Comparison of Volume Support, Volume-Assured Pressure Support, and Spontaneous Modes in Postoperative Early Extubated Patients

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Abstract

Background: This study aimed to compare respiratorily, arterial blood gas (ABG), and hemodynamics parameters among patients undergoing surgery who were admitted to intensive care unit (ICU), using three ventilation modes, including volume-assured pressure support (VAPS), volume support (VS), and spontaneous modes.

Materials and Methods: One hundred and thirty-two patients were randomly assigned into three groups of VAPS, VS, and spontaneous modes utilizing randomized block procedure. Patients were followed between 12 and 30 h until extubation. Respiratory parameters including; peak inspiratory pressure (PIP), static compliance, resistance, rapid shallow breathing index (RSBI), and P 0.1(P0.1 correlates with respiratory drive and is defined as the negative pressure measured at the airway opening 100 ms after the initiation of an inspiratory effort), along with ABG parameters including; pH level, $PaCO_2$, HCO_3, PaO_2/FiO_2 ratio, extra hydrogen ion, and hemodynamics parameters including; mean arterial blood pressure and heart rate were measured every 3 h and compared among groups.

Results: All studied parameters in three groups improved during the study. PIP, Resistance, PH, HCO_3, extra hydrogen ion, PCo_2, PaO_2/FiO_2 ratio, mean arterial blood pressure were similar among the three groups in most of the time points ($P > 0.05$). In most of the time points, RSBI (from 92.7 to 55.4), P 0.1 (from 6.8 to 1.7) in the VAPS group, static compliance (from 55.3 to 55.7) in the VS group, and heart rate (from 108.5 to 90.1) in spontaneous groups were significantly better than other modes ($P < 0.05$). Changes in RSBI, *P* 0.1, PCo_2, HCO_3, and heart rate during the study were significantly different among studied groups ($P < 0.05$). The length of stay in the ICU in patients who underwent VAPS was significantly shorter than the other modes.

Conclusions: VAPS mode with better effects or at least as effective as VS and spontaneous modes could be select as the best mode of ventilation in postoperative early extubated patients admitted to ICU.

Keywords: Mechanical ventilation, spontaneous, volume support, volume-assured pressure support

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Submitted: 12-Feb-2021; **Revised:** 02-Apr-2021; **Accepted:** 12-Sep-2021; **Published:** 28-Nov-2022

Introduction

Respiratory protection using mechanical ventilation devices has a critical role in patients admitted to intensive care units (ICU) or acute respiratory problems. Mechanical ventilation is based on a series of principles based on the basic concepts of respiratory physiology and basic concepts and complex processes, including interactions between pressure, flow, volume, and time.[1,2] Mechanical ventilators offer many different ventilation modes, depending on the patients' breathing status.[3] In general, mechanical ventilation

Access this article online	
Quick Response Code:	**Website:** www.advbiores.net
	DOI: 10.4103/abr.abr_27_21

How to cite this article: Abbasi S, Alikiaii B, Kashefi P, Haddadzadegan N. Comparison of volume support, volume-assured pressure support, and spontaneous modes in postoperative early extubated patients. Adv Biomed Res 2022;11:99.

is typically performed in pressure control ventilation or volume control ventilation. In pressure control ventilation mode, continuous ventilation support reaches the predetermined pressure and prevents injuries caused by pressure. In volume control ventilation mode, a certain amount of volume is delivered to the lungs, which may lead to injuries from pressure pneumothorax.[4]

The development of mechanical ventilation technology has led to rising complexity. Along with the advantages and disadvantages of both pressure and volume control ventilation modes, it is impossible to select one mode as a routine method. Combining the two pressure and volume control ventilation modes was designed and developed to combine the advantages and overcome the disadvantages of these approaches.[5] These combination modes, so-called hybrid modes, are designed to prevent lung damage, more patient coordination, ventilation, improved oxygenation, and easier extubation. On the other hand, selecting the inappropriate model to longer ventilation time, longer hospitalization, more sedatives, risk of infection, and more expenses for patients and the healthcare system. The best mode must be selected based on the patient's clinical status.[6,7]

Volume-assured pressure support (VAPS) mode, as a hybrid model, has been developed to ensure a more consistent tidal volume while delivering the comfort and advantages of pressure support ventilation. If the expected tidal volume is not achieved, the ventilator will change from the pressure mode to volume mode to reach the target volume.[8] VAPS targets an average tidal volume over several breaths. Typically, the target tidal volume is set based on 6–10 mL/kg ideal body weight. It calculates the average PS provided to the patient over the prior 2 min to achieve a particular tidal volume.[9]

