Research Article

Comparison of patient-ventilator asynchrony during pressure support ventilation and proportional assist ventilation modes in surgical Intensive Care Unit: A randomized crossover study

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Abstract

Background: The patient-ventilator asynchrony is almost observed in all modes of ventilation, and this asynchrony affects lung mechanics adversely resulting in deleterious outcome. Innovations and advances in ventilator technology have been trying to overcome this problem by designing newer modes of ventilation. Pressure support ventilation (PSV) is a commonly used flow-cycled mode where a constant pressure is delivered by ventilator. Proportional assist ventilation (PAV) is a new dynamic inspiratory pressure assistance and is supposed to be better than PSV for synchrony and tolerance, but reports are still controversial. Moreover, most of these studies are conducted in chronic obstructive pulmonary disease patients with respiratory failure; the results of these studies may not be applicable to surgical patients. Thus, we proposed to do compare these two modes in surgical Intensive Care Unit (ICU) patients as a randomized crossover study. **Aims:** Comparison of patient-ventilator asynchrony between PSV and PAV plus (PAV+) in surgical patients while weaning. **Subjects and Methods:** After approval by the Hospital Ethics Committee, we enrolled twenty patients from surgical ICU of tertiary care institute. The patients were ventilated with pressure support mode (PSV) and PAV+ for 12 h as a crossover from one mode to another after 6 h while weaning. **Results:** Average age and weight of patients were 41.80 ± 15.20 years (mean ± standard deviation [SD]) and 66.50 ± 12.47 (mean ± SD) kg, respectively. Comparing the asynchronies between the two modes, the mean number of total asynchronous recorded breaths in PSV was 7.05 ± 0.83 and 4.35 ± 5.62, respectively, during sleep and awake state, while the same were 6.75 ± 112.24 and 10.85 ± 11.33 in PAV+. **Conclusion:** Both PSV and PAV+ modes of ventilation performed similarly for patient-ventilator synchrony in surgical patients. In surgical patients with acute respiratory failure, dynamic inspiratory pressure assistance modalities are not superior to PSV with respect to cardiorespiratory function.

Keywords: Patient-ventilator dyssynchrony, pressure support ventilation, proportional assist ventilation

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Introduction

The patient-ventilator asynchrony is the mismatching between patient's neural inspiratory drive and breath delivery by the ventilator. Alterations in respiratory drive, timing, respiratory muscle pressure, and respiratory system mechanics influence the interaction between the patient and the ventilator.[1] It is well known that patient-ventilator asynchrony affects adversely on lung mechanics, gas exchange, ventilator-induced lung injury, and ventilator-free days in Intensive Care Unit (ICU). Pressure support ventilation (PSV) is a commonly used flow-cycled mode for weaning in ICU. In PSV, the ventilator applies constant preset pressure for every detected patient's inspiratory effort.[2] Proportional assist ventilation (PAV) was developed as a mode to enhance ventilator responsiveness to patient's breathing effort. Like PSV, PAV uses a sensitive inspiratory set trigger in the form of negative pressure or flow, but unlike PSV that uses a clinician preset inspiratory pressure, PAV provides dynamic pressure in proportion to the patient's spontaneous breathing effort as determined by instantaneous feedback from an in-line pneumotachometer. In addition, cycling from inspiration to expiration is not dependent on a predetermined reduction in inspiratory flow. Rather PAV, when properly adjusted, terminates delivery of inspiratory assistance with cessation of inspiratory effort.[2,3] PAV plus (PAV+ in Puritan Bennett 840 ventilator range) is a commercially available implementation of PAV which automatically amplifies the patient's own spontaneous effort to breathe by increasing airway pressure during inspiration proportionally to a set amplification factor.

Although some studies have shown that PAV+ improves synchrony between patient and ventilator as compared to PSV, some other studies have challenged the superiority of PAV+.[4-6] Thus, to work on this controversy, so we studied these two modes as a crossover study.

