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Impact of Minimizing Asynchronies in Mechanical Ventilation on Patient's Outcome in Pediatric Intensive Care Unit

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Background: Patients-ventilator asynchrony defined as a mismatch between the patient's respiratory effort and the ventilator delivered breaths and it is common in clinical practice. Patient ventilator interaction is a key element in optimizing MV. The change from inspiration to expiration is a crucial point in the mechanically ventilated breaths and is termed cycling, PVA may occur if the flow at which the ventilator cycles to exhalation does not coincide with the termination of neural inspiration. Ideally, the ventilator terminates inspiratory flow in synchrony with the patients neural timing, but frequently the ventilator terminates early or late.
Aims: The aim of this study was to detect the prevalence of asynchrony during assisted MV, IT and DT were the two main patterns of asynchrony.

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Patients and Methods: This prospective study was carried out upon 60 patients from 2 to 180 months, 38 males and 22 females, with spontaneous triggering on MV, admitted to the PICU, Tanta University Hospital.
Results: Fortunately, ITI is increased with volume SIMV +PSV compared with pressure SIMV +PSV and PRVC. ITI is a highly significant diagnostic for synchronization. Pressure regulated volume control was better than pressure SIMV+PSV and both were better than volume SIMV +PSV proved by less ITI and increase mortality with ITI ≥10%.
Conclusion: Pressure regulated volume control was better than pressure SIMV+PSV and both were better than volume SIMV +PSV proved by less ITI and increase mortality with ITI ≥10%. The patient-ventilator synchrony is crucial in determining the patient comfort, MV duration, and survival ITI is diagnostic for synchronization. ITI, PIP/ITI on 1st day, and SpO_2 on 3rd day were significant predictors for synchronization.

Keywords: Asynchronies; mechanical ventilation; pediatric; PICU.

1. INTRODUCTION

In critically ill patients, mechanical ventilation (MV) aims to improve oxygenation and decrease the work of breathing and load on the respiratory muscles to support patients until their condition improves [1].

Optimal patient-ventilator interaction can help avoid excessive sedation, anxiety, discomfort, episodes of fighting on the ventilator, diaphragmatic dysfunction and atrophy due to disuse, potential cognitive alterations, prolonged mechanical ventilation, and additional lung or respiratory muscle injury [2].

Research has shown that patients ventilated for 24 hours who can trigger the ventilator have a high incidence of asynchrony during assisted mechanical ventilation [3].

Asynchrony is common throughout MV, [4] occurs in all MV modes, and might be associated with a bad outcome, especially when they occur in clusters [5].

Patient-ventilator asynchrony (PVA) exists when the phases of breath delivered by the ventilator do not match those of the patient [6]. To meet the patient's demands, the ventilator's inspiratory time and gas delivery must match the patient's neural inspiratory time [7].

Asynchronies occur with minimal differences between day and night, and the most prevalent asynchrony overall and in every MV mode is ineffective inspiratory efforts, followed by double triggering [8].

When the entire period of MV is taken into account, asynchronies are slightly more frequent in pressure support ventilation (PSV) than in volume control-continuous mandatory ventilation or pressure control-continuous mandatory ventilation [9].

Nevertheless, within each mode, the settings for peak airflow, airway pressure, minute ventilation, rise time, and the criteria to terminate inspiration can strongly affect asynchrony generation, ITI and PIP/ITI are highly significant diagnostic for synchronization [10].

The efforts to minimize asynchrony are being observed and its beneficial outcome on patient morbidity is expected to have a fruitful end.

2. PATIENTS AND METHODS

This prospective study was carried out upon 60 patients from 2 to 180 months, 38 males and 22 females, with spontaneous triggering on MV, admitted to the PICU, Tanta University Hospital. This study was conducted between September 2020 and July 2022.

2.1 Ethical Considerations

- The study was accepted by the Research Ethics Committee of Faculty of Medicine Tanta University before starting the field work.
- An informed consent was signed by all the patients.
- Explanation of the study aim in a simple manner to be understood by the common people.
- The patient had the right to get a copy from the informed consent.
- No harmful maneuvers were performed or used.

- All data were considered confidential and did not used outside this study without patient's approval.
- All patients were notified with the results of imaging.
- Patients had the right to withdraw from the study at any time without giving any reason and were excluded from the study.
- The patient did not pay for any investigations in the research.