Volume support (VS) mode ventilation is a spontaneous mode where a target goal volume is set on the ventilator. This ventilatory strategy is dependent on patients spontaneously breathing and triggering (or activating) the ventilator to support the breath. The respiratory rate is fully dependent on the patient. Spontaneous ventilation is a patient-triggered, pressure-limited, flow-cycled mode in which airway pressure is maintained constant during the whole inspiration, and when inspiratory flow reaches a certain threshold level, the cycling from inspiration to expiration occurs.[10]

On the other hand, the use of hybrid modes has been studied. The studies reported different findings along with the fact that most studies focused on ventilation time, early extubation, and reduction of ICU stay.[11-18] Remarkably, no studies on the effects of VAPS mode on respiratory and hemodynamics parameters have yet been performed in patients undergoing surgery and who need mechanical ventilation. The present study aimed to compare respiratory and hemodynamic parameters in patients undergoing surgery and were admitted to ICU, using three ventilation modes, including VAPS, VS, and spontaneous modes.

Materials and Methods

Study design and setting

In this randomized clinical trial, the study population included all patients who underwent surgery that required mechanical ventilation and were admitted to ICU in Al Zahra Hospital in Isfahan, Iran, recruited from April to July 2020. Of this population, according to the results of previous study[14] based on the mean ± standard deviation (SD) of rapid shallow breathing index (RSBI) in the two groups equal to 119 ± 6.9 and 109.9 ± 8.4, 95% confidence interval (CI) level and 80% test power, 44 people in each group have been assigned.

Inclusion and exclusion criteria

Inclusion criteria were as follows age between 18 and 70 years, body mass index lower than 30, no need to receive neuromuscular blocker in ICU, expected duration of ventilation between 12 and 72 h, stable hemodynamic without using vasopressor drugs, and no history of pulmonary surgery. Exclusion criteria were pregnancy, acute renal failure (normal blood urea nitrogen, creatinine, and electrolyte), no chronic respiratory disease, and addiction. Furthermore, patients who died and those withdrawn from the ICU before 12 h were excluded from the analysis.

Randomization

First, eligible patients will be simple randomly selected. Then they will be divided into three groups of 44 using the random block method with 3 blocks. So that the first three cases are separated and assigned to group one, the second three cases are separated and assigned to group two, then the next three cases are separated and assigned to group three, and this will be continued in the same way till the ending of samples.

Intervention

Following approval of this study given by the Medical Ethics Committee of Isfahan University of Medical Sciences (IR.MUI.MED.REC.1397.033). Eligible admitted patients to ICU were receive mechanical ventilation with SIMV mode, and respiratory parameters were set as follow; tidal volume = 6–8 ml/kg, respiratory rate = 12–14 bpm, and RR/VT = 60–105 bpm/L; also, FiO_2 was adjusted automatically to reach a target oxygen saturation measured by pulse oximetry more 88%. Therefore, mechanical ventilation was followed until it would be found that the patient could be under the studied modes according to the checklist to identify candidates for a spontaneous breathing trial. After that, patients were randomly assigned to one of the three studied modes and were followed (at least 12 h) until extubation. Studied groups included 44 patients in VS mode, 44 patients in VAPS mode, and 44 patients in spontaneous.[16] Patients in three studied groups were sedated using intravenous administration of 2 mg of morphine and 2 mg of midazolam, and then 2 mg of morphine and midazolam at intervals of at least 2 h if was required, to reach a target patient's sedation level between −1 and −2 based on Richmond criteria.[19] The Richmond Agitation and Sedation Scale is a validated and reliable scale used to measure the agitation or sedation level of a patient. It is mostly used in mechanically ventilated patients to avoid over and under sedation.[20] Besides, all patients were monitored with a C2 mechanical ventilation device.

Main outcomes

The present study's main outcomes were respiratory mechanics, arterial blood gas (ABG), and hemodynamics parameters, collected every 3 h in all patients for at least 12 h and a maximum of 30 h. Studied respiratory mechanics were peak inspiratory pressure (PIP), Static compliance, resistance, RSBI, and *P* 0.1(P0.1 correlates with respiratory drive and is defined as the negative pressure measured at the airway opening 100 ms after the initiation of an inspiratory effort). Studied ABG parameters were pH level, $PaCO_2$, HCO_3, PaO_2/FiO_2 ratio, and extra hydrogen ion. Besides, studied hemodynamics parameters were mean arterial blood pressure and heart rate. ABG analysis was collected every 3 h and analyzed in a reference laboratory to measure ABG analysis in each patient.

