

Influence of prone position on oxygenation, respiratory rate and muscle strength in preterm infants being weaned from mechanical ventilation

Influência da posição prona na oxigenação, frequência respiratória e na força muscular nos recém-nascidos pré-termo em desmame da ventilação mecânica

Influencia de la posición prona en la oxigenación, frecuencia respiratoria y en la fuerza muscular en los recién nacidos pre-término en destete de la ventilación mecánica

Rita de Cássia Malagoli¹, Fabiana Fagundes A. Santos², Eduardo Araújo Oliveira³, Maria Cândida F. Bouzada⁴

ABSTRACT

Objective: To verify the influence of preterm infant positioning on respiratory muscle strength, oxygenation and respiratory rate.

Methods: Cross-sectional study with a paired sample of intubated infants born with gestational age less than 34 weeks, in the final process of weaning from mechanical ventilation. Infants with malformation, genetic syndromes, neuromuscular diseases, tracheotomies and in the postoperative period of abdominal and thoracic surgery were excluded. Maximum inspiratory pressure measures were checked by a digital manometer; respiratory rate was visually observed during one minute and oxygen saturation was measured by a pulse oximeter in prone and supine postures. Kruskal-Wallis and Student's *t*-test and Pearson correlation coefficient were applied, being significant $p < 0.05$.

Results: 45 infants with respiratory distress syndrome were evaluated. The mean gestational age was 30.4 weeks and the mean birth weight was 1522g. The oxygen saturation was higher in prone position ($p < 0.001$). Values of maximum inspiratory pressure were lower in prone when compared to infants in the supine position ($p < 0.001$). Respiratory rate was similar in the two studied positions ($p = 0.072$).

Conclusions: There was a lower inspiratory pressure and a higher oxygen saturation in prone position when compared to the supine one. Concerning the respiratory rate there was no variation between prone and supine position.

Key-words: posture; infant, premature; oxygenation.

RESUMO

Objetivo: Verificar a influência do posicionamento do recém-nascido prematuro sobre a força da musculatura respiratória, oxigenação e frequência respiratória.

Métodos: Estudo transversal com amostra pareada de recém-nascidos com idade gestacional inferior a 34 semanas, intubados, em processo final de desmame de ventilação mecânica. Foram excluídos aqueles com malformações, síndromes genéticas, doenças neuromusculares, traqueostomizados e em pós-operatório de cirurgias abdominais ou torácicas. As medidas de pressão inspiratória máxima foram aferidas utilizando-se manovacuômetro digital; a frequência respiratória através da observação das incursões respiratórias das crianças em um minuto e a saturação de oxigênio por oxímetro, nas posturas prona e supino. Os testes estatísticos aplicados foram Kruskal-Wallis, o teste *t* de Student e o coeficiente de correlação de Pearson, sendo significante $p < 0,05$.

Instituição: Hospital das Clínicas da Universidade Federal de Minas Gerais (UFMG), Belo Horizonte, MG, Brasil

¹Mestre em Ciências da Saúde pela UFMG; Fisioterapeuta do Hospital das Clínicas da UFMG, Belo Horizonte, MG, Brasil

²Acadêmica de Medicina da UFMG, Belo Horizonte, MG, Brasil

³Doutor em Ciências da Saúde pela UFMG; Professor Titular da UFMG, Belo Horizonte, MG, Brasil

⁴Doutor em Ciências da Saúde pela UFMG; Professor Adjunto da UFMG, Belo Horizonte, MG, Brasil

Endereço para correspondência:

Maria Cândida Ferrarez Bouzada
Avenida Professor Alfredo Balena, 190 – sala 2.002
CEP 30130-100 – Belo Horizonte/MG
E-mail: bouzada@medicina.ufmg.br

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Resultados: Foram estudadas 45 crianças com síndrome do desconforto respiratório. A idade gestacional média foi de 30,4 semanas e o peso médio ao nascer de 1522g. Os valores de saturação de oxigênio foram mais elevados ($p < 0,001$) e os de pressão inspiratória máxima mais baixos ($p < 0,001$) na posição prona. Os valores de frequência respiratória foram semelhantes nas duas posições estudadas ($p = 0,072$).

