Hemodynamic effects of noninvasive ventilation with facial mask in premature infants

Efeitos hemodinâmicos da ventilação não invasiva com máscara facial em prematuros

Efectos hemodinámicos de la ventilación no invasiva con máscara facial en prematuros

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ABSTRACT | Premature infants present inspiratory muscles disadvantage of their biomechanics, which predisposes to muscular fatigue and airway collapse, therefore noninvasive ventilation (NIV) is the choice expansion therapy for this population. Despite this, studies concerning the risk and beneficial effects of its application by facial mask in neonates are not available. The aim of this study was to evaluate hemodynamic variables in premature infants (PTI) submitted to NIV by facial mask, as a therapeutic resource. It is a case series study, in which 14 PTI were evaluated, with gestational age (GA) <37 weeks, both genders, according to indication of lung expansion therapy. The PTI were evaluated before, during, immediately after, 30 and 60 minutes after application of NIV, and a heart rate (HR), blood pressure (BP) and peripheral oxygen saturation (PO_2S) were collected. It was observed a significant increase in PO_2S when compared the moment during to the moment before the application of NIV (96.95 [94.98; 99.48] versus 99.15 [97.98; 100.00], p<0.05). Non-significant variations of HR and mean BP resulting from NIV by facial mask were observed. With the present results, it is suggested that NIV by facial mask is beneficial for the PTI, without adding hemodynamic instability.

Keywords | Infant, Premature; Intermittent Positive-Pressure Ventilation; Physical Therapy Specialty.

RESUMO | Recém-nascidos prematuros apresentam desvantagem mecânica dos músculos inspiratórios, predisposição à fadiga muscular e colapso das vias aéreas. A ventilação não invasiva (VNI) é a terapia de expansão de escolha para essa população. No entanto, não existem estudos sobre a avaliação do risco-benefício de sua aplicação por máscara facial em neonatos durante a fisioterapia respiratória. O objetivo desse estudo foi avaliar variáveis hemodinâmicas em recém-nascidos prematuros (RNPT) submetidos à utilização da VNI por máscara facial para terapia de expansão pulmonar. Trata-se de um estudo quase experimental do tipo antes e depois, em que foram avaliados 14 RNPT, com idade gestacional (IG) <37 semanas, de ambos os sexos, com indicação de terapia de expansão pulmonar. Os RNPT foram avaliados antes, durante, imediatamente após, 30 e 60 minutos após a aplicação da VNI, tendo sido coletados frequência cardíaca (FC), pressão arterial (PA), pressão arterial média (PAM) e saturação periférica de oxigênio (SpO_2). Foi observado um aumento significativo da SpO_2 quando comparados os momentos antes e durante a aplicação da VNI (96,95 [94,98; 99,48] *versus* 99,15 [97,98; 100,0], p<0,05). Não foram observadas variações significativas da FC e PAM decorrentes da VNI por máscara facial. Com os presentes resultados, sugere-se que a VNI por máscara facial é benéfica para o recém-nascido, sem promover instabilidade hemodinâmica.

Descritores | Prematuro; Ventilação com Pressão Positiva Intermitente; Fisioterapia.

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RESUMEN | Recién nacidos prematuros presentan desventaja mecánica de los músculos inspiratorios, predisposición a la fatiga muscular y colapso de las vías aéreas. La ventilación no invasiva (VNI) es la terapia de expansión de elección para esa población. Mientras tanto, no existen estudios sobre la evaluación del riesgo-beneficio de su aplicación por máscara facial en neonatos durante la fisioterapia respiratoria. El objetivo de este estudio fue evaluar variables hemodinámicas en recién nacidos prematuros (RNPT) sometidos a la utilización de la VNI por máscara facial para terapia de expansión pulmonar. Se trata de un estudio casi experimental del tipo antes y después, en que fueron evaluados 14 RNPT, con edad gestacional (IG) <37 semanas, de ambos sexos, con indicación de terapia de expansión pulmonar. Los RNPT fueron evaluados antes, durante, inmediatamente después de 30 e 60 minutos de la aplicación de la VNI, habiendo sido colectados frecuencia cardíaca (FC), presión arterial (PA), presión arterial media (PAM) y saturación periférica de oxígeno (SpO_2). Fue observado un aumento significativo de la SpO_2 cuando fueron comparados los momentos antes y durante la aplicación de la VNI (96,95 [94,98; 99,48] *versus* 99,15 [97,98; 100,0], p<0,05). No fueron observadas variaciones significativas de la FC e PAM resultantes de la VNI por máscara facial. Con los presentes resultados, se sugiere que la VNI por máscara facial es benéfica para el RN, sin promover inestabilidad hemodinámica.

