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Results of airway clearance techniques in respiratory mechanics of preterm neonates under mechanical ventilation

Efeitos de técnicas de desobstrução brônquica na mecânica respiratória de neonatos prematuros em ventilação pulmonar mecânica

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ABSTRACT

Objectives: This research aimed to evaluate the impact of specific chest physiotherapy procedures in mean airway resistance and dynamic compliance on preterm infants under mechanical ventilation.

Methods: Eighteen preterm infants under conventional mechanical ventilation were submitted to one session of chest physiotherapy (manual chest compression during expiration + intermittent suction of intratracheal tube). Mean airway resistance and dynamic compliance measurements were taken before, 10, 40 and 70 minutes after intervention using a pneumotachograph with graphic display (Newport Navigator GM-250®), coupled to a flow transducer (Varfley-Bicore®). For analysis of results infants were divided into 2 groups; less than 5 days (group mechanical ventilation <5) and 5 days or more (group mechanical ventilation ≥5) on mechanical ventilation. Values were analyzed by Friedman Test, with Dunn's Multiple Comparisons Test ($p<0.05$ significant).

Results: In group mechanical ventilation <5 a significant reduction of mean airway resistance was observed at the 10^{th} minute after intervention ($p<0.05$). There were no significant alterations in dynamic compliance. The group mechanical ventilation ≥5 mean airway resistance had a significant reduction at the 10^{th} ($p<0.001$), 40^{th} ($p<0.05$) and 70^{th} ($p<0.05$) minute after intervention. Dynamic compliance improved significantly only at the 10^{th} minute ($p<0.05$).

Conclusions: Airway clearance techniques used in preterm neonates under conventional mechanical ventilation ≥5 improved mean airway resistance and dynamic compliance, with best results for the mean airway resistance.

Keywords: Infant, newborn; Respiratory mechanics; Physical therapy modalities

INTRODUCTION

Airway clearance techniques are the objective of respiratory physiotherapy and may be defined as external application of combined forces to increase mucus transport in the airways.[1] In newborn under mechanical pulmonary ventilation (MPV), these techniques were widely introduced and disseminated after the Gregory publication in 1971,[2] where indication of mechanical vibration and percussion associated to postural drainage to fluidize and displace lung secretion of neonates under MPV were first discussed.

Since then, studies on the effects of respiratory physiotherapy in high risk neonates have continued. However, results are controversial. Many of the physiotherapeutic techniques used, implementation, time and frequency of treatment, heterogeneity of the population and of methodological study in-

struments, found in literature justify inconsistency of results.[1,3] Notwithstanding controversies, the physiotherapist in the neonatal intensive care unit (NICU) has become a global reality.[3,4]

Concurrently, important changes in the profile of high risk neonates are the outcome of conceptual progress in neonatal intensive care, together with technology and specialized human resources. Currently, a growing number of very prematurely born neonates, with prolonged hospital stay has been observed. These prematures develop chronic pulmonary disease and are subject to multiple complications, reversible or not with significant social and economic consequences.[5] Concern in the quest for better conclusions on the effects of respiratory physiotherapy for bronchial clearance in this population has been growing.

Therefore the objectives of this study were: to verify the effects of association of respiratory physiotherapy techniques for airway clearance in mean resistance of the airway (Raw) and dynamic compliance (Cdyn) of preterm newborn (PTNB) under (PMV).

METHODS

This was a nonrandomized crossover clinical trial in which 18 PTNB (gestational age ≤37 weeks) were included. They were assessed by the Ballard[6] method under conventional PMV – continuous flow, time cycled and pressure limited – for at least 24 hours, with fraction of inspired oxygen (FiO_2) ≤0.6, positive inspector pressure (PIP) ≤30cmH_2O and respiratory rate (RR) ≤30 cycles per minute in the controlled mode, clinically stable under effect of analgesia and sedation. If they had been submitted to a procedure of intratracheal tube suction or had received surfactants, at least 8 to12 hours respectively, would have gone by before beginning the intervention. PRNB with clinical conditions suggesting atelactasis observed at clinical and/or radiological exam, or bearers of congenital malformations, with thoracic drains or gas flue around the intratracheal tube were excluded from the study. Gender, gestational age, Apache score at the 5th minute and time of PMV were considered.

Parents or those responsible signed an Informed Term of Consent for the survey, which was approved by the Research Ethics Committee on Human Beings of the Universidade Federal de Mato Grosso do Sul (CEP 106/2001).

