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Original Article (Pages: 17487-17494)

Oxygenation and Ventilation Indices in Relation to the Duration of Mechanical Ventilation in 2-Month to 14-Year-Old Children Admitted to PICU

Zahra Pourramazan [1], * Nemat Bilan [2], Farinaz Amirikar [3]

[1] Pediatric Health Research Center, Tabriz University of Medical Sciences, Tabriz, Iran.

[2] Professor, Pediatric Health Research Center, Tabriz University of Medical Sciences, Tabriz, Iran.

[3] Assistant professor, Pediatric Health Research Center, Tabriz University of Medical Sciences, Tabriz, Iran.

Abstract

Background: Respiratory diseases are the most common cause of death in the pediatric population and acute or progressive respiratory failure, which requires mechanical ventilation, is the most common cause of children's hospitalization in the intensive care unit. Despite advances in recent decades regarding the treatment of acute respiratory diseases in children and innovative settings in mechanical ventilation, there are no clear and comprehensive guidelines for the use of mechanical ventilation in children.

Objective: This research aimed to evaluate the correlation between oxygenation and ventilation indices in predicting the duration of mechanical ventilation in children aged two months to 14 years old admitted to PICU.

Methods: In this cross-sectional study, 56 patients were included. The required information was extracted from the patients' clinical records and entered into the prepared questionnaires. They included age, sex, and diagnosis, duration of intubation, extubation time, mechanical ventilation parameters, and blood gas parameters. Patients' blood and ventilation data were collected and calculated from the first day of mechanical ventilation until 7 days later to calculate Oxygenation (OI) and Ventilation (VI) indices.

Results: Pneumonia, the most common cause of hospitalization in the intensive care unit and the need for intubation, was present in our population (82%) due to aspiration and Covid-19 disease. There was a significant relationship between higher levels of FiO2 and longer duration of patients' intubation ($P < 0.001$). The amount of PIP in each of the first days of intubation was significantly correlated with the duration of the study. A significant direct relationship was found between the ventilation index and oxygenation index. ($P < 0.05$) Except for the sixth day, oxygenation index and duration of intubation were significantly correlated. ($P < 0.05$) This means that along with the increase in oxygenation index, the duration of intubation was also increased. Ventilation index and duration of intubation were also significantly correlated, except on the fourth and fifth days ($P < 0.05$). None of the extubated patients required re-intubation. Eventually, a very weak statistical correlation was found between the intubation period and the final result in the form of discharge and recovery of the patient or his death.

Conclusion: Using variables such as gender, PIP and oxygenation, and ventilation indices, in the early days of mechanical ventilation, the prognosis of these patients and better management of their treatment can be judged. It is, finally, emphasized that further studies on larger populations, with more variables and long-term follow-ups are required.

Key Words: Blood gasses, Intubation, Oxygenation index, Ventilation index.

* Please cite this article as: Pourramazan Z, Bilan N, Amirikar F. Oxygenation and Ventilation Indices in Relation to the Duration of Mechanical Ventilation in 2-Month to 14-Year-Old Children Admitted to PICU. Int J Pediatr 2023; 11 (03):17487-17494. DOI: **10.22038/ijp.2023.66353.4989**

Corresponding Author:

Nemat Bilan, Professor, Pediatric Health Research Center, Tabriz University of Medical Sciences, Tabriz, Iran. Email: bilannemat@yahoo.co.uk

Received date: jul.04,2022; Accepted date: Mar.02,2023

1- INTRODUCTION

Respiratory failure is the main reason for admission of children to the intensive care unit. Mechanical ventilation is considered as an effective method in the PICU department and is widely used in the treatment of critically ill patients with acute respiratory failure (ARF) to maintain adequate gas exchange (1). Therefore, mechanical ventilation is the main therapeutic tool used in the pediatric intensive care unit. Proper use of this tool is difficult due to the often complex pulmonary manifestations and developmental differences in children, in the functioning of the respiratory system in certain age groups of children (2). The lungs of infants and children are not the same as those of adults. Numerous changes occur from birth to adulthood in the hardness and function of the human lung. Smaller and narrower airways are an important risk factor for respiratory diseases in infancy and childhood. At birth and even in the early years of life, corticosteroids, mechanical ventilation, oxygen, nutritional disorders, and inflammation may affect alveolar formation (3). Invasive mechanical ventilation (MV) is a common practice in pediatric intensive care units, but may lead to a variety of complications that lead to increased mortality and serious illness (4). Among patients admitted to the Pediatric Intensive Care Unit (PICU), about 40 to 60% are intubated and mechanically ventilated (5) .Optimizing strategies to improve patient-ventilator synchronization has been a vital goal in reducing the adverse clinical consequences of mechanical ventilation (6). MV) mechanical ventilation) time is directly related to patient infection, upper airway trauma, longer hospital stay, more complications, stress, increased treatment costs, and increased mortality (7). Therefore, determining the best time to separate from the ventilator and timely extubation seems necessary, though it is often neglected in children (8). And the efficiency of predictor parameters for separating the respiratory tract from the ventilator of patients, including respiratory rate, fractional inspired oxygen (FIO2), and PAO2 should be investigated. Limited re-intubation is required to estimate the successful extubation time for patients (9). Therefore, the aim of this study, conducted for the first time in our country, was to investigate the correlation between oxygenation and ventilation indices in predicting the duration of mechanical ventilation in two-months to 14-year-old children hospitalized in PICU to identify patient prognosis and treatment interventions. It is helpful during the early stages of the disease, thus invasive mechanical ventilation is performed on patients.

2- MATERIAL AND METHODS

This cross-sectional study included 56 children (6 months to 14 years old) who underwent intubation and mechanical ventilation with a diagnosis of respiratory distress at the PICU of Tabriz Children Hospital and were willing to participate in the study. The study period was 6 months from December 2021 to May 22. All patients who refused to participate in the study, patients with hemoglobinopathies, patients with neuropathy, intubation patients who were sent to Tabriz Children's Center from other hospitals were excluded from the study.

2-1. Sample size

Based on the trend of previous referrals and according to similar studies, an estimated 50 cases were considered sufficient, and finally, 56 patients were included in the present study.

2-2. Materials and Methods

In this study, the patients' information during the period of intubation was recorded. The data included intubation

time, extubation time, mechanical ventilation parameters (PC, Respiratory rate, MAP, FiO2, PEEP), and blood gas parameters (PaO2, PaCO2). Patients' blood and ventilation data were collected from the first day of mechanical ventilation to calculate oxygenation (OI) and ventilation (VI) indices. Indication of weaning and extubation of patients is based on the clinical decision of the pediatric lung specialist. Also, ventilator parameters for extubation include: FiO2 less equal to 0.4, pao2 more equal to 60, Spo2 more equal to 90%, and the number of breaths less equal to 10 per minute. Weaning failure was defined as the failure to pass a spontaneous-breathing trial or need for re-intubation and invasive mechanical ventilation during 72 h after weaning. The calculations of OI and VI indices are as follows:

$OI = [FiO_2 \times MAP \text{ (mean airway pressure)} \times 100]/PaO_2$

$VI = (PaCO_2 \times PIP \times \text{Respiratory rate})/1000$

$PIP = PEEP + PC$

The comparison between the study variables is to examine the correlation between OI and VI parameters in predicting the duration of aggressive mechanical ventilation through Pearson equation. Patients are divided into two groups based on the duration of invasive mechanical ventilation, less than and equal to 7 days and more than 7 days. Based on mortality, extubation failure was also compared between the study groups.

3- RESULTS

The study included 56 children comprising 30 (53%) boys and 26 (46%) girls. The mean age of the patients was 3 years. In both groups of the patients (<7 d & >7 d intubation) the age and sex of male and female patients had normal distribution. Pneumonia, the most common cause of hospitalization in the intensive care unit and the need for intubation, was present in our population (82%) due to aspiration (53%) and Covid-19 disease (29%). Diagnosis of covid19 was confirmed with PCR (**Table 1**). Extubation failure was not recorded in our study population.

Table-1: Demographic Data

Specification		Number	Percentage
Sex	Male	30	53.5
	Female	26	46.5
Intubation Duration	< 7	24	42.8
	< 7	22	39.2
Pneumonia	Covid19	30	53
	Others	16	29
Hydrocarbon Aspiration		2	3.57
Cystic Fibrosis		2	3.57
Drowning		4	7.14
Empyema		2	3.57

As you can see in **Table 2**, the mean FiO2 decreased during the intubation period. Also, a statistically significant relationship was found between FiO2 levels and duration of intubation in patients. Regarding the number of breaths, because a large number of patients had extubated or some had died before the 7th day of intubation, the mean number of breaths on the 7th day was disproportionately higher.

The number of breaths on all days had a direct and positive relationship with the number of days of intubation, except for the sixth day, in which they were negatively correlated.

Table-2: Ventilator data and the relationship between FIO2, PIP, RR, MAP, and intubation duration

Number of intubation days	FIO2*	P-value FIO2	PIP**	P-value PIP	RR***	P-value RR	MAP****	P-value MAP
Day 1	74	0.002	0.66	0.0001>	27	0.0001>	9	0.003
Day 2	65	<0.0001	0.72	0.0001>	22	0.0001>	9	0.0001>
Day 3	57	0.002	0.72	0.0001>	21	0.042	8	0.015
Day 4	55	0.024	0.72	0.0001>	19	0.039	8	0.097
Day 5	54	<0.0001	0.71	0.0001>	20	0.0001>	8	0.0001>
Day 6	51	<0.0001	0.68	0.0001>	21	0.0001>	8	0.0001>
Day 7	50	<0.0001	0.76	0.0001>	42	0.0001>	8	0.0001>

* Fraction of Inspired Oxygen; ** Peak Inspiratory Pressure; *** Respiratory Rate; **** Mean Airway Pressure

As you can see in **Fig.1**, Pearson correlation test revealed that the amount of PIP in each of the first days of intubation was significantly correlated with the length of hospital stay. This means that only for the PIP values of the first, third, fourth days, along with the increase in the amount, a longer duration of intubation was observed.

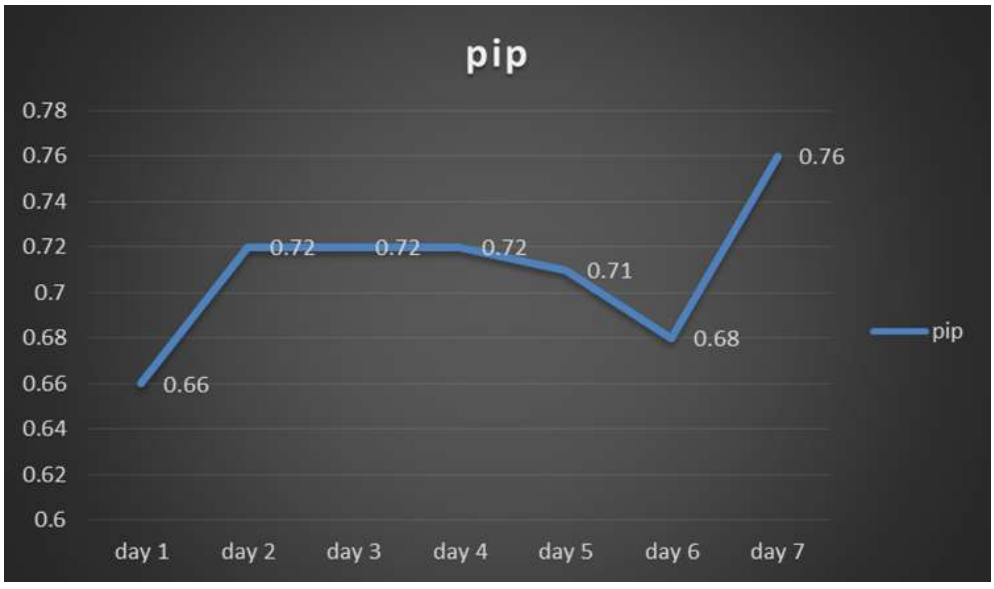

Fig. 1: Mean PIP in the first seven days of intubation

Fig. 2 shows the number of breaths per minute (RR), mean airway pressure (MAP) and Fraction of Inspired Oxygen (Fio2) during the first 7 days.

As you can see in **Fig. 2**, the mean FiO2 decreased during the intubation period and also a significant relationship was found between the FiO2 values and the duration of the patients' intubation. In the large number of patients who had had an extubation before the 7th day of intubation or some who had died, the mean number of breaths on the 7th day was disproportionately higher. The number of breaths on all days had a direct and positive relationship with the number of days of intubation, except on the sixth day, in which a reverse correlation was observed.

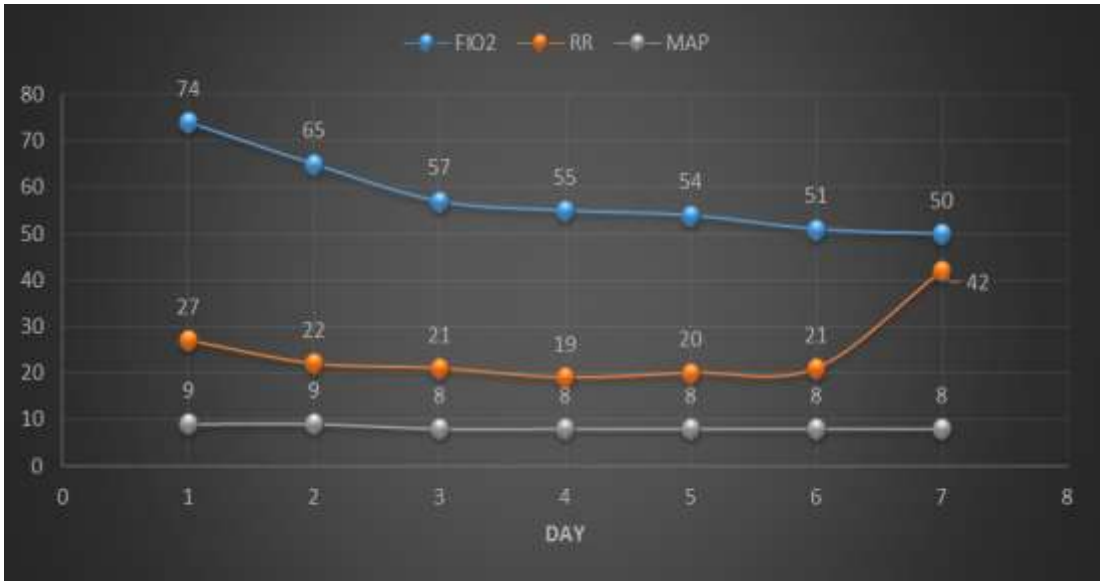

Fig. 2: Average rate of Ventilator characters in the first 7 days of hospitalization

3-1. Indicators of Oxygenation and Ventilation

Examining the correlation between ventilation index and oxygenation index, a significant direct relationship was found (P <0.05). Furthermore, Mann-Whitney test also revealed a significant relationship between oxygenation index and duration of intubation, except for the sixth day (P <0.05). This means that long with the increase in oxygenation index, a longer duration of intubation was observed. These results are presented in **Table 3**.

Table-3: Intubation duration in relation to oxygenation and ventilation

Number of intubation days	P-value Relationship indicators Oxygenation and ventilation	P-value Oxygenation Index	P-value Ventilation index
Day 1	0.0001>	0.001	0.001
Day 2	0.0001>	0.020	0.001
Day 3	0.0001>	0.001	0.023
Day 4	0.0001>	0.012	0.074
Day 5	0.0001>	0.040	0.072
Day 6	0.0001>	0.081	0.001
Day 7	0.019	0.001	0.001

The mean numbers of oxygenation and ventilation indices in patients who were under intubation for less than 7 days were much lower than in those who experienced more than seven days of intubation (**Fig. 3**). The mean Pearson correlation coefficient for seven days was about 0.4.

Regarding the relationship between ventilation index and duration of intubation, significant relationships were observed, except for the fourth and fifth days (P <0.05) this means that along with the increase in ventilation index, a longer duration of intubation was observed. The mean Pearson correlation coefficient for seven days was 0.2.