Conclusões: Observaram-se menores valores de pressão inspiratória além de aumento da saturação de oxigênio na posição prona quando comparada à supino. Em relação à frequência respiratória, não foi observada variação entre as posturas prona e supino.

Palavras-chave: postura; prematuro; oxigenação.

RESUMEN

Objetivo: Verificar la influencia del posicionamiento del recién-nacido prematuro sobre la fuerza muscular respiratoria, oxigenación y frecuencia respiratoria.

Métodos: Estudio transversal con muestra pareada de recién nacidos con edad gestacional inferior a 34 semanas, entubados, en proceso final de destete de ventilación mecánica. Se excluyeron a aquellos con malformaciones, síndromes genéticos, enfermedades neuromusculares, traqueostomizados y en postoperatorio de cirugías abdominales o torácicas. Las medidas de presión inspiratoria máxima fueron verificadas mediante el uso de manovacuómetro digital; la frecuencia respiratoria, mediante la observación de las incursiones respiratorias de los niños en un minuto y la saturación de oxígeno por oxímetro, en las posturas prona y supina. Las pruebas estadísticas aplicadas fueron Kruskal-Wallis, la prueba t de Student y el coeficiente de correlación de Pearson, siendo significativa $p < 0,05$.

Resultados: Se estudiaron 45 niños con síndrome de dificultad respiratoria. La edad gestacional mediana fue de 30,4 semanas, y el peso mediano al nacer fue de 1522g. Los valores de saturación de oxígeno fueron más elevados ($p < 0,001$) y los de presión inspiratoria máxima más bajos ($p < 0,001$) en la posición prona. Los valores de frecuencia respiratoria fueron semejantes en las dos posiciones estudiadas ($p = 0,072$).

Conclusiones: Se observaron menores valores de presión inspiratoria, además de aumento en la saturación del oxígeno en la posición prona cuando comparada a la supina. Respecto a la frecuencia respiratoria, no se observó variación entre las posturas prona y supina.

Palabras clave: postura; prematuro; oxigenación.

Introduction

Prone position has been related to higher oxygenation due to the significant increase of the movement of the chest wall in this position⁽¹⁾ and due to the better synchronism between thorax and abdomen, caused by the fact that the incursion and the percentage of diaphragm shortening are higher in prone position than in supine⁽²⁾. Some studies indicate that the increase in current volume is responsible for the higher oxygenation in prone position^(3,4), as it is for the increase of functional residual capacity⁽⁵⁾, of the ventilation-perfusion ratio⁽⁶⁻⁷⁾ and of alveolar recruitment⁽⁸⁾.

Prone position may affect preterm infants' respiratory mechanisms, leading to changes in gas exchanges. Some studies on the positioning of preterm infants, with or without respiratory diseases, show a significant improvement in oxygenation in prone position, when compared to supine^(9,10). Prone position is also related to a better sleep pattern^(11,12), less variability in heart rate^(11,12), lower frequency of central and mixed apnea^(13,14), lower frequency of bradycardia and desaturation episodes during apnea periods⁽¹³⁾, besides being related to a higher respiratory rate (RR)⁽¹⁵⁾. However, RR variation was not reported on other studies^(16,17).

Some studies were performed to try to explain why oxygenation is improved when children are in the prone position^(3,5-9). Based on these studies, it can be inferred that the diaphragm acts as the main muscle when preterm infants breathe and that expiratory muscles are responsible for generating more strength in prone position. However, Dimitriou *et al*⁽¹⁸⁾ stated that the measurement of the maximum inspiratory pressure (MIP) were higher in the supine position than in prone, indicating that the higher oxygenation in the prone position is not due to the greater diaphragm strength in this position. Thus, the effects of positioning on the respiratory mechanisms responsible for the improvement of oxygenation in prone position were not yet completely clarified. The population of preterm children of the previous studies varied in relation to gestational age, presence or absence of respiratory compromise, used technique and measured pulmonary function parameters.

