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Prevalence of Ventilatory Dyssynchrony in Critically Ill Patients

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Abstract: **Background**: Patient-ventilator Dyssynchrony is a common challenge in mechanically ventilated Intensive care unit patients, where mismatches occur between a patient's respiratory efforts and ventilator-delivered breaths. These dyssynchronies can lead to adverse outcomes, including increased respiratory effort, impaired gas exchange, prolonged ventilation, and higher mortality rates. Despite advancements in ventilator technology, patient-ventilator dyssynchrony still needs to be explored in specific clinical settings for over one year. **Aim of the study:** the study aimed to evaluate Patient-Ventilator Dyssynchrony prevalence, types, causes, and outcomes among Ghazi Al-Hariri Teaching Hospital, Iraq Intensive care unit patients. **Methods:** A prospective cohort study was conducted between October 1, 2023, and October 1, 2024, including 296 patients admitted to the Intensive care unit who met the inclusion criteria. Data were collected on patient demographics, clinical characteristics, ventilator settings, and outcomes using continuous monitoring and ventilator waveform analysis. Statistical analysis included Chi-square tests and student t-tests, with significance set at $p < 0.05$. **Results:** out of the 296 intensive care unit patients, 185 (62.5%) experienced patient-ventilator dyssynchrony. The mean age of Patient-Ventilator Dyssynchrony patients was 52.6 ± 19.2 years, and 54% were male. Trigger dyssynchrony was the most prevalent type (62.7%), followed by flow dyssynchrony (27%) and cycle dyssynchrony (10.3%). The most frequent cause was Insufficient tidal volume, and Insufficient inspiratory time was reported in 70 out of 185 patients (37.8%), followed by Insufficient flow reported in 50 out of 185 patients (27%). Pressure support assist mode was the most frequently associated ventilator mode (77.8%). **Conclusion:** Patient-ventilator dyssynchrony is a significant concern in Intensive care unit environments, impacting more than 50% of patients on mechanical ventilation and leading to major clinical issues. The most frequent and dangerous type is trigger dyssynchrony, highlighting the necessity for optimized ventilator settings and continuous monitoring to improve synchronization.

Keywords: Patient-Ventilator Dyssynchrony, Mechanical Ventilation, Intensive care unit, Trigger Dyssynchrony.

INTRODUCTION

Invasive mechanical ventilation often saves the lives of patients suffering from acute respiratory distress. (Schönhofer, B. *et al*., 2008) Critical care medicine heavily relies on the patient-ventilator relationship to provide adequate respiratory support. (De Haro, C. *et al*., 2019) However, despite the progress in mechanical ventilation technology, achieving synchrony between patients and ventilators remains a complex challenge. (Antonogiannaki, E. M. *et al*., 2017)

Patient-ventilator dyssynchrony or asynchrony (PVA), characterized by a mismatch in timing, Flow, or volume between the patient's respiratory efforts and the ventilator's delivery of breaths, can have significant implications for patient outcomes. (Zhou, Y. *et al*., 2021) Prolonged dyssynchrony can lead to patient discomfort, agitation, and increased sedative requirements. (Oto, B. *et al*., 2021) Moreover, it may contribute to ventilator-associated lung injury, barotrauma, and prolonged mechanical ventilation, ultimately impacting patient outcomes, including morbidity and mortality. (Bates, J. H., & Smith, B. J. 2018) Therefore, early recognition and management of dyssynchrony are paramount in optimizing ventilator support and enhancing patient care in the intensive care unit (ICU). (Sottile, P. D. *et al*., 2018)

The epidemiology of patient-ventilator dyssynchrony is less extensively studied and documented than some other aspects of critical care medicine. (Carlucci, A. *et al*., 2013) However, patient-ventilator dyssynchrony is common in mechanically ventilated patients, particularly those in intensive care units (ICUs) and those with acute respiratory failure. (Mirabella, L. *et al*., 2020)

Patients and Methods

A prospective cohort study about the prevalence of patient-ventilator dyssynchrony in the Intensive Care Unit of Ghazi Al-Hariri Teaching Hospital in Medical City, Iraq, involving all patients on mechanical ventilation from October 1, 2023, to October 1, 2024. The Iraq Council of Medical Specialization approved the study. This study included 296 patients who were on mechanical ventilators.