Subjects and Methods

After approval by the Hospital Ethics Committee, the study was carried out in twenty surgical ICU patients of tertiary care institute. The written informed consent was obtained from patients' attendants. Patients with head injury, history of stroke/cerebrovascular accidents, having chronic obstructive pulmonary diseases (COPDs), and myopathies were excluded from the study to minimize bias. The patients were ventilated with pressure support mode (PSV) and PAV+ for 12 h as a crossover from one mode to another after 6 h. Order of ventilation modes was selected randomly once the patient started triggering all ventilator breaths on assist-control (A/C) ventilation. All patients were given analgesia and sedation using fentanyl 0.5 µg/kg/h by body weight through intravenous infusion and were sedated using midazolam infusion keeping sedation score of 3–5 on Ramsay scale at the start of the study. Ventilator settings depending on the mode and patient characteristics were chosen. Triggering was adjusted during sedation period to minimize ineffective breaths and auto triggering. Thereafter, 2 h before second recordings at 0400 h, midazolam infusion was stopped to awaken the patient. Recording was done at 0600 h, and ventilator mode was then changed to second study mode and sedation was stepped up to Ramsay scale 3 again. Recordings were done at 0700 and 1200 h again with and without sedation, respectively. Puritan Bennett 840 was used for the entire study. Pressure support in PSV was set to achieve a tidal volume of 6 ml/kg approximately. PSV cycling-off criterion was set at 20% of the peak flow. PSV rise time was set at 0 s. PAV+ was set to adjust work of breathing between 0.3 and 0.7 J/L. The ventilator settings other than FiO_2 and positive end-expiratory pressure were kept constant. In case of difficulty and failure to ventilate, patients were excluded from analysis. Average spirometric data were noted over ten consecutive breaths. The asynchrony was recorded visually on 10 min recordings of flow and airway pressure. In addition, ventilator graphics were recorded on video for 10 min for 0100, 0600, 0700, and 1200 h. These recorded videos were later analyzed to see the types of patient-ventilator asynchrony as described in Table 2. In addition to the above data, change in patient's hemodynamic data, spirometric data, and arterial blood gas was also recorded and analyzed.

Results

There was no dropout case during the entire study period because of failure to ventilate with either mode. Patient demographic, characteristics, and respiratory parameters are shown in tables and figures [Table 1, and Figure 1a, b]. Average age of patients was 41.80 ± 15.20 (mean ± standard deviation [SD]) years. Nearly 75% of patients were male. The weight of patients ranged between 40 and 90 kg with a mean of 66.50 ± 12.47(mean ± SD) kg.

The mean number of cycles studied in PSV was 254.50 ± 63.86 (mean ± SD) in sedated and 267.50 ± 65.20 (mean ± SD) in awake state and the difference was found to be statistically insignificant (P = 0.528). The same for PAV+ was 241.50 ± 47.82 (mean ± SD) in sedated and 273.50 ± 61.84 (mean ± SD) in awake state and difference again insignificant (P = 0.075). Furthermore, the difference between cycles of two modes was found

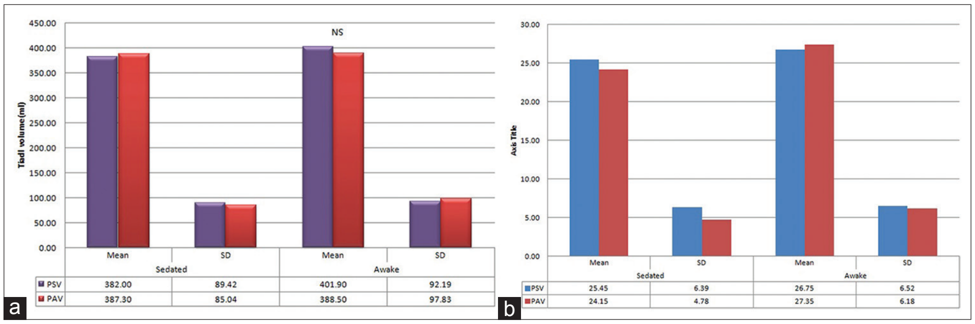

Figure 1: (a) Similar tidal volume among two modes in different states. (b) Similar respiratory rates among two modes in different states

Table 1: Patient characteristics (n=20), crossover study

Parameter	Mean±SD
Age (years)	41.80±15.20
Gender	
Male:female	15:5
Weight (kg)	66.50±12.47
Height (cm)	169.16±8.66
BMI	23.01±2.42