Statistical analyses

Statistical analyses were carried out by IBM SPSS Statistics version 26 (IBM SPSS Statistics Corp., Armonk, NY, USA). Data were express as mean (SD) and frequency (%) for numeric and categorical variables, respectively. The normality of the distribution of numeric variables was assessed by the Shapiro–Wilk test and verified by distribution measures, including skewness (within ± 1.5) and kurtosis (within ± 2). The results confirmed the normality of almost all variables. We compared the distribution of sex and age across groups using the Chi-squared test with the exact procedure or one-way analysis of variance (ANOVA) followed by Tukey's *post hoc* test.

The baseline comparisons of main variables were conducted using one-way ANOVA followed by Tukey *post hoc* tests. Besides, the main variables' measurements in other time points were compared using analyses of covariance (ANCOVA) by controlling over baseline measures and sex and age of participants as the covariates across groups followed by Sidak *post hoc* tests when ANCOVA showed significant results. Two-way ANOVAs with repeated measures were used to test the measurements (time trend) effect, group effect, and possible interactions and followed by Sidak *post hoc* tests, considering which of the effects mentioned above were significant.

Results

Participants' recruitment

Of 158 assessed patients for eligibility in our study, 26 patients (19 not eligible and 7 patients refused consent) were not included. One hundred and thirty-two eligible patients were randomly assigned in three studied groups and were followed for at least 12 h and a maximum of 72 h. All studied patients in three groups completed a follow-up period (at least 15 h). All the patients in the VAPS group were discharged from the ICU after 21 h, whereas some patients in both VS and spontaneous groups were staying in the ICU after 30 h of follow-up [Figure 1].

Participants' sex and age distribution

The sex distribution was similar among the three studied groups ($P = 0.623$). However, the age distribution showed significant difference across groups ($P < 0.001$), so that the VAPS mode had a lower mean compared to VS mode (mean difference: −6.5 and 95% CI: −10.0–−3.0, $P < 0.001$) and Spontaneous mode (mean difference: −3.9 and 95% CI: −7.4–−0.4, $P = 0.026$) according to the Tukey *post hoc* test [Table 1].

Respiratory mechanics parameters

Table 2 shows the results of respiratory mechanics. According to the GreenhouseGeiser test for PIP levels, the interaction effect was not significant, so the trend of changes was not significantly different across groups ($P = 0.064$). However, regarding the group main effect, the differences among groups were significant in each time point ($P < 0.05$) but not in the baseline measurements ($P = 0.535$). VS mode has a lower compliance level than the VAPS and Spontaneous modes in all time points. Whereas, concerning the measurement's main effect, the trend of changes during the follow-up period was not significant ($P > 0.05$), such that negligible changes were observed in each group [Table 2]. Furthermore, the interaction effect was significant for the resistance level, so changes were significantly different across groups ($P < 0.001$). The decreasing trend was steeper in VAPS mode than the two other groups, which showed similar decreasing trends [Table 2]. Moreover, the interaction effect was significant for RSBI, so changes were significantly different across groups ($P < 0.001$). The decreasing trend was steeper in VAPS and spontaneous modes than the VS mode [Table 2]. Regarding the group's main effect, the differences among groups were significant in all of the time points ($P < 0.05$) but not in T9, with VAPS mode showed lower RSBI than the other two groups but not in baseline T3. Besides, concerning the measurement's main effect, the trend of changes during the follow-up period was significant ($P < 0.001$), so that a decreasing trend was observed in all groups [Table 2]. The decreasing trend was steeper in VAPS mode than the two other groups, which showed similar decreasing trends [Table 2]. Regarding the group main effect, the differences among groups were significant in all of the time points ($P < 0.05$) with VAPS mode showed lower P0.1 level than the other two groups in T9 time point and over.