Palabras clave | Anciano; Ventilación con Presión Positiva Intermitente; Fisioterapia.

INTRODUCTION

Premature infants (PTI), including those with gestational age between 34 and 36 weeks, considered of lower risk, present anatomic and physiological peculiarities which make them more susceptible to respiratory complications, such as mechanical disadvantage of the inspiratory muscles, predisposition to muscle fatigue and airway system collapse[1,2].

Respiratory disorders are responsible for the largest parcel of complications related to prematurity, which increases the need for invasive and noninvasive respiratory support, making the presence of a respiratory physical therapist inside the neonate intensive care unit (NICU) more and more necessary each time[3-7]. However, there is still little evidence in literature which evaluates the risk-benefit relation of the physical therapeutic resources in the population of PTI, which are, many times, selected according to the evidence of its application in the pediatric and adult population[3,8,9].

Besides knowing the benefits of the physical therapeutic resources to be used, it is important to make sure the elected resource does not cause alterations in the PTI's hemodynamic parameters, considering that this population is most likely to have variations in the systemic blood pressure (BP) as a result of various factors, such as vasomotor tonus alterations, decrease of ventricular compliance, effect of applied positive pressure during ventilator support and the respiratory muscle activity[10,11]. The variability of BP is related to the floating of the brain's blood flow, what implies the risk of intraventricular hemorrhage[10], white matter injury and worse motor outcome[12].

The noninvasive ventilation (NIV) is a resource used by physical therapists who work in ICU. There are still no data on its applications as a physical therapeutic resource in NICU. When applied, it can be offered as continuous positive pressure in respiratory airways (nasal continuous positive airway pressure – NCPAP) or as nasal intermittent positive airway pressure (NIPPV), with interfaces that include masks (facial and nasal ones) and prongs[13]. Its physiological benefits include the stabilization of the respiratory airways; increase of functional residual capacity of lung volume and of the gas exchange surface; decrease of airway resistance and the pulmonary shunt; inflation of the previously collapsed alveoli and the normalization or minimization of the respiratory work[14-17].

The scientific evidence regarding physiological alterations, resulting from the use of NIV as a therapeutical resource in neonates, are still sparse. Given the above, the present study aimed to evaluate the hemodynamic variables of premature infants (PTI) submitted to the use of NIV, through facial mask, as a therapeutic resource for lung expansion therapy.

METHODOLOGY

This study was approved by the Ethics and Research Committee involving human beings from the Hospital Agamenon Magalhães, under the CAAE n. 0199.0.236.000-10, and was carried out in the period from July 2010 to May 2011 in the Neonate Intensive Care Unit of a high complexity public hospital in the city of Recife (PE), being the data for this study obtained only for the purposes of this research. The anonymity of the newborns was maintained.

A Quasi-experimental study was conducted, using a pre-post test design. A convenient, consecutive sample was selected, formed by premature infants of both sex, of gestational age (GA) <37 weeks, birth weight (BW) <2.500 g, with at least 48 hours of life and without the use of vasoactive drugs. We also included PTI who were using continuous positive airway pressure (NCPAP), through nasal prongs, in oxygen therapy by oxi hood (oxygen supplementation device) or in room air, considered to be more susceptible to hypoventilation.

The PTI included were all in treatment with the respiratory physical therapist and were indicated to lung expansion therapy by the physical therapist in service. The indication included the presence of signs of distress (intercostals, subcostal and fucula prints; esternal depression; nose flaring).

As exclusion criteria, were considered the PTI who were in NIPPV mode through nasal prongs, bearers of genetic syndromes and/or malformations of airways, undrained pneumothorax, necrotizing enterocolitis diagnosis, intestinal obstruction, abdominal pathologies (omphalocele/gastroschisis), congenital diaphragmatic hernia, active gastrointestinal bleeding and obstruction of the upper airways. After verifying the elegibility criteria, the mothers or responsible for the NB were contacted and informed of the objectives of the research in order to allow their participation in such by signing the Informed Consent form (IC).

Then, anthropometric (gestational age, birth weight and current wight) and clinical (gender, APGAR at 5 minutes, admission diagnosis into neonate ICU, history and usage of the ventilaroty support) data were collected, from the patients' charts.