SD: Standard deviation; BMI: Body mass index

Table 2: Types of patient-ventilator asynchrony

Inspiratory dyssynchrony	
SC or erroneous triggering	Inspiratory assistance from the ventilator without demand by patient or false triggering to movements such as cardiac oscillations
NED or wasted effort	Patient inspiratory effort but no flow response from the ventilator
Expiratory dyssynchrony	
IS	Interruption of ventilatory support during patient inspiration
PMI	Maintenance of ventilatory support during patient expiration or breath holding at the end of inspiration
DBSC	Sequence of inspiration-expiration-inspiration of the patient within a single assisted inspiration

SC: Self-cycled; NED: No effort detected; IS: Interrupted support; PMI: Prolonged mechanical inspiration; DBSC: Double breath, single cycle

to be statistically insignificant in sedated (P = 0.471) and awake states (P = 0.767) [Tables 3 and 4].

Comparing the asynchronies between the two modes [Table 3], the mean number of total asynchronous cycles in sedated and awake states in PSV was 7.05 ± 10.83 (mean ± SD) and 4.35 ± 5.62 (mean ± SD), respectively, and in PAV+ was 38.35 ± 15.62 (mean ± SD) and 44.10 ± 12.64 (mean ± SD), respectively. We also calculated the percentage distribution of asynchronies in both the modes and in both states. Patients during PAV+ mode had variable inspiratory hold for a short period unlike prolonged mechanical inspiration (PMI) extending into expiratory phase. To minimize interpretation and conclusion bias, we calculated asynchrony frequency with and without PMI. The number of PMI asynchronies in PSV was nil in both awake and sedated states. In PAV+, the mean number of PMI asynchronies in sedated and awake states was 31.70 ± 7.91 (mean ± SD) and 33.25 ± 7.99 (mean ± SD), respectively, and this difference was found to be statistically insignificant (P = 0.541). The results showed that the difference between the total asynchronies in sedated and awake states was statistically insignificant in both modes during intragroup comparison (P = 0.329 for PSV and P = 0.208 for PAV+). However, for intergroup comparison, the difference between the two modes was found to be highly significant in both sedated and awake states if we considered inspiratory hold in PAV+ as PMI (P = 0.000001 for both states). The second type of asynchrony observed was no effort detected (NED). The mean number of patients with NED asynchronies in sedated and awake states in PSV was 4.00 ± 7.46 (mean ± SD) and 2.70 ± 4.26 (mean ± SD), respectively, and in PAV+ is 3.15 ± 6.18 (mean ± SD) and 4.15 ± 4.85 (mean ± SD), respectively. On intragroup comparison, the difference between the number of NED asynchrony was insignificant in PSV (P = 0.503) and in PAV+ (P = 0.596). The intergroup difference between PSV and PAV+ was also found to be insignificant in sedated and awake states (P = 0.709 for sedated and P = 0.321 for awake). The third type of asynchrony was interrupted support (IS), and as shown in the table in awake state, there were 3.15 ± 5.22 (mean ± SD) cases of IS in PAV+ as compared to 1.65 ± 3.01 (mean ± SD) in PSV, and this difference was statistically significant (P = 0.026). The double-breath, single cycle (DBSC) type of asynchrony was also uncommon, and the difference was statistically insignificant during both intra- and intergroup comparison (P = 0.868 for sedated and 0.114 for awake). The self-cycled type of asynchrony was not observed during the entire study period in either mode. The total asynchronies were 2.77% in PSV sedated, 1.63% in PSV awake, 15.87% in PAV+ sedated, and 16.12% PAV+ awake. If we exclude PMI type of asynchrony, the percentage is same in PSV mode, but in PAV+, it is 2.79% in sedated and 3.97% in awake state. Respiratory and hemodynamic parameters were comparable in both modes [Table 5]. There was an interesting observation that changeover between modes resulted in swings in hemodynamics and respiratory mechanics indicating that patients were either uncomfortable to change or got disturbed due to change [Figures 2 and 3].

Discussion

The patient-ventilator asynchrony has been an issue concern and is observed in almost all spontaneous modes of ventilation. This asynchrony not only results in patient discomfort but also leads to heterogeneous ventilation distribution and atelectasis. Patients with high level of asynchrony require a longer duration of mechanical ventilation (MV), higher incidence of tracheostomy, weaning failure, longer ICU, and hospital stay with additional economic burden.[7-10] To improve upon this patient-ventilator interaction, various new modes of ventilation are designed and tested.