Arterial blood gas parameters

Table 3 presents the results of ABG parameters. According to the Greenhouse-Geiser test for PH levels, the interaction effect was not significant, so the trend of changes was not significantly different across groups ($P = 0.932$). Regarding the group main effect, the differences among groups were not significant at any time point ($P > 0.05$). PH levels, after some raises and falls, remained stable around 7.4 in all groups [Table 3]. Furthermore, the interaction effect was significant for PCO_2, so changes were significantly different across groups ($P = 0.049$). There are many ups and downs in

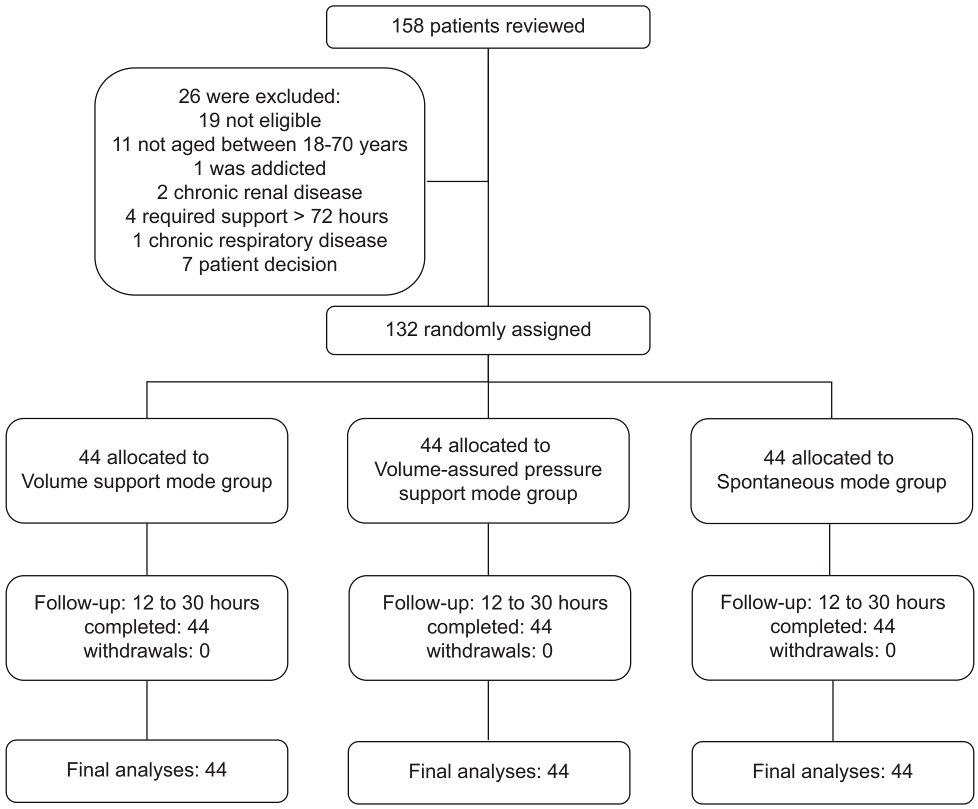

Figure 1: Consort flow diagram of the study progress

Table 1: Sex and age distribution of participants across groups

Variable	VS mode (*n*=44)	VAPS mode (*n*=44)	Spontaneous mode (*n*=44)	*P*#
Sex (male), *n* (%)	19 (43.2)	23 (52.3)	24 (54.5)	0.623
Age (year)	60.8±4.4	54.4±8.6	58.3±7.2	<0.001

#Based on Chi-squared exact procedure or one-way analysis of variance. VS: Volume support, VAPS: Volume-assured pressure support

each group and finally remained between 38 and 40 [Table 3]. Regarding the group main effect, the differences among groups were not significant in all points ($P > 0.05$) except for the T6 time point with spontaneous mode showed higher PCO_2 than the other two groups. In addition, concerning the measurement's main effect, the trend of changes during the follow-up was significant only for VS mode [$P = 0.022$; Table 3]. However, as shown in Table 3, there is no clear decreasing/increasing trend for this variable. However, the interaction effect was not significant for HCO_3, so the trend of changes was not significantly different across groups ($P = 0.567$). The values of HCO_3 changed between 22 and 27 in all groups [Table 3]. Regarding the group main effect, the differences among groups were not significant in all points ($P > 0.05$) except for baseline time point with spontaneous mode showed lower HCO_3 values than the other two groups. Besides, concerning the measurement's main effect, the trend of changes during the follow-up was not significant in any group [$P > 0.05$; Table 3]. Nonetheless, the interaction effect was not significant for extra hydrogen ions, so the trend of changes was not significantly different across groups ($P = 0.447$). The extra hydrogen ion values changed between around −0.5 and 4 in all groups [Table 3]. Regarding the group main effect, the differences among groups were not significant at any time points ($P > 0.05$). Also, concerning the measurement's main effect, the trend of changes during the follow-up period was not significant in any group [$P > 0.05$; Table 3]. Nevertheless, the interaction effect was significant for PaO_2/FiO_2 ratio, so changes were significantly different across groups ($P = 0.027$). The values of PaO_2/FiO_2 ratio in VAPS mode, after a raise, felled to around 380, in the VS mode, the values go upward to reach around 380, and in the spontaneous group, it oscillates around this value [Table 3]. Regarding the group main effect, the differences among groups were significant only in baseline and T6 time points ($P < 0.05$). Besides, concerning the measurement's main effect, the trend of changes during the follow-up period was not significant in any group [$P > 0.05$; Table 3].