After collecting the data of the patients, an assessment was carried out through the observation of the PTI in five moments: before, during, immediately after, 30 minutes after and 60 minutes after the use of noninvasive ventilation with facial mask. The lung expansion therapy was carried out for 10 minutes.

In the moments before, immediately after, 30 and 60 minutes after the use of NIV, the PTI was assessed for 5 minutes, being collected the heart rate (HR) and the peripheral oxygen saturation (PO_2S) in minutes 1, 3 and 5; during the 5 minutes only one blood pressure assessment was conducted. As the NIV procedure lasted 10 minutes, the newborn was observed during this time, being collected the HR and the PO_2S in minutes 1, 5 and 10.

The NIV by facial mask, as a therapeutical resource for the lung expansion therapy, was conducted using the NICU mechanical ventilators, depending on the bed the patient was in, those being: Inter 3 Plus, Inter 3, Inter Neo and Inter 5 Plus (Intermed® EquiBPento Médico Hospitalar, São Paulo, Brazil). The parameters adjusted in the NIV by facial mask were: minimum positive inspiratory pressure (PIP) required for a thoracic expansion of 1 cm, measured by measuring tape (Butterfly, Shanghai – China), positioned below the nipple line; positive end expiratory pressure (PEEP) of 5 cmH_2O; inspiratory time (IT) of 0.45 sec.; adjusted respiratory rate (aRR) of 15 breaths per minute (bpm); flow of 10 L/min. The last two parameters may vary according to the need of each patient, expressed by the poor adaptation of the PTI to the NIV by mask. However, all the PTI included presented good adaptation to the parameters described, without the need for adjustments. The inspired fraction of oxygen (iFO_2) was the same previously used by the NB. Those who were in room air received the NIV with $iFiO_2$ of 21%.

The HR and the PO_2S were obtained by the monitors PM 9000 Express Mindray (manufactured by Shenzhen Mindray Bio-Medical Eletronics CO, LTD, China), DX2023 and Dixtal DX2022 (manufactured by Dixtal, Manaus), and the BP was obtained by the monitos PM 9000 Express Mindray (manufactured by Shenzhen Mindray Bio-Medical Eletronics CO, LTD, China), with cuffs adequate to premature infants, on the left arm, in dorsal decubitus.

For the statistical analysis, the STATA/SE 9.0 and the Excel 2007 softwares were used. All the tests were conducted with 95% of confidence, and the results presented in tables with their respective absolute and relative frequency. The numerical variables are represented by the central tendencies and dispersion measures. In order to verify the distribution of quantitative variables the Kolmogorov-Smirnov normality test was carried out; for the comparative analysis of the measured variables among different moments, the Wilcoxon paired test was used (for non-normal distributed data).

RESULTS

The sample consisted of 14 PTI who presented the following diagnostic hypotheses: respiratory distress syndrome (RDS) (92.85%), perinatal infection (21.43%) and hypoxia (28.57%).

The clinical and anthropometric data regarding the newborns in the sample are described in Table 1. For the thoracic expansion of 1 cm, during the NIV by facial

mask, it was not necessary elevated values of PIP, considering that a median value of 15 cmH_2O was used (Table 1).

In Table 2, it can be verified that the HR remained unaltered in four moments. The values of diastolic arterial pressure (DAP) and mean arterial pressure (MAP) were also not influenced by the use of the NIV by facial mask ($p>0.05$). Only the sistolic arterial pressure (SAP) presented a statistically significative decrease after 60 minutes of use of the NIV, but without clinical significance, since its value remained within the normality range for the age. In addition to that, a significative increase of the PO_2S during the NIV with facial mask was observed.

Table 1. Carachteristics of the sample

Variables	n	%
Gender		
Male	7	50.0
Female	7	50.0
Type of labor		
Caesarian	10	71.4
Vaginal	4	28.6
Type of ventilatory support		
RA	5	35.7
HALO	5	35.7
CPAP	4	28.6
	Median	**[Q1; Q3]**
GA (weeks)	29.00	[28.46; 31.65]
Birth weight (grams)	1,148.00	[991.00; 1,343.00]
Days of life	8.00	[2.75; 15.00]
MVTime (h)	36.00	[0.00; 168.00]
NIVP Time (h)	30.50	[13.50; 120.00]
CPAP Time (h)	24.00	[4.50; 33.00]
Halo Time (h)	2.50	[0.00; 30.00]
RA Time	0.00	[0.00; 48.00]
PIP to LET	15.00	[15.00; 18.00]

GA: gestational age; MV: mechanical ventilation; NIVP: noninvasive ventilation by prongs; CPAP: continuous positive airway pressure; RA: room air; PIP: positive inspiratory pressure; LET: lung expansion therapy

DISCUSSION

In this study, there was a significant improve of the PO_2S during the application of the NIV, without alterations in the hemodynamic parameters, considering that HR and BP were maintained similar to basal levels in the moments during and after the use of NIV. Studies about the effects of the NIV as a therapeutic resource in neonates were not found.