Any Patient who is over 18 years old and admitted to ICU on assistant ventilated patient, stay more than 48 hours, was included in our study.

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Any patients with no evidence of spontaneous breathing was excluded.
All patients admitted to the ICU for critical illness management with invasive mechanical ventilation were included in continuous, close monitoring immediately upon admission for 30 minutes. The following measures were implemented to ensure optimal care:

- ❖ Ventilator Waveform Monitoring: Continuous real-time observation of ventilator waveforms, including airway pressure-time and flow-time curves, was conducted.

Regular assessment ensured ventilator settings were appropriate for the patient's needs, helping to detect abnormalities indicative of ventilatory dyssynchrony.

- ❖ Patients underwent regular assessments to evaluate breathing patterns and efforts. Observations focused on signs of discomfort, including:
- ➢ Increased work of breathing.
- ➢ Use of accessory respiratory muscles.
- ➢ Signs of anxiety or agitation.
- ➢ Sedation levels were assessed using the Richmond Agitation-Sedation Scale (RASS) for all patients to ensure appropriate sedation and minimize dyssynchrony.

- ❖ Respiratory and Vital Sign Monitoring: The respiratory rate was continuously monitored and compared with ventilator settings to detect mismatches suggestive of asynchrony.

Vital signs, including pulse rate (PR), blood pressure (BP), and oxygen saturation (SpO_2), were continuously monitored to identify abnormalities potentially related to dyssynchrony.

- ❖ Spontaneous Breathing Trials (SBTs): Periodic SBTs were performed to assess the patient's ability to breathe independently. Observations during SBTs were used to identify asynchronous breathing patterns

- ❖ Neurological and Clinical Scoring: Regular evaluations included monitoring the Glasgow Coma Scale (GCS), body temperature, Sequential Organ Failure Assessment (SOFA) score, and Acute Physiology and Chronic Health Evaluation II (APACHE II) score. These assessments provided insights into the overall clinical status and potential impacts of ventilatory dyssynchrony.

- ❖ Investigations and Outcome Evaluation:
- ➢ All relevant investigations were regularly reviewed to identify dyssynchrony causes and guide appropriate interventions (altering ventilator settings, changing the ventilation mode, and optimizing sedation).
- ➢ Continuous monitoring enabled the identification of ventilatory dyssynchrony, including its types, frequency, and underlying causes.
- ➢ The impact of dyssynchrony on patient outcomes was systematically evaluated, and each instance was managed according to its specific cause and type.

The data was collected by predesigning a mobile-based electronic investigation form using Kobo collect software, and the output was a Microsoft Excel sheet.

All data were collected during the first episode of mechanical ventilation during the first ICU stay, whether multiple episodes occurred during the same hospital stay.

The data collected, including demographic, clinical, and observational information of the patients (name, age, gender, underlying health conditions, reason for ICU admission, duration of ventilation, presence and type of ventilatory dyssynchrony, SpO2, Blood pressure, Heart rate, and clinical outcomes).

Quantitative variables are presented as the mean ± standard deviation (SD), and the categorical data are expressed as a number (percentage). The statistical significance differences in the categorical data were evaluated using the Chi-square (χ^2) test. A comparison of quantitative variables was performed using the student t-test. 95% confidence interval (CI). The p-value of <0.05 was unconsidered significant.

RESULT

From October 1, 2023, to October 1, 2024, 590 patients were admitted to the ICU; 296 (50%) met the study inclusion criteria.

A total of 185 out of 296 (62.5%) experienced PVD Figure 1.