Hemodynamics parameters

The analysis of hemodynamics parameters presented in Table 4 exhibited the interaction effect not being significant for mean arterial blood pressure, so the trend of changes failed to be

Table 2: Comparison of respiratory mechanics parameters across groups

Respiratory mechanics parameters	VS mode (*n*=44)	V[A]PS mode (*n*=44)	Spont[a]neous mode (*n*=44)	*P*[#]
PIP (cm H_2O)				
Baseline	23.2±8.0[a]	22.6±7.2[a]	24.4±7.3[a]	0.535
3	20.8±7.4[a]	20.2±6.2[a]	20.4±7.6[b]	0.035
6	20.9±8.9[a]	17.5±5.6[b]	18.9±6.2[b,c]	<0.001
9	19.4±6.2[a]	16.7±5.3[b]	17.9±5.6[b,c]	0.004
12	18.7±6.2[a]	16.5±5.1[b]	18.2±5.1[a]	0.036
15	18.8±5.9[a]	16.1±4.8[b]	18.0±5.5[b,c]	0.004
18	18.8±5.8[a]	16.2±5.5[b]	17.7±5.0[a,b]	0.025
P[$]	**<0.001**	**<0.001**	**<0.001**	
Static compliance				
Baseline	55.3±8.6[a]	58.1±6.4[a]	59.1±7.1[a]	0.052
3	55.9±8.1[a]	58.7±9.2[a]	59.1±6.3[a]	0.250
6	56.3±7.2[a]	57.8±10.5[a]	59.0±5.7[a]	0.877
9	55.8±6.6[a]	60.4±6.9[b]	58.6±5.6[a,c]	0.004
12	55.3±7.2[a]	60.6±6.1[b]	59.2±4.7[b]	0.001
15	55.7±6.9[a]	60.5±5.6[b]	60.1±6.0[b]	0.004
18	55.7±7.0[a]	60.3±5.9[b]	60.6±4.3[b]	0.009
P[$]	**<0.001**	**<0.001**	**<0.001**	
Resistance				
Baseline	7.8±2.5[a]	10.7±1.3[b]	7.8±2.2[a]	<0.001
3	7.0±2.3[a]	8.5±1.8[b]	6.8±1.8[a,c]	0.009
6	6.4±2.1[a]	7.9±1.5[a]	6.2±1.8[a]	0.689
9	5.9±2.0[a]	6.7±1.8[b]	5.5±1.9[a]	0.006
12	5.7±1.9[a]	6.3±2.0[b]	5.5±1.9[a]	0.015
15	4.5±1.8[a]	6.1±1.8[a]	5.1±2.0[a]	0.208
18	4.9±1.6[a]	6.1±1.9[a]	4.9±1.9[a]	0.913
P[$]	**<0.001**	**<0.001**	**<0.001**	
RSBI				
Baseline	83.4±18.2[a]	92.7±21.6[b]	101.0±15.0[c]	<0.001
3	78.2±15.7[a]	78.1±22.1[a]	86.9±20.0[b]	0.018
6	74.9±16.8[a]	71.7±20.6[a]	80.6±23.5[b]	0.025
9	68.7±20.6[a]	66.4±19.7[a]	76.5±19.2[a]	0.142
12	70.5±15.6[a]	60.4±18.2[b]	70.7±18.1[a]	<0.001
15	66.8±15.2[a]	58.7±18.3[b]	67.3±17.6[a]	<0.001
18	64.1±17.1[a]	55.4±15.4[b]	67.7±16.6[a]	0.001
P[$]	**<0.001**	**<0.001**	**<0.001**	
P. 01				
Baseline	5.8±1.2[a]	6.8±2.1[b]	4.6±2.4[c]	<0.001
3	5.1±1.3[a]	4.6±1.9[a], c	3.9±2.0[c]	0.032
6	4.7±1.3[a]	3.3±1.8[b]	3.7±2.0[b]	0.003
9	4.2±1.2[a]	2.4±1.4[b]	3.0±1.3[c]	<0.001
12	3.9±0.8[a]	2.0±1.2[b]	2.9±1.5[c]	<0.001
15	3.8±0.8[a]	1.9±1.1[b]	2.6±1.1[c]	<0.001
18	3.7±0.8[a]	1.7±1.1[b]	2.5±1.2[c]	<0.001
P[2]	**<0.001**	**<0.001**	**<0.001**	