The PTNB included in the study were submitted to respiratory physiotherapy intervention by a single physiotherapist. The objective was to achieve an increase in tracheobronchial secretion transport. This consisted of associating selective decubitus techniques, manual chest compression during expiration and aspiration of the intratracheal tube. Decubitus used were supine, right and left lateral and left semi-lateral with a 20° to 30° bed elevation. Body symmetry was respected and the head maintained in the middle line in all positions. Permanence in any position was according to response to intervention, such as absence of adventitious sounds suggestive of secretion in the airway corresponding to the chest region handled and absence of secretion aspired in the intratracheal tube. Manual chest compression was associated to decubitus and performed at the expiratory stage of the respiratory cycle, on the chest region in a non-dependent position. Pressure was sufficient to cause a quick expiratory chest displacement, without going beyond the equilibrium position, in view of the instability and tendency to collapse of the PTNB airways.[7] Suction was performed at least once in each decubitus by an ICU professional that helped the physiotherapist during intervention.

Non invasive monitoring of oxygen saturation (SpO_2) and heart rate (HR) were maintained and analyzed during the entire physiotherapy intervention. In cases of SpO_2 reduction below 87%, tachycardia or bradycardia (alterations >15% of that predicted for the age), the intervention was interrupted and FiO_2 increased by 10% over the baseline level. If the alteration persisted, the baseline respiratory rate level was increased 20 to 40% in the PMV equipment. By stabilizing SpO_2 and HR, the child was again ventilated with the initial parameters and intervention is resumed. If the SpO_2 and/or HR were not reversed with these actions, physiotherapeutic intervention would be interrupted and appropriate therapeutic measures carried out with data recorded and evaluated.

With the child in supine decubitus, once Raw and Cdyn pre-intervention had been measured in the 10th, 40th and 70th minute after physiotherapeutic intervention, using a pneumotachograph with graphic monitor (NewPort Navigator GM-250, NMI Newport Medical Instruments, INC, USA®), coupled to a flow transducer (Varfley-Bicore®) positioned between the intratracheal tube and the circuit the PMV equipment at the time of measurement. Recorded values corresponded to the mean of the last 10 respiratory cycles.

Results were statistically analyzed by the GraphPad Software®, Instat version 3.0, program with $p<0.05$ being significant. Continued variables were expressed by mean and mean standard deviation (SD) and categorical variables by frequency. For comparison of the variables gestational age, weight at birth and Apgar score, the Stu-

dent's t test was used. For comparison of the variables, age and PMV time, the Mann-Whitney test was used; gender was analyzed by the Fisher exact test. For all data of Raw and Cdyn, the Friedman test was performed with the Dunn's multiple comparison post test.

RESULTS

Eighteen PTNB in the ICU with diagnosis of newborn respiratory distress syndrome (RDS) were studied. The study was concluded in all children since there were no SpO_2 and HR instability episodes that would lead to interrupt interventions, according to criteria described in the method. Total Intervention duration ranged from 15 to 30 minutes.

Regarding birth conditions of the population under study, 11 were male and 7 female with a mean gestational age of 30.9 ± 1.9 SD weeks, mean weight at birth from 1233.6 ± 211.1 SD grams, mean Apgar score on the 5th minute of 8.2 ±1.1 SD. Means of age and PMV time, at study were 6.5 ±5.5 SD days of life and 5 ±3.2 SD days respectively.

Considering mean time of PMV at data collection (5 days) and mean (4.5 days) of the sample, newborns were stratified into two groups: less than 5 days PMV time (PMV<5) and 5 or more days of PMV (PMV≥5).

When variables for characterization of each group were compared, it was observed that there was only a significant difference for age and time of PMV (Table 1).

Regarding measurements of respiratory mechanics, it was noted that Raw decreased after intervention in both groups, especially in the PMV≥5, group (Table 2). In this group there was significant improvement of Raw at the 10^{th} minute ($p<0.001$), 40^{th} and 70^{th} minutes ($p<0.05$) after treatment. There was an improvement of Raw in the PMV<5 group, however it was only statistically significant at 10^{th} minute after treatment ($p<0.05$).

Impacts of interventions on Cdyn are shown in table 3. There was significant improvement ($p<0.05$) of Cdyn at 10^{th} minute after treatment in the group PMV≥5. No significant changes of Cdyn were observed in children of the PMV<5 group.