In our crossover study of PSV and PAV+ modes, in PAV+ mode, we found no flow near the end of inspiration in some patients, i.e., end-inspiratory hold/PMI. However, inspiratory hold did not have apparent detrimental effect on gas exchange in our study. Costa *et al*. observed this finding in PSV also.[11] Authors found that during PSV trials, the mechanical inspiratory time Ti (flow) was significantly longer than patient inspiratory time Ti (pat) as compared to PAV+ ($P < 0.05$). PAV+ significantly reduced delay ($P < 0.001$). If we include this as asynchrony, then PSV had lesser asynchronous breaths as compared to PAV+ ($P = 0.000001$). However, if we exclude this asynchrony from analysis, both modes performed clinically in a similar fashion. More patient-ventilator asynchronies were observed in PAV+ than PSV while patients were awake ($P = 0.043$). During inspiratory cycle, two asynchronies (self-cycling and no effort) were comparable and statistically insignificant in both the modes. During expiratory phase, the IS type of asynchronies was noted more frequently in PAV+ as compared to PSV during awake state. DBSC type of asynchrony was also comparable in both modes. Compliance, resistance, tidal volume, and hemodynamics were comparable without statistical significance. The changes in PCO_2 and PO_2 were statistically insignificant in all the comparisons. The comparison of the mean SaO_2 values, PaO_2/FiO_2 ratio, and $\Delta(A\text{-}a)\ O_2$ difference was all statistically insignificant. Thus, it means there is no superiority or inferiority of any mode for pulmonary mechanics and gas exchange. Hart *et al*. had similar finding while comparing these two modes in patient with chest deformity and muscle disease having chronic respiratory failure. However, they found greater unloading in PSV than in PAV, associated with greater benefit too.[12] Although some authors in short-term studies found some physiological and symptomatic improvements in patients with chronic respiratory failure due to COPD and cystic fibrosis with PAV mode, most of the studies at large have failed to prove superiority of either mode.[8] Our observations were similar to those reported by Kondili *et al*. and Porta *et al*.[5,6] Bosma *et al*. found fewer patient-ventilator asynchronies and better quality of sleep with PAV.[7] Dirk Varelmann *et al*. compared randomly PSV and PAV as a crossover study on 12 patients and did not observe a significant difference in hemodynamics and blood gas

Table 3: Total asynchronous breaths including and excluding prolonged mechanical inspiration (*n*=20)

	Mean±SD		*P*
	Sedated	Awake	
(a) Total asynchronous breaths including prolonged mechanical inspiration			
Total asynchrony with PMI			
PSV	7.05±10.83	4.35±5.62	0.328618
PAV+	38.35±15.62	44.10±12.64	0.208392
P	0.000001	0.000001	
(b) Total asynchronous breaths excluding prolonged mechanical inspiration			
Total asynchrony without PMI			
PSV	7.05±10.83	4.35±5.62	0.328618
PAV+	6.75±12.24	10.85±11.33	0.15000
P	0.871528	0.042609	

PMI: Prolonged mechanical inspiration; SD: Standard deviation; PSV: Pressure support ventilation; PAV+: Proportional assist ventilation plus