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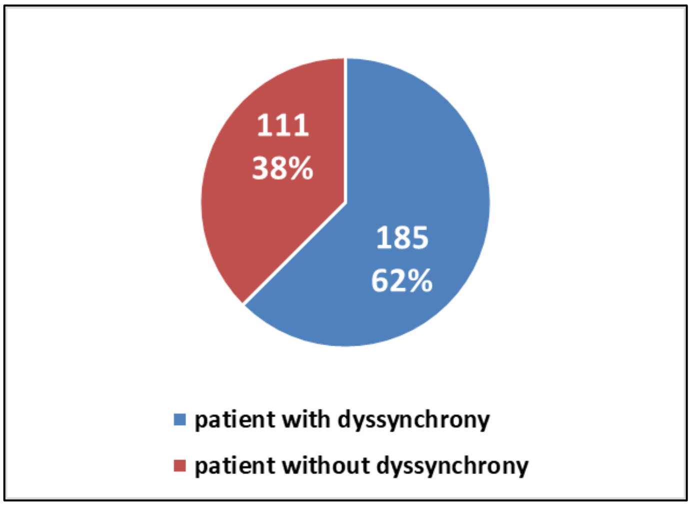

Figure 1: Prevalence of patient-ventilator Dyssynchrony.

The mean age and ± standard deviation were 52.6 ±19.2 years, ranging from 24 to 95 years. Male was 99 (54%) while female was 86 (46%) figure 2.

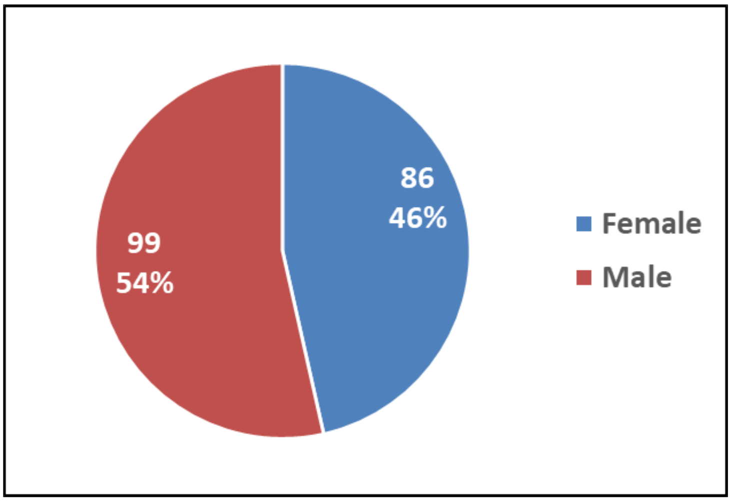

Figure 2: Distribution of patient-ventilator dyssynchrony patients by sex.

Regarding the vital signs of the PVD cases, the mean ± SD of systolic BP was 107 ± 13.3 mmHg, ranging from 80 to 150 mmHg. The mean ± diastolic BP was 57.7 ± 9.5 mmHg, ranging from 50 to 90 mmHg. The mean ± SD of HR was 87.7 beats per minute, and the mean ± SD of SpO2 was 94±3.7; the mean RASS score was -0.56±1.15, the APACHI II score mean was 32±10.5 and the temperature mean 37.7± 0.31.

Table 1: patient-ventilator dyssynchrony patients vital signs.

Vital sign	Mean	SD	Range
Systolic BP (mmHg)	107	±13.3	80---150
Diastolic BP (mmHg)	57.7	± 9.5	50--- 90
Heart rate (bite per minute)	87.7	±14.6	60---120
SpO2 (%)	94.2	±3.7	80--- 100
RASS score	-0.56	±1.15	-3---1
APACHE II	32	±10.5	14---38
Temperature	37.7	±0.31	36.5—39

The correlation of PVD patients with the cause of admission to the ICU was respiratory in 54 patients (29.2%), neurological in 52 patients (28.1%), sepsis in patients 44 (23.8%), postoperative 25 patients (13.5%), and others 10 (5.4%) figure 3.