This study aimed to investigate and compare the influence of prone and supine positions on oxygenation, RR and respiratory muscle strength in preterm infants.

Method

This is a cross-sectional study with a paired sample in which each child is its own control. 45 children with a

gestational age of 34 weeks or less who were in the process of weaning from mechanical ventilation were assessed from June, 2006, to August, 2007. Every admitted child had a term of free and informed consent signed by its parents. The protocol of the study was approved by the Research Ethics Committee of Universidade Federal de Minas Gerais, Brazil. Children with malformations, genetic syndromes or neuromuscular diseases and those who suffered tracheotomy or who were in postoperative from abdominal or thoracic surgery were excluded from the study.

MIP, RR and oxygen saturation (SatO₂) measures were obtained when the child showed spontaneous breathing with over 30 breaths per minute (bpm) and a stable condition. The evaluation was performed when children had eaten at least an hour before, after two hours of sedation interruption, and when the children appeared not to be irritated or crying during measurement. For this study, patients were under cardiac monitoring, continuous non-invasive blood pressure monitoring (PNI), oximetry with a Dixtal® monitor and had their body temperature stabilized around 36–37°C in incubators. No child used steroids or bronchodilator before the measurement of respiratory data. The data were collected in the period up to two hours prior to extubation.

Each child was assessed just once, at the moment its clinical data were collected (birth weight, gestational age, Apgar score, sex, date of birth, type of delivery, use of aminophylline and/or steroids by the child, use of steroids by the mother, date of intubation, mechanical ventilation, post-extubation ventilatory support – continuous positive airway pressure (CPAP) –, extubation weight and occurrence of bronchopulmonary dysplasia). Soon after, MIP, RR e SatO₂ were measured in the prone and the supine positions, randomly chosen, beginning the assessment with the position the child was in at the moment.

The newborn was positioned in prone position over a roller placed longitudinally to the body, which maintained the chest wall and the abdomen stabilized. Thus, the abdomen remained restricted during breaths. The head was positioned to the right side, upper limb were in 90° abduction, external rotation of the shoulders and a 90° flexion of the elbows. The supine position was performed with head in midline, upper limbs adducted to the side of the chest wall, lower limbs slightly flexed (30–40°) in hips and knees. For both positions, prone and supine, the bed was 15° elevated.

Before measuring MIP, SatO₂ and RR, bronchial hygiene and adequate positioning of the child were performed,

followed by a 15 minute wait so the patient calmed down. The RR, MIP and SatO₂ were then measured in this order. The child's position was then changed and another 15 minute wait followed for the patient to stabilize. New measurements of RR, MIP and SatO₂ were then taken. The measurements were taken by the same examiner, randomly in relation to positioning.

MIP values were assessed using a MDV 300 (Globalmed®) digital vacuum manometer connected to a unidirectional valve which allowed expiration but not inspiration, and this valve was connected to the endotracheal tube. The MIP measurements were performed by the occlusion of the device for 20 seconds or at the most 10 spontaneous breath cycles of the child, with no drop in saturation below 85% or drop in heart rate below 90 bpm^(19,20). Three series of occlusions were performed, with a five-minute interval between them^(21,22). The highest value of inspiratory pressure was elected as MIP.

The saturation measures were collected with the oximeter (Dixtal®). Its sensor was fixed on the child's left foot. RR was measured by observing the occurrence of breaths in the children in one minute.

As no data was found in literature about the proportion of children who present MIP alteration in prone and supine position when weaning from mechanical ventilation, a pilot study was performed with 10 preterm infants, following the methodology described in this study. Results showed that 90% of children showed alterations when changing from the supine to the prone position or the reverse, that is, the first MIP measurement changed when the child was moved from the initial position. From these findings, the sample calculation was made with the computer program Epi-Info 6. To calculate the sample to be included in the study, two factors were considered: a study power of 80% and a significance level of 5%. The ratio of the level of exposed (prone position) and non-exposed (supine position) was considered as 9:10, that is, the frequency of MIP alteration in prone position was 90% and in supine, 100%. By using these parameters a sample of 34 children was calculated.

