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Variations in Patient-Ventilator Asynchrony Frequencies Across Different Sedation Levels in Critically Ill Patients

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Abstract

Background: Patient–ventilator asynchrony (PVA) is a frequent but often underrecognized phenomenon in mechanically ventilated patients, associated with adverse outcomes. Sedation depth is a modifiable factor affecting PVA, yet data from resource-limited ICUs remain scarce. This study aimed to evaluate PVA prevalence and its association with sedation depth and mechanical ventilation duration.

Methods: A cross-sectional observational study included 60 adult ICU patients on mechanical ventilation. Ventilator waveform recordings were analyzed over 30-minute periods, totaling 41,372 breaths. PVA events were identified, classified, and quantified. Sedation depth was categorized as fully awake, light sedation, or deep sedation. Associations between sedation depth, PVA frequency, and mechanical ventilation duration were assessed using statistical tests.

Results: A total of 2,539 PVA events were detected, yielding an overall asynchrony rate of 6.1%. Ineffective effort was most common (58%), followed by double triggering (17.2%) and flow asynchrony (15.3%). Mean PVA values increased significantly with deeper sedation ($p<0.05$). A weak but statistically significant positive correlation existed between average PVA and duration of mechanical ventilation ($r=0.306$, $p<0.05$).

Discussion: PVA is prevalent in mechanically ventilated ICU patients, with ineffective effort predominating. Deeper sedation levels are associated with higher PVA frequency, which correlates with prolonged ventilation. These findings emphasize the need for careful sedation management and routine ventilator waveform monitoring to improve patient–ventilator interaction.

Conclusion: Patient–ventilator asynchrony is common and significantly associated with sedation depth and ventilation duration. Optimized sedation and vigilant waveform monitoring may enhance synchrony and reduce ventilation time.

Keywords: Ineffective trigger; mechanical ventilation; patient-ventilator asynchrony (PVA); sedation

Introduction

Mechanical ventilation is one of the most common interventions used in intensive care units (ICUs), because it is necessary to maintain critical patients with acute respiratory failure.[1]

The primary goal of mechanical ventilation is to maintain adequate gas exchange and reduce effortful breathing until the patient's clinical condition indicates that mechanical ventilation is no longer indicated.[2] For each matter said, there is interaction between patient and

ventilator, with a balance between the effort of inspiration and the ventilator trigger, between requested ventilation and distribution flow and tidal volume, and between the patient's inspiration and cycles tool.

Patient-ventilator asynchrony (PVA) is a mismatch between the patient and the ventilator in timing, flow, volume, or demand, or in the pressure control of the respiratory system during mechanical ventilation. Event asynchrony can range from changes that are not obvious, the detection of which requires strong suspicion and careful monitoring, resulting in real "resistance". Between the patient and the ventilator, the interface can be managed.[3] Patient-ventilator asynchrony (PVA) has a wide range of 10–85%, which is quite varied. [4–8] This can be explained by the fact that multiple factors influence events and the way PVA is detected.

Repairing PVA automatically, in general, involves optimizing settings from ventilator mode, including flow, trigger, and pressure, in accordance with the patient's needs, and eliminating technical disturbances, such as leakage or fluid or plaque, that interfere with the ventilation network. In addition, sedation is one method to reduce PVA in patients' ventilatory mechanics. Too much sedation will give rise to PVA-type ineffective trigger, whereas too much sedation light will cause agitation and can give rise to PVA-type insufficient flow, double triggering and short cycling.[1]

The Richmond Agitation-Sedation Scale (RASS) is a general scale used to assess sedation in patients. Research shows that RASS implementation is clearer and more convenient and requires less time, resulting in shorter ventilator durations and shorter ICU stays, compared to other scales.[9]

Subjects and Methods

This research is an analytical comparative study with a cross-sectional design. Samples that meet the inclusion criteria will be included as research subjects. Population study: ICU patients using mechanical ventilators in the

ICU. The sampling method was consecutive sampling. With the subject study, patients treated in the ICU, according to inclusion and exclusion criteria, in February through May 2024 at Dr. Hasan Sadikin General Hospital, Bandung. Criteria for inclusion are patients who are fully conscious, lightly sedated, or sedated. Criteria for exclusion in research: patient with invasive mechanical ventilation ≤24 hours; patient without; patient with respiratory effort; patient under the influence of a paralytic drug; presence of acidosis or severe alkalosis; severe neuromuscular disorders; obstructive/restrictive lung disease; and patient with chest tube insertion.