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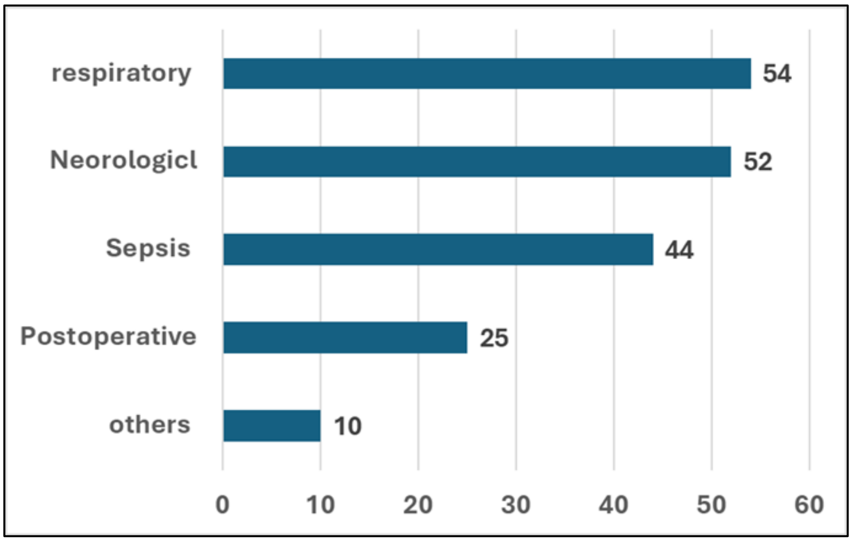

Figure 3: Distribution of patient-ventilator dyssynchrony patients according to causes of admission.

For the respiratory causes, ARDS 26 patients (48.1%), 14 patients (25.9%), COPD 10 patients (18.5%), and four patients (7.4%) Figure 4.

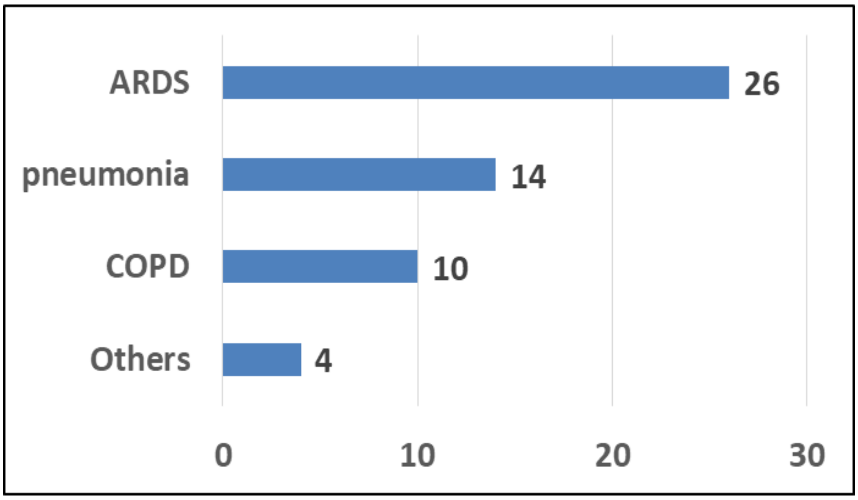

Figure 4: Respiratory patients by cause of admission.

A total of 185 patients has PVD. 116 (62.7%) trigger dyssynchrony, 50(27%) Flow dyssynchrony, and 19(10.3%) cycle Figure 5.

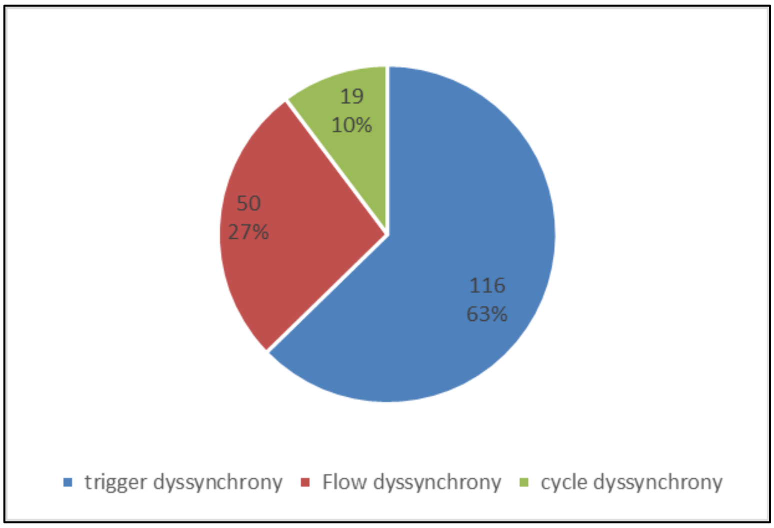

Figure 5: Distribution of type of patient-ventilation dyssynchrony.