[#]Based on one-way ANOVA for baseline comparison and baseline-, age- and sex-adjusted ANCOVA for other time points, [$]Based on repeated measures analysis of variance within each group (after Greenhouse-Geiser correction). Different letters in each row indicate the significant differences between groups (P<0.05), P values are shown in bold for significant results, Data are expressed as mean±SD. PIP: Peak inspiratory pressure, RSBI: Rapid shallow breathing index, SD: Standar deviation, VS: Volume support, VAPS: Volume-assured pressure support, ANOVA: Analysis of variance, ANCOVA: Analysis of covariance

significantly different across the groups ($P = 0.205$). The mean arterial blood pressure values reduced in a similar pattern in all groups [Table 4]. With regard to the group main effect, differences among the groups proved significant at T15 and T18 time points ($P < 0.05$) with VS mode bearing higher mean arterial blood pressure than the other two protocols and the VAPS mode demonstrating the lowest values. In addition, given the measurement's main effect, the trend of changes during the follow-up period turned not to be pointintsignificant in any group [$P > 0.05$; Table 4].

Table 3: Comparison of arterial blood gas parameters across groups

Arterial blood gas parameters	VS mode (*n*=44)	VAPS mode (*n*=44)	Spontaneous mode (*n*=44)	*P*#
pH (mol/L)				
Baseline	7.4±0.05[a]	7.4±0.05[a]	7.3±1.1[a]	0.463
3	7.4±0.05[a]	7.4±0.05[a]	7.1±1.5[a]	0.053
6	7.4±0.08[a]	7.4±0.06[a]	7.2±1.1[a]	0.270
9	7.3±1.0[a]	7.4±0.05[a]	7.2±1.1[a]	0.556
12	7.4±0.05[a]	7.4±0.05[a]	7.2±1.0[a]	0.377
15	7.4±0.06[a]	7.4±0.07[a]	7.4±0.05[a]	0.059
18	7.4±0.06[a]	7.4±0.05[a]	7.4±0.06[a]	0.067
P$	0.889	0.924	0.067	
PCO2 (mmHg)				
Baseline	42.1±7.9[a]	39.4±7.2[a]	36.3±9.6[b]	0.006
3	40.5±7.8[a]	40.2±7.9[a]	38.4±8.2[a]	0.907
6	36.4±8.8[a]	38.7±6.1[a], [b]	40.2±9.9[b]	0.027
9	40.5±7.0[a]	40.6±7.8[a]	38.9±9.3[a]	0.736
12	40.6±8.1[a]	40.8±8.3[a]	38.5±10.1[a]	0.665
15	38.0±9.0[a]	38.9±6.8[a]	39.8±9.3[a]	0.671
18	39.6±8.8[a]	39.1±5.3[a]	38.3±8.2[a]	0.821
P$	**0.022**	0.785	0.364	
HCO_3				
Baseline	25.9±4.2[a]	24.3±5.4[a]	22.5±5.7[b]	0.012
3	25.0±4.8[a]	25.3±4.6[a]	23.4±4.3[a]	0.452
6	24.4±5.5[a]	25.1±4.1[a]	24.6±6.1[a]	0.564
9	26.4±4.9[a]	26.2±6.1[a]	24.2±5.6[a]	0.434
12	26.3±5.5[a]	25.1±4.8[a]	24.0±5.2[a]	0.750
15	25.6±4.9[a]	25.5±4.3[a]	24.0±5.6[a]	0.433
18	26.3±5.6[a]	24.6±4.1[a]	23.8±5.4[a]	0.250
P$	0.508	0.482	0.408	
Extra hydrogen ion				
Baseline	1.6±4.1[a]	0.5±5.5[a]	−0.7±5.8[a]	0.103
3	1.3±4.1[a]	1.5±4.3[a]	−0.4±4.0[a]	0.167
6	0.9±4.4[a]	0.9±4.7[a]	1.0±5.0[a]	0.766
9	2.9±4.5[a]	1.7±5.1[a]	0.5±5.0[a]	0.168
12	2.6±4.9[a]	1.3±4.8[a]	0.5±4.6[a]	0.394
15	2.5±4.2[a]	1.3±4.2[a]	0.2±5.2[a]	0.107
18	2.5±5.1[a]	0.4±3.9[a]	0.4±0.5[a]	0.066
P$	0.169	0.717	0.304	
PaO_2/FiO_2 ratio				
Baseline	359.8±59.7[a]	392.3±50.9[b]	379.1±48.2[a,b]	0.019
3	359.9±47.9[a]	404.5±50.9[a]	384.9±54.3[a]	0.064
6	364.9±45.1[a]	405.2±57.9[b]	370.2±52.5[a]	0.038
9	370.2±44.1[a]	395.2±48.8[a]	384.1±40.9[a]	0.291
12	377.4±47.4[a]	386.1±48.9[a]	381.4±49.2[a]	0.746
15	375.8±36.1[a]	398.1±46.1[a]	390.5±48.0[a]	0.234
18	373.0±40.8[a]	395.1±34.8[a]	376.7±42.9[a]	0.419
P$	0.448	0.294	0.220	