The studied patients were divided according to MV modes into three groups:

Group (I): Twenty patients on pressure SIMV+ PSV mode.
Group (II): Ten patients on volume SIMV+ PSV mode.
Group (III): Thirty patients on PRVC mode.

Inclusion criteria:

All patients aged from 2 months to 15 years, on invasive MV with spontaneous triggering for at least 7 days.

Exclusion criteria:

- Age more than 15 years old.
- Positive end-expiratory pressure > 9 cm H2O.
- Ventilation through a tracheotomy.
- Inability to initiate breaths including that due to neuromuscular-blocking agents
- Patient with neuromuscular disorders.

2.2 Methods

All studied patients were subjected to:

(1) Detailed history taking:

- Demographic data: name, age, sex, socio-economic status.
- Cause of PICU admission and MV.
- Length of PICU stay.
- Duration and mode of MV.

(2) Thorough clinical examination:

- Anthropometric measurements.
- Vital signs (blood pressure, heart rate, respiratory rate, temperature).

(3) Neurological examination:

- Conscious level (all patients was on midazolam (Dormicum ®) sedative from 0.5-2 mic/kg/ hr intravenous infusion.

(4) Routine investigation:

(5) Setting for three modes:

a) Setting for the patients on pressure SIMV +PSV:

1. Driving airway pressure: PIP (range from 12-22 cm H2O) and PEEP (range from 5-8 cm H2O).
2. Other Ventilator settings: FiO2 (range from 0.21- 0.4), triggering (range from 1-2 L/min (or) -1- -2 cm H2O), pressure support (range from 5-8 cm H2O), RR (according to age mostly between 10-35 cycle / minute), Ti (differ with RR change mostly from 0.4-1second).
3. Airflow (inpiratory flow and expiratory flow).

Monitoring:

1. ITI (either ≥ 10% or <10%), I:E ratio (keep I:E ratio range ≈1.5:2.5).
2. VE (range from 7-12 L/min), SpO2 (targeted around 92%-95%).

b) Setting for the patients on volume SIMV +PSV:

1. Tidal volume (range from 4-8 mL/kg) and PEEP (range from 5-8 cm H2O).
2. Other ventilator settings: FiO2 (range from 0.21- 0.4), triggering (range from 1-2 L/min (or) -1- -2 cm H2O), pressure support (range from 5-8 cm H2O), RR (mostly between 10-35 cycle /minute), Ti (0.4-1second).

Monitoring:

1. ITI (either ≥10% or <10%), I:E ratio (keep I:E ratio range ≈1.5:2.5), VE (range from 7-12 L/min), SpO2 (targeted around 92%-95%).
2. Airflow Flow Sensor is a medical accessory used to accurately measure the flow of gases in Ventilators and Anesthesia workstations also known as Respiratory gas monitors (RGM). The flow sensor in a RGM measures the flow rate and derives to give Inspired and Expired volume of the patient during ventilation (inspiratory flow and expiratory flow).

c) Setting for the patients on PRVC:

1. Tidal volume (range from 4-8 mL/kg), PEEP (range from 5-8 cm H2O), and

driving pressure limit (range from 20-25 cm H2O).
2. Other ventilator settings: FiO2 (range from 0.21- 0.4), triggering (range from 1-2 L/min (or) -1- -2 cm H2O), pressure support (range from 5-8 cm H2O), RR (mostly between 10-35 cycle /minute).
3. Airflow (inspiratory flow and expiratory flow).

Monitoring:

1. Plateau pressure (range from 15-25 cm H2O).
2. ITI (either ≥ 10% or <10%), I:E ratio (keep I:E ratio range ≈1.5:2.5), VE (range from 7-12 L/min), SpO2 (targeted around 92%-95%), Ti (0.4-1second).
3. All of these data were measured every 2 hours on admission, 3rd and 7th days. The mean was calculated for every single day.