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Trigger dyssynchrony: There were 116 patients with trigger dyssynchrony; the majority, 85 (73%), were extra triggers, and 31(27%) were ineffective triggers. There is a statistically significant difference between the three subtypes, with a value of 0.0001.

Flow dyssynchrony: 50 out of 50 (100%) are flow starving dyssynchrony.

Cycle dyssynchrony: Premature cycle dyssynchrony in 11 out of 19 patients (57.9%) while delay cycle dyssynchrony in 8 out of 19 patients (42.1%) Table 2.

Table 2: Distribution of PVD subtypes.

PVD type	PVD subtype	Frequency	%	P-value
Trigger	Extra trigger	85	73%	0.0001
	Ineffective trigger	31	27%	
Flow dyssynchrony	Flow starving dyssynchrony	50	100%	N/A
cycle dyssynchrony	premature cycle dyssynchrony	11	57.9%	0.49
	Delayed cycle dyssynchrony	8	42.1%	

The most frequent cause was Insufficient tidal volume, and Insufficient inspiratory time was reported in 70 out of 185 patients (37.8%), followed by Insufficient flow reported in 50 out of 185 patients (27%). In contrast, the less frequent cause was muscle weakness (Guillian - barre syndrome), reported in only 5(2.7%). Other causes are summarized in Table 3. There is a statistically significant difference between the causes, with a p-value of 0.0001.

Table 3: causes of patient-ventilator dyssynchrony.

Dyssynchrony Type	Dyssynchrony subtype		Causes	Frequency	%	P-value
Trigger	Extra trigger	Auto trigger	Low trigger threshold Leaks and bubbles in the circuit	15	8.1%	<0.0001
		Double trigger	Insufficient tidal volume Insufficient inspiratory time pain, anxiety	70	37.8%	
	Ineffective trigger		Significant air trapping (auto peep, intrinsic peep)	11	5.9%	0.49
			High respiratory rate or short expiratory time	7	3.8%	
			Muscle weakness (Guillian barre syndrome)	5	2.7%	
			High-pressure trigger threshold	8	4.3%	
Flow dyssynchrony	Starving flow		Low inspiratory flow rate (Insufficient flow)	50	27%	N/A
cycle dyssynchrony	Premature cycle		Short inspiratory time (hypoxemia, hypercapnia)	11	5.9%	0.491
	Delayed cycle		Prolonged expiratory time (COPD patients)	8	4.3%	

The most frequent mode of ventilation during asynchrony was pressure support assisted mode, representing 144 out of 185 (77.8%) PVD patients, while the lowest reported was assisted control ventilation mode, only 3 out of 185 (1.6%) PVD patients. Another mode frequency is summarized in Table 4. There is a highly statistically significant difference between the ventilation modes, with a p-value less than 0.0000.

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Table 4: Modes of ventilator during asynchrony.

Mode of ventilator during asynchrony	Frequency	%	p-value
Pressure support Assist mode	144	77.8%	0.0000
Assisted control	3	1.6%	
PRVC	17	9.2%	
Bilevel	21	11.4%	
Grand Total	185	100.0%	

A total of 105 out of 185(57%) PVD cases were cured, while 80 out of 185 (43%) PVD cases died. There was no statistically significant difference (p-value 0.066) in Figure 6.