Table 1 – Comparison of the variables on newborn submitted to technique to increase bronchial secretion according to time of pulmonary mechanical ventilation

	PMV <5 days (n=9)	PMV≥5 days (n=9)	p Value
GI (weeks))	31.10 ±2.26	30.80 ±1.48	0.71
WB (grams)	1257.8 ±237.4	1202.8 ±194.3	0.55
Gender (m/f)	6:3	5:4	1.0
Age (days)	4.0 ±2.8	9.0 ±6.6	0.03
AS	8.0 ±1.3	8.3 ±1.0	0.56
Days of PMV	2.55 ±0.73	7.44 ±3.00	<0.001

GI – gestational age; WB weight at birth; m - male; f - female; AS - Apgar score at 5^{th} minute; PMV pulmonary mechanical ventilation at time of the study. Results expressed in mean ± standard deviation or number.

Table 2 – Evolution of mean airway resistance of newborn submitted to techniques to increase transport of bronchial secretion according to time of pulmonary mechanical ventilation

	Mean airway resistance ($cmH_2O/l/s$)			
	Pre-treatment	10th minute	40th minute	70th minute
PMV<5days(n=9)	68.35 ±15.17	62.73 ±19.04*	64.15 ±18.87	64.23 ±13.49
PMV≥5days(n=9)	80.23 ±17.51	64.39 ±16.84 †	64.45 ±13.64‡	63.49 ±13.49‡

PMV pulmonary mechanical ventilation. Results expressed in mean ± standard deviation. *$p<0.05$ relating pre treatment to 10^{th} minute; † $p<0,.01$ comparing pre with 10^{th} minute; ‡ $p<0.05$ comparing pre with 40^{th} and 70^{th} minutes.

Table 3 – Evolution of dynamic lung compliance of newborn submitted to the technique to increase transport of bronchial secretion according to time under pulmonary mechanical ventilation.

	Dynamic compliance (ml/cmH_2O)			
	Pre-intervention	10th minute	40th minute	70th minute
PMV<5diaysn=9)	0.69 ±0.21	0.68 ±0.22	0.75 ±0.29	0.76 ±0.29
PMV≥5days(n=9)	0.76 ±0.18	0.88 ±0.37*	0.83 ±0.25	0.84 ±0.28

PMV pulmonary mechanical ventilation.. Results expressed in mean ± standard deviation. *$p<0.05$ comparing pre with 10^{th} minute.

DISCUSSION

This study assessed impacts of the association of selective decubitus, manual chest compression techniques during expiration and intratracheal suction on the respiratory mechanics of PTNB under PMV.

The term airway clearance is often associated to tapotage and vibration techniques together with postural drainage. To avoid reductionism regarding the term "respiratory physiotherapy" De Boeck et al.,[8] in a recent publication, recommend that the expression "airway clearance technique " be used, always specifying the respiratory physiotherapy techniques for bronchial clearance, and taking into account that the different techniques may have different impacts in different situation.

Regarding results of respiratory mechanics, making analogies of this study with others is difficult since publications[9,10] on the effects of airway clearance in respiratory mechanics relate to populations and techniques with different specificities from those used in this study. These are premature and full term newborns in various states of consciousness, under PMV or spontaneous breathing, submitted to vibration and chest percussion, occasionally to postural drainage and suction applying these techniques for pre-established and different periods. In such studies no improvement of respiratory mechanics was found when using airway clearance techniques. Heterogeneity of studies in the area is highlighted in literature review regarding evidences of benefits of these techniques for airway clearance in children[8] and also in a systematic review of literature and Meta analysis about respiratory physiotherapy to reduce morbidity of newborn requiring ventilatory support.[3]

Measurements of respiratory mechanics in PTNB under PMV have been used to diagnose and establish the evolution of respiratory diseases, as well as in research to assess effects of therapeutic interventions.[14] They are defined by characteristics of flow, lung volume, length and radius of the airways and by inspired gas composition.[15] According to the Poiseuille law, resistance to flow through a cylinder is inversely proportional to the fourth power of the cylinder's radius. Thereby, considering that basal airway resistance in neonates is greater in children in relation to adults, presence of secretion in the intratracheal tube and in the airways may significantly contribute to increase of resistance, because it causes a decrease in the diameter of these ways.[16]

Given that this study was conducted so that measurements were performed without changes in the diameter and length of the intratracheal tube, in the parameters of the PMV equipment or in the gas composition, possibly, changes in the diameter of the airway of newborn aided by removal of bronchial secretion established the significant decrease of mean resistance of the airway in the newborn under study according to the measurements taken after intervention. Removal of tracheobronchial secretion of the PTNB studied, caused decrease of resistance to passage of airflow due to removal of the secretion, with probable decrease of the resistance imposed to the flow.