#Based on one-way ANOVA for baseline comparison and baseline-, age- and sex-adjusted ANCOVA for other time points, $Based on repeated measures analysis of variance within each group (after GreenhouseGeiser correction). Different letters in each row indicate the significant differences between groups ($P<0.05$), *P* values are shown in bold for significant results, Data are expressed as mean±SD. VS: Volume support, VAPS: Volume-assured pressure support, SD: Standard deviation, ANOVA: Analysis of variance, ANCOVA: Analysis of covariance

On the other hand, the results disclosed the interaction effect being significant for the heart rate, that is, changes were significantly different across the groups ($P < 0.001$). Heart rate values diminished approximately with a similar pattern in VAPS and spontaneous modes, but it smoothed around 104 in the VS group after the T9 time point [Table 4]. In regard with the group's main effect, the differences among groups proved significant at all-time points ($P < 0.05$), yet not in T9, with the spontaneous mode showing the lowest heart rate and the VAPS mode revealing lower values than the VS mode

Table 4: Comparison of hemodynamics parameters across groups

Hemodynamics parameters	VS mode (*n*=44)	VAPS mode (*n*=44)	Spontaneous mode (*n*=44)	*P*[1]
Mean arterial blood pressure				
Baseline	96.3±11.5[a]	95.7±19.4[a]	96.3±10.3[a]	0.972
3	92.8±11.8[a]	90.8±13.8[a]	93.7±10.1[a]	0.527
6	91.7±11.1[a]	88.4±11.9[a]	90.5±9.8[a]	0.286
9	91.3±11.5[a]	86.4±16.1[a]	87.6±15.7[a]	0.234
12	88.4±17.2[a]	84.9±11.3[a]	88.3±9.0[a]	0.174
15	90.1±9.9[a]	85.0±11.8[b]	87.2±9.5[a]	0.017
18	90.3±11.5[a]	81.8±16.7[b]	85.1±10.4[a]	0.016
P[$]	**0.043**	**<0.001**	**<0.001**	
Heart rate (beats/min)				
Baseline	110.6±6.6[a]	113.9±7.1[b]	108.5±7.1[a]	0.002
3	109.1±7.1[a]	108.5±7.4[a]	102.7±6.4[b]	<0.001
6	105.7±6.6[a]	103.5±7.5[a]	99.1±10.2[b]	0.039
9	105.1±7.3[a]	102.6±9.8[a]	97.2±9.2[a]	0.080
12	103.8±6.9[a]	99.1±8.0[a]	94.5±10.2[b]	<0.001
15	103.2±8.3[a]	98.7±10.1[a]	93.0±10.1[b]	<0.001
18	103.5±10.6[a]	96.1±8.6[a]	90.1±8.3[b]	<0.001
P[$]				

[#]Based on one-way ANOVA for baseline comparison and baseline-, age- and sex-adjusted ANCOVA for other time points, [$]Based on repeated measures analysis of variance within each group (after GreenhouseGeiser correction). Different letters in each row indicate the significant differences between groups (*P*<0.05), *P* values are shown in bold for significant results, Data are expressed as mean±SD. VS: Volume support, VAPS: Volume-assured pressure support, SD: Standar deviation, ANCOVA: Analysis of covariance, ANOVA: Analysis of variance

after T9 time point. Besides, given the measurements' main effect, the trend of changes during the follow-up turned out to be significant in all groups ($P < 0.05$) so that on average, the heart rate decreased from around 110 at the baseline to 97 at T18 [Table 4].