Ventilators used were:

1. Raphael (Hamilton Medica l AG.CH-7403, Rhazuns, Switzerland).
2. Vela (Model 16186-07, Serial no. AGT 04378, Bird Products Corporation CareFusion, India).
3. Neumovent (TECME S.A., Calle publica sin, Altav. la voz Del interior 5400X500BHJY, Cardoba, Argentina).
4. E-vent Medical (Inspiration tm LS company, model 2007WO30258, Ireland).
5. FlexiMag plus (Magnamed Ventilator Company, model 1756, Brazil).
6. MEK (MEKICS CO ventilator company, model MV2000, Korea).
7. GE (General Electric, model CARESCAPE R860, USA).

Types of asynchrony monitored and their managing strategies:

- Double triggering: was defined as two cycles separated by a very short TE, less than one-half of the mean inspiratory time, the first cycle being patient-triggered. It was managed by decreasing sedation and checking breathing frequency.
- Trigger asynchrony: in which the patient's inspiratory effort fails to trigger the ventilator. It was managed by checking trigger sensitivity, excessive air trapping, excessive inspiratory, time or excessive pressure support.
- Auto-triggering: is typically seen when respiratory drive is low, RR is low, and when there is no PEEP. It was managed by checking trigger sensitivity, air leak or water in circuit.
- Delayed Triggering: the patient is able to trigger a breath but gas flow delivery is abnormally delayed. It was managed by checking for air trapping, excessive assistance or auto-PEEP, check for comfort and tidal volume.

2.3 Statistical Analysis

Statistical analysis was done by SPSS v27 (IBM©, Chicago, IL, USA). Shapiro-Wilks test and histograms were used to evaluate the normality of the distribution of data. Quantitative parametric data were presented as mean and standard deviation (SD) and were analysed by unpaired student t-test [11,12].

Quantitative non-parametric data were presented as the median and interquartile range (IQR) and were analyzed by Mann Whitney-test [13].

Qualitative variables were presented as frequency and percentage (%) and were analyzed utilizing the Chi-square test or Fisher's exact test when appropriate [14]. Repeated measures ANOVA was performed to compare the three measures within the same group [15].

Two-tailed P value ≤ 0.05 was considered statistically significant.

3. RESULTS

Table 1 shows that regarding PIP: There was highly significant increase in group I compared with group II and III on the 1st, 2nd and 3rd days. Otherwise there was non-significant difference between studied groups.

Table 1. Comparison among the studied groups regarding peak inspiratory pressure (cm H_2O)

			Group I P- IMV+PSV (n = 20)	Group II V- SIMV+PSV (n = 10)	Group III PRVC (n = 30)	Test	p		
PIP	1st day	Mean±SD	16.65±3.17	13.8 ±3.61	14.25 ±2.59	F= 49.036	0.006*	p1	0.034*
		Range	11-22	10-21	10-18			p2	0.002*
								p3	0.876
	2nd day	Mean±SD	16.85 ±2.46	14 ±0.82	13.6 ±0.68	F = 15.454	<0.001*	p1	<0.001*
		Range	14-21	13-15	13-15			p2	<0.001*
								p3	0.184
	3rd day	Mean±SD	18.5 ±2.06	15.5 ±1.51	14.95 ±1.76	F = 16.630	<0.001*	p1	<0.001*
		Range	15-21	13-17	13-18			p2	<0.001*
								P 3	0.469

Cm H_2O: centimeter water, PIP: Peak inspiratory pressure, PRVC: Pressure-regulated volume control, P-SIMV: Pressure-Synchronized intermittent mandatory ventilation, PSV: pressure support ventilation, V-SIMV: Volume-Synchronized intermittent mandatory ventilation

** significant as p <0.05, P1: p between group I and group II, P2: p between group I and group III, P3: p between group II and group III, F: one-way ANOVA*

Table 2. Validity of ITI for Diagnosis of Synchronization

Cut off	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	P	AUC
ITI >10	88.89% (51.8 - 99.7)	98.04% (89.6 - 100.0)	88.9% (53.1 - 98.3)	98.0% (88.7 - 99.7)	<0.001*	0.927

ITI: ineffective triggering index.