The comparison between continuous and categorical variables was made through a non-parametric test, the Kruskal-Willis test, calculated by Epi-Info. When comparing the values of the same patient in the supine and the prone position, the Student *t* test was used. When comparing two continuous variables, the Person coefficient correlation was calculated. $p < 0,05$ was considered significant.

Results

Forty-five preterm children, born with a mean gestational age of 30.4 weeks (26–34 weeks) and a mean birth weight of 1522g (700–2590g) were assessed. Of these, 23 (51%) were male and 25 (56%) were born through vaginal delivery. Twenty-four (53%) mothers had steroids for fetal lung maturation before delivery. Thirty-six (80%) children used surfactants.

The mean RR in the 45 studied newborns was 57bpm in supine position and 53.6bpm in prone ($p=0.072$). $SatO_2$ in supine was 93.5%, while in prone it was 96.8% ($p<0.001$). MIP was 53.4cmH₂O in supine and 43.9cmH₂O in prone ($p<0.001$) (Table 1).

Twenty-five (56%) of the 45 preterm children studied presented MIP in the supine position higher than the MIP average shown in the study that is, 53cmH₂O. Fourteen (56%) of these had a postconceptional age greater than or equal to 33 weeks.

Tables 2 and 3 show there is no correlation between the MIP and RR variation and any of the clinical characteristics analyzed: sex, type of delivery, use of surfactant by the child, use of steroids by the mother, use of ventilator support (CPAP) in the post-extubation period, need for reintubation, occurrence of bronchopulmonary dysplasia, gestational age, birth weight, weight at extubation, Apgar score at 5

minutes, duration of mechanical ventilation. However, patients who used surfactant had a higher variation in oxygen saturation than the ones who did not use it ($p=0.008$).

Discussion

This study showed an 87% $SatO_2$ increase in patients in the prone position, a datum confirmed by current literature, which indicates that this position improves oxygenation in children breathing spontaneously^(9,16,23,24) and in children under mechanical ventilation⁽²⁵⁾. This improvement in $SatO_2$ was not related to any other variable in the study, with the exception of the use of surfactant. This suggests an intrinsic causal factor, such as the physiological and mechanical changes in the respiratory tract caused by postural change or the use of surfactant.

The better oxygenation in prone position might suggest a higher efficacy of the diaphragm during its contraction, generating more strength, improving ventilation and, thus, optimizing gas exchange. Previous studies show that the prone position increases the tidal volume^(3,4), increases the functional residual capacity⁽⁵⁾ and leads to the stabilization of the chest wall with more synchrony between thorax and abdomen⁽¹⁾. However, it was also shown that MIP is smaller in prone position in comparison with supine⁽¹⁸⁾. This study also showed that MIP was smaller in prone in comparison

Table 1 - Measures of central tendency, dispersion and comparison of respiratory parameters in the supine and prone position in preterm infants being weaned from mechanical ventilation

	Supine	Prone	p-value
	Mean±SD	Mean±SD	
RR (bpm)	57.0±11.4	53.6±12.6	0.072
SatO ₂ (%)	93.5±11.6	96.8±11.6	<0.001
MIP (cmH ₂ O)	53.4±14.9	43.9± 5.5	<0.001

SD: standard deviation; RR: respiratory rate; bpm: breaths per minute; SatO₂: oxygen saturation; MIP: maximal inspiratory pressure

Table 3 - Variation in oxygen saturation (%) of preterm infants being weaned from mechanical ventilation

	Mean±SD	p-value
Male sex	1.74±1.60	0.330
Cesarean delivery	1.45±1.70	0.570
Surfactant use	1.92±1.59	0.008
Pre-delivery use of steroids	1.67±1.33	0.120
Reintubation	1.86±0.90	0.280
CPAP	1.52±1.38	0.850
bronchopulmonary dysplasia	1.71±0.78	0.450