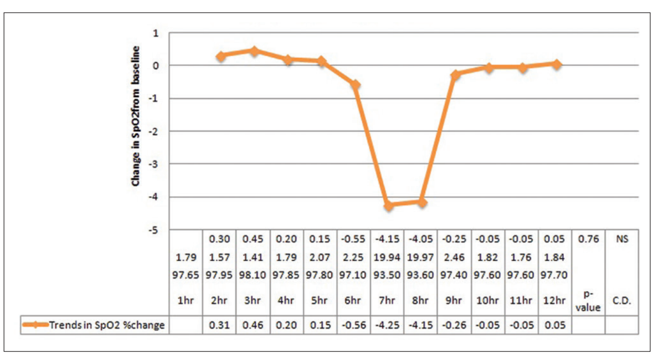

Figure 2: Trends in SpO_2 change during study period

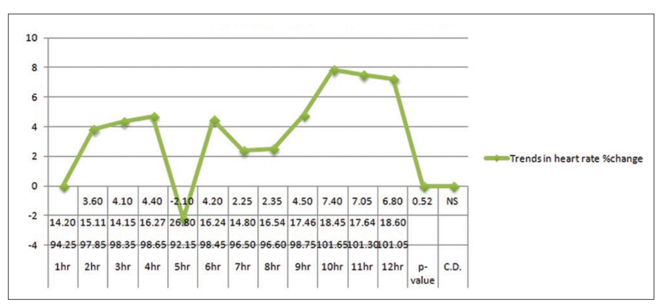

Figure 3: Trends in heart rate during study period

Table 4: Distribution of patient-ventilator asynchronies among two modes (*n*=20)

Percentage distribution of asynchronies	SC	NED	IS	PMI	DBSC	Total without PMI	Total with PMI
PSV							
Sedated	0	1.57	0.33	0	0.86	2.77	2.77
Awake	0	1.01	0.15	0	0.43	1.63	1.63
PAV							
Sedated	0	1.30	0.68	13.13	0.81	2.79	15.87
Awake	0	1.77	0.12	12.16	1.29	3.97	16.12

PSV: Pressure support ventilation; PAV: Proportional assist ventilation; SC: Self-cycled; NED: No effort detected; IS: Interrupted support; PMI: Prolonged mechanical inspiration; DBSC: Double breath, single cycle

Table 5: Comparison of ventilator mode impact on lung compliance and resistance among two modes *n*=20

	Mean±SD		*P*
	Sedated	Awake	
(a) Comparison of ventilator mode impact on lung compliance during study period			
Compliance			
PSV	29.41±9.51	30.03±9.25	0.835564
PAV+	38.35±18.87	36.25±16.77	0.711949
P	0.066122	0.154592	
(b) Comparison of ventilator mode impact on lung resistance during study period			
Resistance			
PSV	10.02±3.86	10.28±4.31	0.841797
PAV+	11.94±7.32	10.46±4.49	0.445617
P	0.306016	0.897772	

SD: Standard deviation; PSV: Pressure support ventilation; PAV+: Proportional assist ventilation plus

parameters.[4] In 2011, Hosking *et al*. compared A/C, PSV, and PAV modes for weaning and found high asynchrony index in 27% of cases in the high PSV group and in 6% in the low PSV group with no cases in the PAV group at its different levels of assist.[13] In studies by Elganady and Xirouchaki *et al*., authors found high asynchrony index with PSV as compared to PAV.[14,15] They observed mainly ineffective triggering and cyclic dyssynchrony with high asynchrony index in PSV. Elganady *et al*. found higher weaning success rate (90%) and fewer ventilator days with PAV in COPD patients as compared to PSV 66.7%. The variation in results might be due to different patient characteristics, sedation, diurnal orientation, and trigger setting, etc.

Recently, Aguirre-Bermeo *et al*. and Teixeira *et al*. in prospective studies found no difference among two modes for tolerance, extubation failure, duration of MV, ICU and hospital stays, and clinical outcomes during weaning from MV.[16,17] Most of the studies on different modes of ventilation conducted for synchrony comparison, have reported similar outcome with PSV and PAV, but with PAV having better tolerance. However, these studies are from COPD patients. Comparing MV modes are difficult as patient characteristics, level of support, pain, sedation, circadian rhythm, coexisting disease, etc., all affect the demand and patient comfort.

There were few limitations in our study as we did not study the esophageal pressures and transpulmonary pressures to detect the ineffective breaths. Another limitation is that we did not study ventilator support at different levels of support. High and low support can alter asynchrony index. Another limitation was that we did not maintain and record the circadian rhythm of the patients.

From the observations made during our study and literature, we conclude that both PSV and PAV+ modes perform overall similarly for patient-ventilator interactions in awake and sedated states. Variable end inspiratory hold was observed in PAV+ mode without detrimental concerns on gas exchange. Patients had a higher compliance and PO_2/FiO_2 ratio values in PAV+ mode although these values did not gain statistical significance. There was an interesting observation that changeover between modes resulted in swings in hemodynamics and respiratory mechanics indicating that patient tunes to ventilator deliveries overtime.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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