	284.6±59.8	0.21
6	93.7±24.9	96.5±5.2	0.43	298.3±23.3	285.6±64.9	0.2
7	102.3±3.8	93.5±6.6	<0.001	296.9±22.6	290.4±72.8	0.55
8	99.7±4.5	92.7±6	<0.001	297.6±30.3	300±64.5	0.81
9	969.2±2.9	91.9±4.8	<0.001	296±63.2	309.6±67.4	0.3
10	99±3.1	90.6±4.2	<0.001	296.8±63.4	308.4±61.9	0.36
P	<0.001#			<0.001##		

Data are shown as mean±SD. *Times of measurement are every 8 h from admission to ICU until 80 h, #According to ANOVA with repeated measures, ##According to Mann–Whitney–Wilcoxon test. SIMV: Synchronized intermittent mandatory ventilation, PRVC: Pressure regulated volume control, ICU: Intensive Care Unit, SD: Standard deviation, PaO_2: Partial pressure arterial oxygen, FiO_2: Fraction of inspired oxygen

CONCLUSION

In the present study, monitoring hemodynamic parameters during the first 80 h after ICU admission revealed better blood pressure levels, indicating lower sympathetic stimulation in PRVC ventilation mode. On the other hand, patients under ventilation with PRVC mode had fewer RRs and better SPO_2 compared to other group.

One limitation of our study was that the patients were not completely followed until extubation and discharge from the ICU because of long duration of ICU stay in head trauma patients. Therefore, duration of intubation and mechanical ventilation was not evaluated and recorded. Furthermore, other respiratory parameters such as lung compliances and airway pressures can be evaluated in future studies.

According to the obtained results, using PRVC mode may be more desirable than using SIMV mode in patients with TBI due to better respiratory and hemodynamic stability.

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Conflicts of interest

There are no conflicts of interest.

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