A total of 20 samples were used in the study. These were based on a comparative test formula with numerical-categorical data. No samples were included in pairs; instead, two groups were used for each group (sedation), for a total of 60 samples.[19]

Researchers selected patients who met the inclusion criteria using consecutive sampling. The selected patients were those treated in the ICU on an invasive mechanical ventilator with respiratory effort who had passed more than 24 hours of treatment. Assessment of the ventilator waveform recording was performed when the patient was in optimal condition, with ventilator settings adjusted to the patient. After the physician-in-charge (DPJP) completed the analysis, the bed was assigned, and the optimal ventilation mode was selected based on the attedning clincians recommendation. Throughout the patient's ventilator tubing, it was ensured that there were no obstructions, such as secretions, blood, or other fluids. Then, recordings were conducted for 30 minutes, without any manipulation of the endotracheal tube (ETT), ETT suction, changes in drug dosage, or ventilator settings during the previous 30 minutes.

All data from the research subjects' recordings will be collected using a consecutive sampling method until the three sedation groups have reached 60 samples. Then, the recordings will be analyzed by experts (three competent trainees), and the researcher will verify the results. Determination of each

sedation level during ventilator recordings will be carried out. Based on PVA recordings, the frequency of PVA occurrence will be estimated for the research subjects. Researchers will compare the mean PVA across the three sedation groups.

Mechanical ventilator monitor data was recorded then reviewed by three experts. This data will then be reviewed by three experts and classified into the following PVA types: ineffective trigger, double trigger, short cycling, prolonged cycling, excessive flow, and insufficient flow. Researchers will also collect data on sedation medication dosages during the recordings.

The frequency of each PVA type will be calculated as the number of PVA subtypes found shared per breath in 30 minutes for each sample. Asynchronies will be classified by triggers, cycling, and flow. In this research, a comparative test was conducted to analyze the relationship between independent variables (X) and dependent variables (Y). A one-way ANOVA test was used to evaluate differences in sedation between the PVA group and the fully conscious, lightly sedated, and sedated groups. Before analysis, the normality of the data was assessed using the Shapiro-Wilk test, and the homogeneity test. The significance value used in hypothesis testing is $p \leq 0.05$. Data on research were processed using IBM SPSS Statistics version 22.0.

Results

This study included 60 patients in the study. Based on the sample data (Table 1), the indications for ventilators are most commonly neurosurgery (41.4 %), sepsis (22.4%), neurological abnormalities (17.2%), stroke (8.6%), I'm as well as trauma, heart abnormalities, and obstetric gynecology cases (3.4%).

In this study (Table 1), 46.7% of patients underwent mechanical ventilation with pressure support (PS), 41.7% with synchronized intermittent mandatory ventilation (SIMV-PS mode), and the remaining

Table 1 Characteristics of Research Subjects

Characteristics	Amount n (%)	Average (±SD)	Median (min- max)
Age (years)		48.5 (±15,9)	48.5 (18.0–85.0)
Indication ventilators			
Neurosurgery:	24 (41.4)		
Sepsis	13 (22.4)		
Abnormalities neurological ; GBS, Myasthenia Gravis, epilepsy	10 (17.2)		
Infarction / hemorrhagic stroke	5 (8.6)		
Trauma	2 (3.4)		
Obstetric	2 (3.4)		
Cardiac anomalies	2 (3.4)		
Ventilator mode types			
SIMV + PS	25 (41.7)		
PS	28 (46.7)		
CPAP	7 (11.7)		
APACHE II Score		19 (±7.4)	18.0 (7.4)
Amount 30 minutes of breathing		689 (±117)	688 (117)

Notes: Variable categorical stated as number/frequency (n) and percentage (%); Variables are continuous, stated as average value with standard deviation (±SD) and median with range (minimum- maximum)

Table 2 Total PVA Subtype

Variables	Amount Cycle breath	Frequency Subtype (%)
PVA Type		
Ineffective trigger/effort	1.129	58
Double trigger	337	17.2
Flow asynchrony	300	15.3
Short cycling	128	6.5
Prolong cycling	58	3
Total	1.952	100

Table 3 Comparison Mean PVA Group Fully Aware with Sedation Light

Sedation Level	Mean PVA (SD)%	Sig	p-value
Fully awake vs light sedation	14.5 (±13.8) vs 32.4±17.5)	0.001	<0.05*
Light sedation vs deep sedation	32.4 (±17.5) vs 57.9 (±12.6)	0.001	<0.05*
Fully awake vs sedation	14.5 (±13.8) vs 57.9 (±12.6)	0.001	<0.05*

Notes: * Significance *Test* with mark significance $p < 0.05$

11.7% with continuous positive airway pressure (CPAP) mode. The average number of breaths per patient recorded over 30 minutes was 688 cycles/breath, the average value of the APACHE II score on all subjects.

The distribution of PVA frequency by type is shown for a 30-minute recording of 60 samples, yielding a total PVA yield of 1,952 (5%) from 41,372 breath cycles. Amount type most obtained PVA type ineffective trigger/effort that is as many as 1,129 cycles (58%), followed by with type double trigger and flow asynchrony were 17.2% and 15.3% respectively, while type other under value 10%. In the research, it was found that at the level of sedation where patients were most fully aware, 7 of 20 patients showed synchronization, indicating no asynchrony.