Substantiating this hypothesis, more evident responses to the intervention were observed in the PMV≥5 group, that presented higher levels of basal Raw (Table 2), possibly due to greater accumulation of bronchial secretion in this group, since newborn were under PMV for longer periods. The artificial airway and PMV favor production and drying of secretion, causing airway obstruction and loss of the mucocilliary function.[3,17,18] Furthermore, children of the PMV≥5 group had been exposed for more days, to sedation (a therapy often used in neonates under PMV), that reduced the coughing reflex and elimination of secretion, leading to clinical conditions that course with pulmonary infection.[19]

Effects of time on PMV on the tracheobronchial secretion were proven by a study where through cytopathologic evaluation of the tracheal aspirate of 108 children under PMV, it was observed that in the first 4 days of PMV destroyed cells of the bronchial epithelium were found and a large amount of preserved and intact cells. However, in children ventilated for 4 and 10 days, some small clusters of preserved bronchial cells were seen, many deteriorated, also leukocytes, monocytes and macrophages,[18] showing occurrence of an intense inflammatory process associated to greater production of pulmonary secretion.

That is why, perhaps children of the PMV≥5, group exposed for longer time to the deleterious effects of invasive PMV and sedation (greater production and accumulation of tracheobronchial secretion) and with a higher basal Raw, responded better to the intervention in comparison to the PMV<5.

Better knowledge of the PTNW morphology and physiology has fostered relatively recent concepts on neonatal physiotherapy. Thereby, therapies not indicated for this population have been abandoned. Airway clearance techniques, currently, considered more effective for this end, directed toward bronchial clearance and selected for this study rely on use of changes in lung flow and

volumes for recruitment of tracheobronchial secretions of newborns.[1]

Effects of these techniques can be explained, as transport of a viscoelastic gel, such as bronchial mucus, by a tube may be optimized by a sufficiently high airflow.[1] Increase of the expiratory flow by manual chest compression during expiration, a technique adopted in this study, generates a shock point of the airway wall with the deposited secretion there. When the airflow reaches this region, secretion is a barrier to passage of gas, which is overcome, and carried together with the expiratory flow towards more central airways.[1,7,18]

Another resource used in this study was selective decubitus which is well known in airway clearance. In healthy individual action of gravity does not seem to contribute to increase of mucus transport, however, whenever this transport is hindered and/or in presence of greater secretion volume, influence of gravity on its transport is important.[18,19] As selective decubitus was associated to a flow-dependent technique, better ventilation due to not dependent positioning of the lung[7] submitted to these techniques caused a greater local ventilation and consequently, greater effectiveness of the technique. As previously mentioned, Trendelemburg position where the head is lower than the trunk is completely contraindicated in prematures as it favors peri-intraventricular hemorrhage.[8,20]

It is noteworthy that airway clearance must be carried out by qualified professional, taking into account children's respiratory system peculiarities, especially of PTNB, because it is developing and presenting morphologic characteristics offering little stability and a tendency to airway collapse,[7] in addition to immaturity of the self-regulatory system of the cerebral blood flow, leading to susceptibility for peri-ventricular hemorrhage.[21]

Resistive components interfering in Cdyn are, possibly responsible for better response of Cdyn of PMV≥5 newborn because Cdyn encompasses the elastic components of the chest wall, of the lungs, of the PMV circuit, besides the resistance imposed by child's airways and intratracheal tube.[14]

In this study, an unavoidable questioning relates to the possibility that benefits would be achieved only with suction, without use of physiotherapeutic techniques to increase secretion transport. Some authors investigated the effects of suction on respiratory mechanics and oxygenation of neonates and infants. In the study of Avena et al.[22] inspiratory resistance of the airways was found, also pulmonary compliance immediately after suction in a group of 13 children (47 days to 5 years of age), returning to baseline levels at 10th minute. In the Prendiville et al.,[23] study with 36 PTNB with 29 weeks ±3.6 SD mean GI and mean weight at birth of 1370g ±740 SD, it was proven that Raw decreased at the 5th minute after suction with a tendency to elevate after this time. Regarding Cdyn no significant changes were perceived after suction. This data lead us to believe that isolated suction procedure offer a temporary decrease of Raw without significant impacts on Cdyn, compatible with results in the PMV<5days group. In view of our results, possibly the physiotherapeutic techniques used support removal of a greater amount of secretion in relation to an isolated suction procedure whenever there is accumulation of tracheobronchial secretion and increased Raw, as in the PMV≥5.

Considering absence of HR and SpO_2 instability leading to interruption of the physiotherapeutic intervention and to eventual help of airway clearance in the optimization of the clinical outcome of PTNB under invasive ventilation support, mainly in the PMV ