

Association between oxygenation and ventilation index with the time on mechanical ventilation in pediatric intensive care patients

Relação entre índice de oxigenação e ventilação com o tempo em ventilação mecânica de pacientes em terapia intensiva pediátrica

Relación entre índice de oxigenación y ventilación con el tiempo de ventilación mecánica de pacientes en unidad de terapia intensiva pediátrica

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ABSTRACT

Objective: To correlate the oxygenation index (OI) and the ventilation index (VI) with the time of invasive mechanical ventilation (IMV) in pediatric patients.

Methods: This prospective and observational study enrolled patients from 28 days to 14 years of age, admitted in the Pediatric Intensive Care Unit of a university hospital. The values of age, weight, pH, partial pressure of oxygen (PaO₂), partial pressure of carbon dioxide (PaCO₂), OI and VI were measured from day one to the day five and they were correlated with the time on IMV. The total time on mechanical ventilation was divided into: <7 days and ≥7 days.

Results: 28 patients were studied. The time spent on IMV showed a significant negative correlation with the pH on the fourth day and with the PaO₂ on the fifth day. The time on IMV showed a positive correlation with the OI on the third and fourth days and with the VI on the third, fourth and fifth days. There were significant differences in the age and pH on the fourth and fifth days and in the VI from the second to fifth days between the group that remained less than seven days and those that remained seven days or more on IMV.

Conclusions: VI, OI, pH and PaO₂ measured during the first five days of IMV were associated with prolonged IMV, reflecting the severity of the initial ventilatory disturb.

Key-words: respiration, artificial; pediatrics; intensive care.

RESUMO

Objetivo: Correlacionar o índice de oxigenação (IO) e o de ventilação (IV) com o tempo de ventilação mecânica invasiva (VMI) em pacientes pediátricos.

Métodos: Estudo prospectivo, observacional, com pacientes de 28 dias de vida a 14 anos de idade, internados na Unidade de Terapia Intensiva Pediátrica de um hospital universitário. Correlacionaram-se valores de idade, peso, pH, pressão parcial de oxigênio (PaO₂), pressão parcial de gás carbônico (PaCO₂), IO e IV, nos primeiros cinco dias em VMI, com o tempo em que o paciente permaneceu em VMI. O tempo total de ventilação mecânica foi dividido em <7 dias e ≥7 dias.

Resultados: Foram estudados 28 pacientes. Houve correlação negativa significante do tempo de VMI com o pH

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Conflito de interesse: nada a declarar

Recebido em: 22/6/2010

Aprovado em: 17/12/2010

no quarto dia e com a PaO_2 no quinto dia. Houve correlação positiva com o IO no terceiro e quarto dias e com o IV no terceiro, quarto e quinto dias. Houve diferença na idade e pH no quarto e quinto dias e IV do segundo ao quinto dias entre o grupo que permaneceu menos de sete dias e o que permaneceu sete dias ou mais em VMI.

Conclusões: IO, IV, pH e PaO_2 , medidos precocemente, associaram-se com VMI prolongada, refletindo a gravidade do distúrbio ventilatório inicial.

Palavras-chave: respiração artificial; pediatria; cuidados intensivos.

RESUMEN

Objetivo: Correlacionar el índice de oxigenación (IO) y el de ventilación (IV) con el tiempo de ventilación mecánica invasiva (VMI) en pacientes pediátricos.

Métodos: Estudio prospectivo, observacional, con variables de pacientes de 28 días de vida a 14 años de edad, internados en la Unidad de Terapia Intensiva Pediátrica de un Hospital Universitario. Se correlacionaron valores de edad, peso, pH, PaO_2 , PaCO_2 , IO e IV los primeros 5 días en VMI, con el tiempo que en que el paciente permaneció en VMI. El tiempo total de ventilación mecánica fue dividido en <7 días y ≥ 7 días de VMI.

Resultados: Se estudiaron 28 pacientes. Hubo correlación negativa significativa del tiempo de VMI con el pH el cuarto día, PaO_2 el quinto día y correlación positiva con el IO el tercero y cuarto días e IV el tercero, cuarto y quinto días. Hubo diferencia en la edad y pH el cuarto y quinto días e IV del segundo al quinto días entre el grupo que permaneció menos de 7 días y el grupo que permaneció 7 días o más en VMI.

Conclusiones: El IO, IV, pH y PaO_2 medidos tempranamente fueron asociados con VMI prolongada, reflejando la gravedad del distúrbio ventilatorio inicial.

Palabras clave: ventilación mecánica/monitoración; pediatria; cuidados intensivos.

Introduction

Invasive mechanical ventilation (MV) of pediatric patients in intensive care units is a routine procedure, but may lead to several complications that increase morbidity and mortality in cases of severe diseases⁽¹⁾. Moreover, long periods

receiving MV increase the incidence of complications, such as nosocomial infections, upper airway trauma and stress, as well as costs⁽²⁾. Therefore, the time during which a patient receives MV should be shortened, and spontaneous ventilation should be resumed as soon as possible⁽¹⁾.

The evaluation of factors associated with time receiving MV may generate important data to optimize the care provided to these patients⁽³⁾. Oxygenation and ventilation indices (OI and VI) are currently used to evaluate MV duration and/or the severity of ventilation disorders⁽³⁻⁸⁾ in pediatric patients, as well as to evaluate therapeutic interventions⁽⁹⁻¹³⁾.

This study evaluated the correlation between OI, VI and other ventilation and blood gas variables with MV duration in children in a Pediatric Intensive Care Unit (PICU).

Method

This prospective longitudinal study was conducted in the PICU of *Hospital de Clínicas of Universidade de Campinas* (Unicamp) from June 1 to October 20, 2006. This study was approved by the Ethics in Research Committee of the School of Medicine of Unicamp.

All patients aged 28 days to 14 years who required MV for at least 24 hours were included in the study. Patients were excluded if they were MV-dependent before the study, became dependent after hospitalization, or died during data collection.

Data were collected during 5 MV days: blood gases, pH, partial oxygen pressure (PaO_2), partial carbon dioxide pressure (PaCO_2), HCO_3^- , oxygen saturation (SatO_2) and MV parameters - fraction of inspired oxygen (FiO_2), peak inspiratory pressure (PIP), positive end-expiratory pressure (PEEP), respiratory rate (RR) and inspiratory time.

The VI was calculated as: $\text{PaCO}_2 \times \text{PIP} \times \text{mechanical RR}$ divided by 1,000. The OI was calculated as: $\text{mean airway pressure} \times \text{FiO}_2 \times 100$ divided by PaO_2 . OI and VI were calculated daily in the first MV days; when blood gases were measured more than once a day, the highest FiO_2 , mechanical RR, mean airway pressure and PaCO_2 and the lowest PaO_2 were selected to calculate the indices.

Age (years) and the values of pH, PaO_2 , PaCO_2 , OI and VI obtained on the first five MV days were correlated with MV duration. Also, the differences between these variables were analyzed, and the patients were divided into two groups: MV for less than 7 days; and MV for 7 or more days. This division was adopted because prolonged mechanical

ventilation has been defined as ventilatory support for more than seven days.

The SPSS for Windows 7.5.1 (SPSS Inc, Chicago, IL) was used to prepare the database and conduct the statistical analyses. The association between two continuous variables was analyzed using the Spearman correlation coefficient (rs). To analyze statistically significant differences between the two groups, less than 7 MV days and greater than or equal to seven MV days, the nonparametric Mann-Whitney test was used. The level of statistical significance was set at $p < 0.05$.

Results

During the study, 34 patients were admitted to the PICU and received MV. Of these patients, six were excluded due to the following factors: two received MV for less than 24 hours; three died; and one was transferred to another PICU before extubation. Therefore, 28 patients were included in the study: 12 (43%) were boys; median age was 0.9 years (0.1 to 11.4 years); and median time receiving MV was 9.1 days (2.7 to 58.7 days).

The patients were distributed according to MV indications (Table 1). Table 2 shows the variables that correlated with MV duration and reveals that the OI had a positive correlation with MV duration on the third and fifth days and with VI on the third, fourth and fifth MV days.

The classification into two groups, less than 7 MV days or greater than/equal to seven MV days, revealed that seven patients (25%) received MV for less than seven days, and 21, for seven or more days. Table 3 describes the variables that were statistically different between the two groups and shows that VI was higher from the second day on in the group of patients that received MV for more than seven days, which reflects the greater severity of their conditions.