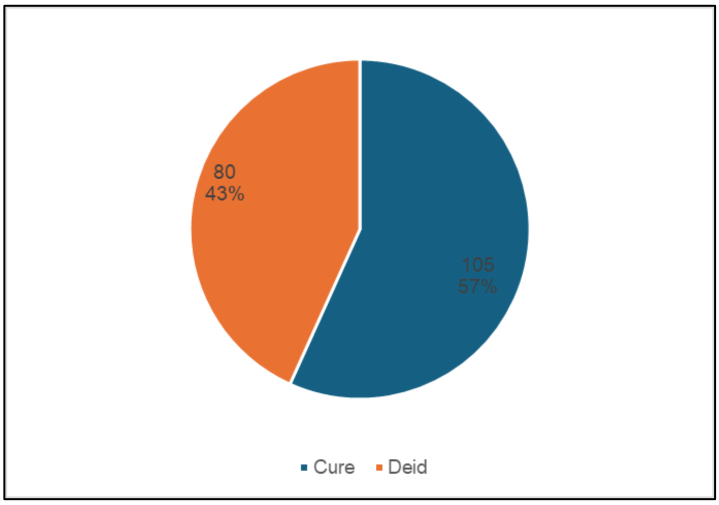

Figure 6: Distribution of PVD cases by outcome.

Regarding the relationship between the type of dyssynchrony, trigger dyssynchrony shows the highest case fatality rate, 65 out of 116 (56%) PVD cases, Flow dyssynchrony 12 out of 50(24%) PVD cases, and cycle dyssynchrony shows the lowest case fatality rate 3 out of 19(16%) PVD cases. A statistically significant difference exists between the three types, with a p-value of 0.001, Table 5.

Table 5: Distribution of dyssynchrony by outcome.

Type of dyssynchrony	Cure frequency (%)	Died frequency (%)	Grand Total	p-value
trigger dyssynchrony	51(44%)	65(56%)	116(100%)	0.001
Flow dyssynchrony	38(76%)	12(24%)	50(100%)	
cycle dyssynchrony	16(84%)	3(16%)	19(100%)	
Grand Total	105(57%)	80(43%)	185(100%)	

Regarding the prolongation of ICU stay, trigger dyssynchrony demonstrated the highest mean ± SD of 20.5 ± 4 days, with a mean prolongation of 12.5 ± 2.3 days on MV. In comparison, flow dyssynchrony resulted in a mean ICU stay of 11.4 ± 1.8 days and a mean MV duration of 8.5 ± 2.1 days, while cycle dyssynchrony showed the shortest prolongation, with 7.2 ± 2.4 days for ICU stay and 5.5 ± 1.9 days for MV duration. There is a statistically significant difference between the three types of dyssynchrony, with a p-value of 0.013 (Table 6).

Table 6: The effect of Patient-Ventilator Dyssynchrony on the prolongation of ICU stay and mechanical ventilation duration by types of PVD.

Type of Dyssynchrony	prolongation ICU Stay (days) mean ±SD	prolongation Mechanical ventilation (days) mean ±SD	P-value
Trigger	20.5 ±4	12.5 ±2.3	0.013
Flow	11.4 ±1.8	8.5 ±2.1	
Cycle	7.2 ±2.4	5.5 ±1.9	

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In the comparison of outcomes between patients with and without PVD, mortality was significantly higher in patients with PVD, at 43% (80/185), compared to 26% (29/111) in those without PVD ($p = 0.003$). The mean ICU stay was also significantly longer for patients with PVD (16.4 days) compared to those without PVD (12.3 days, $p < 0.001$). Similarly, the mean duration of mechanical ventilation (MV) was markedly prolonged in patients with PVD (9.2 days) compared to patients without PVD (3.9 days, $p < 0.001$) (Table 7).

Table 7: Comparison of mortality, mean ICU stay, and mean remaining on mechanical ventilation between patients with PVD and without PVD patients.

Outcome	Patients without PVD N=111	Patients with PVD N=185	P- value
Mortality (%)	29(26%)	80(43%)	0.003
Mean ICU stay(days)	12.3	16.4	<0.001
Mean remaining on MV (days)	3.9	9.2	<0.001

Regarding the sedation requirement by type of dyssynchrony, in double dyssynchrony, Increased sedative requirements were found in 23 out of 70 patients (32.8%), and no cases were associated with decreased sedative requirements.