However, at deeper levels of sedation, patients experienced complete asynchrony. In fully conscious patients, no instances of type DT, SC, or PC asynchrony were observed. The highest frequency of asynchrony, at 85%, was noted for the double triggering type, which occurred in patients under deeper sedation. Additionally, a significant number of IT asynchrony types were identified in sedated patients compared with those under light sedation or in a state of mindfulness, with 13 out of 20 patients experiencing this form of asynchrony (Table 2).

The analysis of data from (Tables 3) along with the results of the ANOVA test, reveals significant differences, indicated by a p-value of 0.001, which is markedly below the threshold of 0.05. This suggests that the average PVA in

Table 4 Connection Correlation Average PVA with Day Ventilation Mechanic

Sedation Level	Mean (± SD)	Sig. (2-tailed)	p-value
Average PVA	34 (± 13)	0.018	<0.05*
Ventilation day	9.9 (± 23)		

Notes: * Significance Test with mark significance $p < 0.05$

the sedation group is slightly higher than in the control group, indicating a rightward shift in values. Furthermore, the sedation group shows a higher average PVA than the "sedation in" group. Overall, these results underscore important distinctions between the sedation protocols and highlight the need for further investigation into their effectiveness.

Table 4 presents the correlation between average Pain–Ventilation Assessment (PVA) scores and mechanical ventilation duration. The mean PVA score was 34±13, while the mean duration of mechanical ventilation was 9.9±23 days. A statistically significant correlation was observed between average PVA and days of mechanical ventilation (two-tailed significance=0.018, $p<0.05$), indicating a significant association between these two variables.

Discussion

In this study involving 60 mechanically ventilated patients, a total of 41,372 breaths were analyzed from 30-minute waveform recordings. The overall PVA yield was 2,539 events, corresponding to an asynchrony rate of 6.1%. This proportion is lower than rates reported in previous studies, which have ranged from approximately 10% to 85%, depending on patient population, ventilatory mode, monitoring technique, and definition of asynchrony.

The most frequently observed form of patient–ventilator asynchrony was ineffective effort, accounting for 58% of all PVA events. Double triggering and flow asynchrony were the next most common types, representing 17.2% and 15.3% of events, respectively, while other forms of asynchrony occurred in fewer than 10% of cases. These findings are consistent with prior literature identifying ineffective effort as the predominant type of asynchrony, with reported frequencies of up to 80%. Other studies have similarly demonstrated that trigger-related asynchronies, including missed and double triggering, constitute a substantial proportion of total events, particularly in specialized surgical or trauma ICU settings.

Variations in asynchrony patterns across studies may reflect differences in patient characteristics, ventilator settings, sedation practices, and institutional monitoring protocols.[8–13]

A significant association was observed between sedation depth and PVA frequency. Mean PVA values increased progressively from fully awake patients to those receiving light sedation and were highest among patients under deep sedation. Fully awake patients demonstrated the lowest PVA values, while deep sedation was associated with the greatest degree of asynchrony. These findings support existing evidence that deeper sedation levels are associated with impaired patient–ventilator interaction, likely due to suppression of respiratory drive and altered neuromuscular coordination.[14–16]

The relationship between sedation and PVA may be explained by several physiological mechanisms, including depression of the respiratory center, reduced responsiveness to ventilatory support, respiratory muscle dysfunction, and metabolic disturbances commonly encountered in critically ill patients. Excessive sedative administration may further exacerbate these effects, increasing the likelihood of ineffective triggering and other forms of asynchrony. These findings underscore the importance of carefully titrating sedation to balance patient comfort with preservation of spontaneous respiratory effort.

In addition, a weak but statistically significant positive correlation was identified between average PVA values and the duration of mechanical ventilation. This association aligns with previous reports linking higher asynchrony burden to prolonged ventilatory support, extended ICU length of stay, and increased mortality. However, it remains unclear whether patient–ventilator asynchrony directly contributes to prolonged mechanical ventilation or primarily reflects underlying disease severity and physiological instability. Further longitudinal and interventional studies are required to clarify this relationship.[8,11,17–20]

Given the limited availability of advanced ventilatory modes such as neurally adjusted ventilatory assist (NAVA) in many settings, particularly in resource-constrained environments, careful manual inspection of ventilator waveforms remains an essential tool for identifying patient–ventilator asynchrony. Systematic waveform monitoring may facilitate earlier recognition of asynchrony and enable timely adjustments to ventilator settings and sedation strategies, potentially improving patient–ventilator interaction and clinical outcomes.

Conclusion

The findings suggest that the predominant PVA type identified in the research is an ineffective trigger. Notably, the data indicate that mean PVA levels correlate inversely with sedation levels, placing the fully conscious group at a lower mean PVA than the light-sedation cohort. This highlights the need for further investigation into the implications of elevated PVA levels, particularly their potential effects on mortality rates and ICU length of stay. Future studies should elucidate these relationships to enhance our understanding and guide clinical practice more effectively.

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