Discussion

The present study results show that patients in the VAPS group had better outcomes than patients in VS and spontaneous groups. Studied parameters in all three groups were improved during the follow-up period. Among respiratory mechanics, patients in the VAPS group show significantly better RSBI and *P* 0.1 than patients in other studied groups during the study period. Of ABG and hemodynamics parameters, PCO_2, HCO_3, and heart rate in VAPS and VS groups were significantly better during the study compared to the spontaneous group. According to our study results, some important studied parameters were superior with VAPS mode of ventilation compared to other modes and with VS mode compared to spontaneous mode. Furthermore, the length of stay in the ICU in patients who underwent VAPS was significantly shorter than the other modes, lower than hours of follow-up. All the patients in the VAPS group were discharged from the ICU, but at the same time, nine patients in VS and nine patients in spontaneous groups stay in the ICU.

This study is the first one that has compared the respiratory, ABG, and hemodynamics parameters among three modes of mechanical ventilation, including VS, VAPS, and spontaneous modes in post-operative early-extubated patients admitted to ICU. PIP, resistance, RSBI, and *P* 0.1 with VAPS mode were better than VS and spontaneous modes. Static compliance with VS mode was better than the other modes. ABG parameters among the three studied modes were similar. Mean arterial blood pressure with VAPS mode and heart rate with spontaneous modes were better than the other modes. The shorter duration of ventilation was the other superiority of the VAPS mode compare to the other modes. These findings confirm the reported benefits of VAPS mode as a hybrid mode of ventilation. It is shown that the VAPS mode adjusts the PIP based on the patient's changing characteristics. Unlike other methods, in VAPS mode, manual titration of the inspiratory pressure is not required, and it will adjust automatically to achieve the set tidal volume.[21-23]

Three VS, VAPS, and spontaneous modes are not compared in previous studies. The concept of VAPS in different patients has been reported the earlier studies. In Amato *et al*. study, VAPS mode was compared with conventional volume-assisted mode. It showed that respiratory muscle workload was significantly reduced in the patients on VAPSV compared to conventional volume-assisted mode.[8] In Battisti *et al*., VAPS mode was compared with conventional pressure support in patients with acute respiratory failure. Their results indicated that $PaCO_2$ levels and pH in both studied modes improved. No significant differences were noted between groups.[24] In Briones Claudett *et al*., study, VAPS mode was compared with bi-level positive airway pressure in patients with acute, chronic obstructive pulmonary disease exacerbations. They showed that although both modes rapidly improved consciousness, the VAPS was more effective in lowering the PaCO2 levels and higher inspiratory airway pressure.[25] VAPS mode was compared with bi-level positive airway pressure in patients with the obesity-hypoventilation syndrome in some limited studies. These studies show that VAPS mode is at least as effective as bi-level positive airway pressure in improving $PaCO_2$ levels and nocturnal oxygenation in patients with chronic hypercarbia respiratory failure obesity-hypoventilation syndrome.[12,13,26] Overall, these findings show the VAPS mode's benefits compared to some other ventilation modes in different patients. Similarly, our findings show that VAPS mode has better results in some parameters on at least as effective as VS and spontaneous modes in some other parameters in postoperative early-extubated patients admitted to ICU.

There were several limitations to the study. First, this was a single-center that may affect external validity. Second, as with most studies on mechanical ventilation, it was impossible to blind the groups. Therefore, multicenter studies are needed to be done to clarify the differences between VAPS mode with better effects or at least as effective as VS and spontaneous modes of ventilation in ICU.

Conclusions

Our results indicated that VAPS mode with better effects or at least as effective as VS and spontaneous modes on respiratory, ABG, and hemodynamics parameters and shorter ventilation time could be selected as the best ventilation mode postoperative early extubated patients admitted to ICU.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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