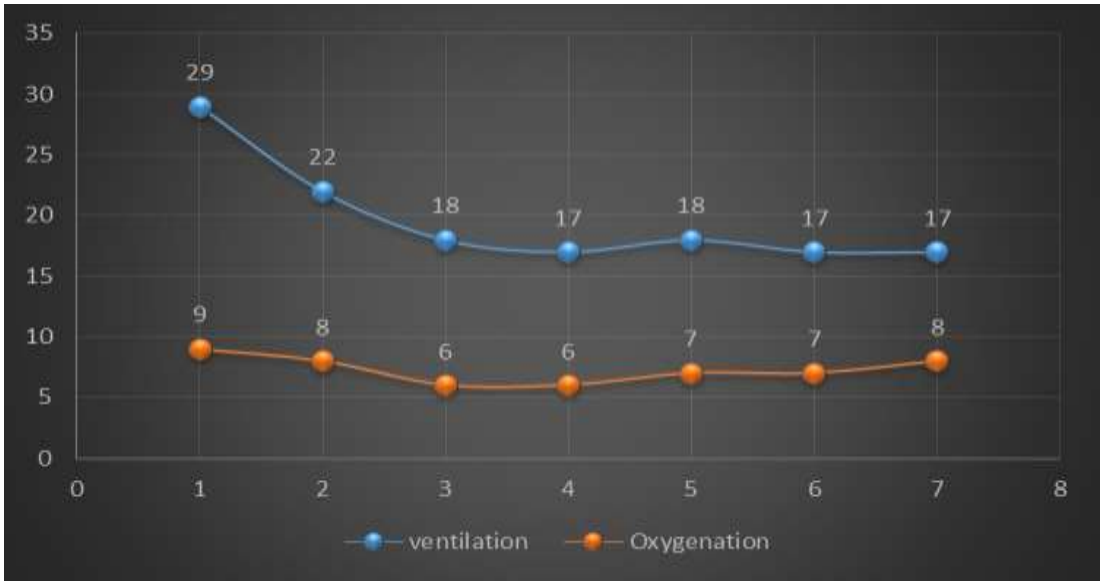

Fig. 3: Mean OI and VI in the first seven days of intubation

4- DISCUSSION

In the present study, it was demonstrated that the number of breaths in all days had a direct and positive relationship with the number of hospitalization days. Therefore, in general, the relative duration of their intubation can be predicted based on the number of patients breathing.

In a study conducted in 2018 by Rocha et al., on the relationship between oxygenation and ventilation indices and the time of invasive intubation in children, it was concluded that oxygenation and ventilation indices were related to the duration of invasive mechanical ventilation (10). In the present study, we examined the relationship between each of these indices and the duration of intubation. In examining the relationship between oxygenation index and the duration of intubation, except on the sixth day, a significant relationship was observed. Examination of the relationship between ventilation index and duration of intubation, also, revealed a significant relationship, except for the fourth and fifth days. According to two studies on patients' PIP, the level of PIP in patients with severe lung injury is directly related to patient mortality. This shows the extent to which the ventilator center can affect the patient's fate)11,12). In our study, increasing PIP values increased the duration of intubation. Continuing this path, we reached Daniel Trachsel and his colleagues who, in a study on 131 patients,

investigated the predictive factors in the result of intubation of these patients. They found that high OI and low age were directly related to prolonged intubation time in these patients. But in a more careful examination, they stated that the amount of OI cannot be accurately demarcated in order to achieve an accurate prediction about the patient's future. To be used as a predictive factor, it requires more detailed and extensive studies (13).

Hammondnv et al., studying 65 patients who underwent mechanical respiration in a children's hospital, concluded that this index can be used as a predictor in some patients, so that, with the increase in OI (Oxygenation Index), patient survival had decreased. For example, they reached a mortality of about 18%, in OIs above 17. In the present study, it was also shown that higher OI is associated with longer intubation duration (14). On the other hand, in a study conducted to examine the ventilation index, Almeida-Júnior et al. examined 29 neonatal patients with acute viral respiratory infection and acute respiratory failure requiring mechanical respiration. Among other side effects, they found that higher Ventilation Indices (VI) were directly related to longer intubation duration (15). These results are consistent with our achievement of the ventilation index. But like the oxygenation index, it needs more crystallization to be used in patients' clinics, and at the moment, with the available information, it cannot be used as a guide for patients' fate.

5- CONCLUSIONS

This study showed that the use of indicators such as blood gasses, specifications related to ventilator settings, oxygenation and ventilation indicators, can predict the clinical course of patients and can lead to the improvement of doctors' understanding of these patients and the modification of treatment recipes in order to achieve the best results and the lowest mortality. This will have a significant impact on reducing treatment costs and better management of resources.

6- ETHICAL CONSIDERATIONS

This study was approved by the Research Ethics Committee of Tabriz University of Medical Sciences. Informed consent forms were obtained from the parents of the patients participating in the study.

7- ACKNOWLEDGMENT

We would like to thank the Clinical Research Development Unit of Zahra Mardani Azari children educational and treatment center, Tabriz University of medical sciences, Tabriz, Iran, for their assistance in this research.

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