In Trigger Dyssynchrony: Ineffective triggering occurred in 31 patients, with no cases requiring increased sedation, but 12 patients (38.7%) showed decreased sedative needs. Auto-triggering affected 15 patients, increasing sedation in 2 (13.2%) and decreasing it in 3 (20%).

Regarding flow Dyssynchrony, 18 out of 50 patients (36%) experienced increased sedation, with no cases of decreased sedation.

In Cycle Dyssynchrony, increased sedation was observed in 5 out of 19 patients (26.3%), with no cases of decreased sedation. (Table 8).

Table 8: Distribution of Dyssynchrony by sedative requirement.

Dyssynchrony type		No. of patients	Increase sedative requirement	Decrease sedative requirement
Triger	Double	70	23 (32.8%)	0
	ineffective	31	0	12(38.7%)
	Auto	15	2(13.2%)	3(20%)
Flow Dyssynchrony		50	18 (36%)	0
Cycle Dyssynchrony		19	5 (26.3%)	0

DISCUSSION

PVD is a common issue in ICUs. It occurs when a patient's respiratory efforts are not synchronized with the ventilator. This mismatch, caused by timing, flow, or cycling issues, increases the work of breathing, leads to respiratory muscle fatigue, and impairs gas exchange, resulting in complications such as hypoxemia or hypercapnia. (Garner, D., & Patel, P. 2022) PVD also prolongs mechanical ventilation and ICU stays, heightening the risk of ventilator-associated complications and mortality. Addressing PVD requires early detection, tailored ventilator adjustments, and a multidisciplinary approach.

This study comprehensively examines patient-ventilator dyssynchrony (PVD) in an ICU setting over one year, analyzing its prevalence, demographic distribution, types, causes, and patient outcomes.

PVD prevalence is significant, affecting 62.5% of ICU patients on mechanical ventilation. The high prevalence of dyssynchrony indicates that more than half of ICU patients may face difficulties with mechanical ventilation. If not addressed effectively, this can lead to discomfort, increased work breathing, and potentially poor clinical outcomes. This prevalence aligns with broader studies, which highlight PVD as a common issue in mechanically ventilated patients, especially those with underlying respiratory conditions such as COPD or ARDS due to the complex interactions between patient respiratory drive and ventilator settings and range from 10% to 85% as documented by Holanda AM *et al*., 2018.[11] The nearly balanced gender distribution (54% male, 46% female) and the mean age of 52.6 years suggest that PVD is not firmly gender-specific and affects a broad adult age range.

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Among patients experiencing PVD, trigger dyssynchrony was the most common type (62.7%), which occurs when the mechanical ventilator fails to synchronize correctly with the patient's spontaneous breathing effort. (Mirabella, L. *et al*., 2020) This is consistent with other studies, like Sottile *et al*., which found that the most common PVD triggers dyssynchrony. (Holanda, M. A. *et al*., 2018) Flow dyssynchrony (27%) and cycle dyssynchrony (10.3%). These findings underscore the challenge of setting appropriate triggering mechanisms and inspiratory flows, as patients may have variable and dynamic respiratory demands.

Extra trigger was particularly prevalent (73%), suggesting frequent issues where the ventilator delivers an additional breath because the first breath failed to meet the patient's inspiratory demand. (Sassoon, C. S. 2011).

Ineffective triggers compose about 27%. This highlights the need for optimized sensitivity and trigger settings. (Unroe, M., & MacIntyre, N. 2010) This finding was consistent with another study by Karen G Mellott *et al*. (2009). (Mellott, K. G. *et al*., 2009).

Flow dyssynchrony is the second most common type, accounting for about a quarter of the PVD cases. It reflects the ventilator's inability to meet the patient's inspiratory flow demands; this finding aligned with a study by Grap M. J *et al*., which mentions flow dyssynchrony is the second most common type. (Mellott, K. 2010)

In cycle dyssynchrony, which accounts for about 10% of PVD, premature or delayed cycling issues indicate that cycle settings may not always align with the patient's natural breathing pattern, further complicating synchronization. (Silveira, J. M. N. *et al*., 2023) In contrast, a study by L. Vignaux *et al*., which included 60 patients, reported a higher prevalence of premature cycling in 7 (12%) and late cycling in 14 (23%), possibly due to different sample sizes and settings. (Vignaux, L. *et al*., 2009)