SD: standard deviation; CPAP: continuous positive airway pressure

Table 2 - Correlation and determination of coefficients between clinical characteristics and maximal inspiratory pressure, oxygen saturation and respiratory rate of preterm infants being weaned from mechanical ventilation

	Respiratory rate		MIP		SatO ₂	
	r	p-value	r	p-value	r	p-value
Gestational age (weeks)	0.012	0.940	-0.098	0.524	-0.002	0.989
Birth weight (g)	-0.107	0.485	-0.151	0.321	-0.107	0.486
Extubation weight (g)	-0.067	0.660	-0.104	0.495	-0.096	0.531
Mechanical ventilation (h)	0.001	0.992	0.151	0.321	0.077	0.617

MIP: maximal inspiratory pressure; SatO₂: oxygen saturation.

to supine position ($p < 0,0001$). This decrease in inspiratory muscle strength in prone position might be due to the alteration in the length-tension relationship of the diaphragm, which occurs with postural change⁽²⁾.

The data found on respiratory rates are similar to the ones found in the literature, which found no influence of the prone or supine position on RR^(10,16,17).

This study was performed on prone and supine position with a head up tilt of 15°, what might have led to different results from others found. Differences between prone position with a head up tilt of 15° and supine position and a head up tilt of 0° were emphasized⁽²⁶⁾. Dimitriou *et al*⁽¹⁸⁾ showed a difference in MIP and SatO₂ when they compared the prone position with a head up tilt of 0° with the supine position with different head up tilts of 0° and 45°. MIP was higher in supine with tilts of 0° and 45° and SatO₂ was higher in prone and in supine with tilt of 45°. The position of the head may also affect the respiratory tract. The excessive flexion of the neck in newborns, especially preterm ones, can lead to airway obstruction and cause apnea⁽²⁷⁾. Dimitriou *et al*⁽¹⁸⁾ say there is no significant difference between the supine position with the infant's head in the midline and supine with the head turned to the right. In this study, prone position with head turned to the right and supine position with head in midline were used.

The time children stay in each position may also interfere in results. Some authors report effects of prone position in a short time, i.e., from 2 to 20 minutes^(5,10). Others indicated more benefits of the prone position, when the time children stay in it is longer, from 30 minutes to 48 hours^(15,19).

The prone position, in this study, was performed with abdominal support, i.e., with abdominal restriction. Abdominal support in prone position has been described both in adults and in children. However, Wagaman

et al⁽²⁸⁾, assessing intubated newborns, compared the prone position with free and restrict abdomen and concluded there is no significant difference between both positions related to the assessed parameters.

The MIP measurement technique also might influence results. This is another controversial topic in literature, since MIP measures are not standardized for children under five years old. With regard to respiratory muscle testing, and specifically the MIP measures, the American Thoracic Society/European Respiratory Society (ATS/ERS)⁽²⁹⁾ recommends, in the item measurement of muscle function in Intensive Care Unit, that the MIP of patients dependent on mechanical ventilation can be measured through a unidirectional valve, in which inspiration is blocked, causing the patient to reach the residual volume of the lung. Thus, the inspiratory pressure measured can be the maximum one. The highest MIP value generated usually occurs after 15–20 efforts or after 15–20 seconds of occlusion. MIP was measured in this study with a unidirectional valve connected to the endotracheal tube, which allows the child to inspire, but not to expire, thus increasing its lung volume to near total lung capacity. Some authors describe this technique in preterm infants^(15,18). The occlusion for the MIP measurement was performed throughout a period of 20 seconds, with a series of three occlusions, as reported above^(19,20). Adopted procedures for MIP measurement, period and methodology used to obtain SatO₂ and RR measures may also have influences the results.

In conclusion, smaller values of inspiratory pressure in prone position were found in comparison with supine position, besides and increase in oxygen saturation. Respiratory rate did not present a variation in prone position when compared to supine. However, further studies are needed for this position to be incorporated in the routine care of preterm infants.

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