It was reported that, in premature infants, the positive intrathoracic pressure decreases the right venous blood return, both systemic and pulmonar, without compromising the left ventricular output nor changing the heart rate and blood pressure[18]. Mortiz *et al.* also did not observe hemodynamic effects with the use of positive intrathoracic pressure, offered noninvasively[19].

In premature infant, when there is a reduction of lung compliance, the pressure transmitted to the vascular system is reduced to one fourth, and the blood does not perfuse the collapsed alveoli, so then there is an increase in pulmonary vascular resistance. The use of noninvasive intrathoracic positive pressure produces the reexpansion of the lung, optimizing lung volume and minimizing pulmonary vascular resistance, which improves the left venous return and cardiac output[18,20].

The oscilations in systemic blood pressure are directly proportinal to the oscilations of brain blood flow in prematures due to the fails in the self-regulation mechanism, but the data regarding developmental delay or brain injury due to these perfusion fluctuations are conflicting[21]. Borch *et al.* observed that blood pressure bellow 29 mmHg are related to

Table 2. Comparison of the hemodynamic parameters in the moments before, during, immediately after, after 30 minutes and after 60 minutes of the use of noninvasive ventilation

Variables	Moment*				
	Before	During	Immediately after	30' after	60' after
	Median [Q1; Q3]	Median [Q1; Q3]	Median [Q1; Q3]	Median [Q1; Q3]	Median [Q1; Q3]
HR	145.15 [132.63; 158.00]	137.65 [133.65; 157.90]	140.50 [126.88; 149.40]	139.95 [131.08; 158.28]	140.80 [123.80; 152.80]
SAP	64.50 [56.25; 82.25]	-	67.00 [57.75; 77.50]	64.00 [57.25; 81.25]	63.00 [56.00; 78.75][b]
DAP	41.50 [30.50; 47.25]	-	39.00 [33.75; 53.25]	38.00 [32.75; 47.50]	39.50 [33.75; 50.25]
MAP	48.00 [37.50; 58.25]	-	48.50 [40.50; 61.25]	45.00 [42.25; 58.00]	47.50 [41.00; 60.75]
PO_2S	96.95 [94.98; 99.48]	99.15 [97.98; 100.00][a]	97.65 [94.35; 99.15]	96.45 [94.90; 99.70]	98.15 [95.45; 99.48]

*Wilcoxon Test; [a]Significative difference between before and during, $p<0,05$; [b]Significative difference between before and 60', $p<0,05$; HR: heart rate; SAP: systolic arterial pessure; DAP: dyastolic arterial pressure; MAP: mean arterial pressure; PO_2S: peripheral oxygen saturation

the decrease of brain blood flow (specifically in the white matter), which may favor the occurence of ischemia[22]. In our sample submitted to the NIV by facial mask, the values of BP remained above these values in all assessed moments, what suggests the safety of its usage.

The studies in literature about physical therapy and the maintenance of cardiovascular stability in prematures investigated other physioterapeutic techniques, including motor physical therapy, so we were not able to compare our results with these studies. In these studies, the premature infants assessed did not present hemodynamic instability, keeping the HR and the BP within values considered to be normal[23,24].

Among the limitations of our study, we can mention the difficulty in measuring, in a noninvasive way, the blood pressure of the PTI, both for their neonate circulatory transition and for their own weight and limbs size[25]. This fact decreased the number of reproducible measures over the 60 minutes in which prematures were evaluated, reducing the sample. It is important to mention that this is a pioneer study on the theme, and so its findings may lead to future hypothesis and better investigation of the efficacy of this intervention in prematures, with more robust methodological study designs and other variables for the outcome assessment.

CONCLUSION

It may be suggested through the study at hand that noninvasive ventilation as a therapeutical resource, by facial mask, brings benefits to the premature newborns during their implementation, with increased peripheral oxygen saturation, without compromising hemodynamics, as shown by the maintenance of basal values of heart rate and blood pressure after its application.

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