** Significant as p-value ≤0.05*

Table 3. Logistic Regression of Different Variables for Prediction of Synchronization

	Coefficient	St. Error	P
Age (years)	0.004	0.008	0.573
Sex	-0.022	0.081	0.786
Duration of ventilation	-0.003	0.002	0.229
ITI	0.049	0.010	<0.001*
PIP	0.010	0.012	0.435
PIP/ITI at 1st day	-0.034	0.015	0.035*
FiO_2 at 1st day	0.013	0.008	0.140
FiO_2 at 2nd day	-0.006	0.009	0.474
FiO_2/ITI at 1st day	0.010	0.008	0.248
SpO_2 at 3rd day	-0.101	0.040	0.014*
PS at 3rd day	-0.015	0.030	0.607
RR/ITI at 1st day	-0.004	0.008	0.558

FiO_2: fraction of inspired O_2, ITI: ineffective triggering index, PIP: peak inspiratory pressure, PS: pressure support, RR: respiratory rate, SpO_2: oxygen saturation
** Significant as P value≤0.05*

In regression analysis, ITI, PIP/ITI on 1st day and SpO_2 on 3rd day were significant predictors for synchronization (Table 3).

4. DISCUSSION AND CONCLUSION

The present study showed that there was a significant increase of PIP with ITI ≥ 10% compared with ITI < 10% on the 1st and 2nd days. There was a highly significant increase in PIP in P-SIMV group compared with V-SIMV group and PRVC on the 1st, 2nd and 3rd days.

In accordance to the present study, thrill et al. [1] found that patients with high incidence of DT, ITI had higher values of PIP, this may be due to the associated increased severity of lung injury.

However, De wit et al. [16] found that no correlation between PIP and asynchrony. This may be explained by the small sample size (pilot study).

The present study showed that there was highly significant increase of PEEP with ITI ≥ 10% compared with ITI <10% on 2rd and 3rd day and There was significant increase in V-SIMV+PSV group compared with P-SIMV+PSV group and PRVC group on 1st day.

In accordance to the present study, Nava et al. [17] found that lower level PEEP in patients with COPD and high levels of intrinsic PEEP reduce the frequency of asynchrony.

This may be explained by that lower PEEP improve synchrony by reducing dynamic hyperinflation and improve the quality of sleep in chronically ventilated patients [17].

However, Chao et al. [2] and Varon et al. [18] found that applying 5 cm H2O of external PEEP had no influence on ITI.

This may be explained by their patient's diagnosis (intrinsic PEEP in COPD) [19].

The present study showed that there was significant increase of RR with ITI ≥10% compared with ITI < 10% in 1st and 2nd day and There was a highly significant increase in T_I with ITI ≥10% compared to ITI <10% on 2nd and 3rd day.

In accordance to the present study, Purro et al. [20] found that high RR occur with increased IT.

This may be explained by that the increase in frequency was proportional to the decrease in ventilator inspiratory time, IT occurs when the patient's demand is high, and TI on the ventilator is too short [20].

However, Tassaux et al. [21] found that ITI was less frequent with high RR in patients with COPD.

This may be explained by the high flow often used for lowering intrinsic PEEP by achieving a shorter TI and thus allowing more time for exhalation. In patients with COPD changing the cycle criteria to a higher percentage of peak inspiratory flow (high frequency) decreased ITI and improve PVI [21].

The present study showed that there was a significant increase in MV duration with ITI ≥ 10% compared with ITI < 10%.

In accordance with the present study, Chao et al. [2]. Thille et al. [1] and De wit et al. [16] found that patients with an asynchrony index ≥10% had a longer duration of MV.

This may be explained by those patients with an ITI ≥10% were more likely to require more than a week of MV due to inappropriate ventilator setting or greater disease severity [22].

However, Nava et al. [23] found that no correlation between high-level asynchrony and the duration of MV. This may be explained by their usage of ventilator settings leading to a reduced frequency of wasted efforts.

CONSENT AND ETHICAL CONSIDERATIONS

The study was accepted by the Research Ethics Committee of Faculty of Medicine Tanta University before starting the field work. An informed consent was signed by all the patients.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Pettenuzzo T, Fan E. Mechanical ventilation. Respir Care. 2017;62(5):29-35.