Discussion

In this study, there was a positive correlation of OI and VI with MV duration starting on the third MV day. Similar findings have been reported in most studies that have investigated the association of these indices with MV duration and severity of the disease under study. Peters *et al* did not find any significant differences when comparing OI and VI

Table 1 - Patient distribution according to indications for invasive mechanical ventilation

MV indications	n (%)
Restrictive and/or obstructive lung disorder, or in upper or lower airways	24 (86%)
Cardiovascular disorders	2 (7%)
Cardiac surgery postoperative care	2 (7%)

Table 2 - Correlation between monitoring lung function variables and mechanical ventilation duration

	Spearman correlation coefficient (rs)
pH 4 th day	-0.61*
PaO ₂ 5 th day	-0.60*
OI 3 rd day	0.52*
OI 5 th day	0.65*
VI 3 rd day	0.45*
VI 4 th day	0.47*
VI 5 th day	0.52*

OI: oxygenation index; VI: ventilation index; * $p < 0.05$

Table 3 - Monitoring lung function variables expressed as median (minimum and maximum) according to mechanical ventilation duration

	<7 MV days	≥7 MV days	p*
Age (years)	2.3 (0.7 to 6.1)	0.5 (0.1 to 11.3)	0.014
pH 4 th day	7.47 (7.38 to 7.57)	7.38 (7.25 to 7.50)	0.045
pH 5 th day	7.46 (7.44 to 7.52)	7.40 (7.35 to 7.55)	0.035
VI 2 nd day	20.8 (9.5 to 28.7)	32.32 (10.8 to 94.5)	0.026
VI 3 rd day	13.8 (2.8 to 22.6)	31.32 (9.5 to 114.6)	0.003
VI 4 th day	18.1 (10.5 to 22.9)	34.28 (10.5 to 80.6)	0.010
VI 5 th day	13.35 (10.41 to 22.1)	32.57 (8.2 to 76.2)	0.035

* Mann-Whitney test; VI: ventilation index.

between survivors and non-survivors of acute respiratory failure, but their data were collected only on the first and second MV days. In contrast, Paret *et al*, who calculated the VI on the first 10 MV days in children with acute respiratory distress syndrome (ARDS), found significantly higher values for non-survivors on the third, fifth, sixth, ninth and 10th MV days than for survivors. In the study conducted by Almeida *et al*, the pH and VI variables were associated with time receiving MV, and their results were similar to the ones found in our study. However, those authors conducted their study with infants that had acute viral bronchiolitis, and the association between the VI and time receiving MV was seen as early as on the second day. Trachsel *et al* analyzed the OI in a group of children with acute respiratory failure and reported that the same index was significantly predictive of prolonged MV when collected from the second MV day on.

The younger the age, the greater the lung immaturity, the smaller the number of alveoli and the more predominant the type-1 muscle fibers, which results in greater propensity to fatigue and the need for longer recovery times. This may explain why this study found a lower median age in the group that received prolonged MV when the patients were classified according to MV duration.

The pH values on the fourth and fifth days showed a statistically significant decrease in the group of patients with MV for 7 or more days. However, median pH on these days in the group that received MV for less than 7 days showed

alkalemia, which suggested that ventilatory support was excessive and that the ventilation parameters should have been reviewed.

The VI was statistically different between the two groups on the second to the fifth days, and was a good marker of the need for MV for more than seven days when its values were elevated. To evaluate whether the VI is a good predictor of prolonged MV in infants and children, further controlled studies should be conducted.

The OI on the third and fifth days had a positive correlation with MV time, but PaO₂ on the 5th day had a negative correlation with MV duration. However, when patients were classified into two groups according to MV duration, there were no statistically significant differences in these values. The reduced number of patients included in the study may explain this fact and be considered a limitation of this study, as the patients could not be grouped according to age, which would provide a more detailed evaluation of their condition.

The analysis of age, pH and VI collected sequentially suggests that these markers may be used as possible predictors to support prolonged MV. The confirmation of the association of these markers with ventilatory support duration may become useful in routine pediatric practice for the adaptation and control of mechanical ventilation in PICUs. Clinical studies with larger samples may clarify the differences between patients that receive MV for shorter or longer times.

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