The predominant cause (37.3%) was Insufficient tidal volume and Insufficient inspiratory. This misalignment, often influenced by inadequate flow or timing adjustments, indicates the need for vigilant monitoring and real-time adjustments in ventilator settings, the same finding mentioned by LF Damiani *et al*. in 2020. (Damiani, L. F. *et al*., 2020) Insufficient ventilator flow rate accounted for 27% of dyssynchrony cases, stressing the importance of adjusting ventilator flow to meet the patient's variable inspiratory demands. (Mulqueeny, Q. C. 2011) The least frequent cause, muscle weakness, was reported in only 5(2.7%). This suggests that while it is not a primary factor in dyssynchrony, it must be monitored to prevent compounding issues. The same finding was mentioned by Holanda, M. A. *et al*., 2018. (Holanda, M. A. *et al*., 2018).

Pressure support Assist mode, representing 144 out of 185 (77.8%) PVD patients, was the most frequently associated with dyssynchrony. This mode requires close alignment between the patient's effort and the ventilator's support, which may be challenging to achieve, leading to higher dyssynchrony incidents; this finding is consistent with the study by Damiani, L. *et al*. in 2020. (Damiani, L. F. *et al*., 2020) Volume control modes were also noted but at significantly lower frequencies. These results reinforce the complexities of synchronizing ventilator support with patient efforts, especially in assistive ventilation modes.

Outcomes varied significantly with dyssynchrony type. Trigger dyssynchrony patients showed the highest mortality rate, 56%, which aligns with the study by Sottile *et al*. published in 2020. This indicates a potentially severe impact when inspiratory trigger mechanisms are not synchronized. (Sottile, P. D. *et al*., 2020) In contrast, cycle dyssynchrony had the lowest mortality rate, 16%, suggesting that the timing of ventilator cycling may be somewhat less critical than trigger sensitivity for patient survival. This distribution, with a statistically significant p-value, highlights the clinical importance of specific dyssynchrony types on patient outcomes. This is consistent with a study by De Oliveira *et al* , 2021. (De Oliveira, B. *et al*., 2021).

The study demonstrates that PVD is associated with increased mortality, longer ICU stays, and prolonged mechanical ventilation. Furthermore, the type of dyssynchrony significantly influences these outcomes, with trigger dyssynchrony posing the highest risk; this result is consistent with many studies like a study by Arnaud W. *et al*., which find that the presence of dyssynchrony increases both the mean ICU stay and also prolonged the remaining on MV (Thille, A. W. *et al*., 2006) and the same with another study by L. F. Damiani *et al* , 2020. (Damiani, L. F. *et al*., 2020)

The study results highlight variations in sedative requirements based on dyssynchrony type. Double

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Dyssynchrony and Flow Dyssynchrony had the highest impact on increasing sedation, potentially indicating greater discomfort or difficulty managing these conditions. Conversely, Trigger Dyssynchrony (especially ineffective triggering) was unique in decreasing sedation needs, possibly due to reduced ventilatory demand or lower respiratory effort. The same finding was documented by Damiani, L. F, *et al*, 2020. (Damiani, L. F. *et al*., 2020) The findings highlight the importance of personalized sedation strategies that are tailored to the specific type of dyssynchrony. In cases of patient-ventilator asynchrony, such as double and flow dyssynchrony, increased sedation may be required to provide relief. Conversely, reducing sedation could improve outcomes for patients experiencing ineffective triggering. (Oto, B. *et al*., 2021)

CONCLUSIONS

- This study revealed a high prevalence of patient-ventilator dyssynchrony among ICU patients, highlighting its significant clinical burden.
- Respiratory, neurological conditions and sepsis were the most common causes of admission for patients with PVD.
- Trigger dyssynchrony was the most frequent PVD type.
- Pressure support was the most used ventilation mode during PVD episodes.

PVD prolonged ICU stay, and the duration of mechanical ventilation also affected sedation requirements and increased ICU mortality.

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