2. Mauri T, Yoshida T, Bellani G, Goligher EC, Carteaux G, Rittayamai N, et al.; Pleural pressure working Group (PLUG—Acute Respiratory Failure section of the European Society of Intensive Care Medicine). Esophageal and transpulmonary pressure in the clinical setting: meaning, usefulness and perspectives. Intensive Care Med. 2016;42(9):1360-60.
3. Thille AW, Rodriguez P, Cabello B, Lellouche F, Brochard L.; Patient-ventilator asynchrony during assisted mechanical ventilation. Intensive Care Med. 2006; 32(10):1515-22.
4. Blanch L, Villagra A, Sales B, Montanya J, Lucangelo U, Luja´n M, et al.; Asynchronies during mechanical ventilation are associated with mortality. Intensive Care Med 2015;41(4): 633-41.
5. Vaporidi K, Babalis D, Chytas A, Lilitsis E, Kondili E, Amargianitakis V, et al.; Clusters of ineffective efforts during mechanical ventilation: impact on outcome. Intensive Care Med 2017;43(2):84-91.
6. Gilstrap D, MacIntyre N.; Patient–ventilator interactions. Implications for clinical management. Am J Respir Crit Care Med. 2013;150(4):896-903.
7. Murias G, Villagra A, Blanch L.; Patient-ventilator desynchrony during assisted invasive mechanical ventilation. Minerva Anestesiol 2013;79(4):34-44.
8. Kallet RH.; Patient-ventilator interaction during acute lung injury, and the role of spontaneous breathing: part 1: respiratory muscle function during critical illness. Respir Care 2011;56(2): 81-89.
9. Sassoon CS. Triggering of the ventilator in patient-ventilator interactions. Respir Care 2011;56(1):39-51.
10. Georgopoulos D, Prinianakis G, Kondili E.; Bedside waveforms interpretation as a tool to identify patient-ventilator asynchronies. Intensive Care Med 2006; 32(1):34-47.
11. Mishra P, Pandey CM, Singh U, Gupta A, Sahu C and Keshri A. Descriptive statistics and normality tests for statistical data. Ann Card Anaesth. 2019;22(1): 67-72.
12. Mishra P, Singh U, Pandey CM, Mishra P and Pandey G. Application of student's t-test, analysis of variance, and covariance. Ann Card Anaesth. 2019;22(4): 407-11.
13. Vermeulen K, Thas O, Vansteelandt S. Increasing the power of the Mann-Whitney test in randomized experiments through flexible covariate adjustment. Stat Med. 2015;34(6):1012-30.
14. Pandis N. The chi-square test. Am J Orthod Dentofacial Orthop. 2016;150(5): 898-9.
15. Shen J and He X. Generalized F test and generalized deviance test in two-way ANOVA models for randomized trials. J Biopharm Stat. 2014;24(3): 523-34.
16. Vignaux L, Vargas F, Roeseler J, Tassaux D, Thille AW,Kossowsky MP, et al. Patient-ventilator asynchrony during non-invasive ventilation for acute respiratory failure: a multicenter study. Intensive Care Med. 2009;35(5): 840-6.
17. Ostermann ME, Keenan SP, Seiferling RA, Sibbald WJ. Sedation in the intensive care unit: a systematic review. JAMA. 2000; 283:1451-9.
18. Fabry B, Guttman J, Eberhard L, Bauer T, Haberthur C, Wolff G, et al. An analysis of dysynchornization between the spontaneously breathing patient and ventilator during inspiratory pressure support. Chest. 1995;107(5):1387-94.
19. Vitacca M, Bianchi L, Zanotti E, Vianello A, Barbano L, Porta R, et al. Assessment of physiologic variables and subjective comfort under different levels of pressure support ventilation. Chest. 2004;126: 851-9.
20. Purro A, Appedini L,Degateono A. Appedini L, A physiological determinants of ventilator dependence in long term mechanically ventilated patients. Am J Respir Crit Care Med. 2000;161(4pt1): 1115-23.
21. Tassaux D, Gainnier M, Battisti A, Jolliet P. Impact of expiratory trigger setting on delayed cycling and inspiratory muscle workload. Am J Respir Crit Care Med. 2005;172(10):1283-9.
22. Thille AW, Cabello B, Galia F, Lyazidi A, Brochard L. Reduction of patient- ventilator asynchrony by reducing tidal volume during pressure support ventilation. Intensive Care Med. 2005;172(10):1283-9.

23. Pohlman MC, Mc Callister KE, Schweickert WD, Pohlman AS, Nigos CP, Krishman JA, et al. Excessive tidal volume from breath stacking during lung protective ventilation for acute lung injury. Crit. Care Med. 2008;36(11):3019-23.

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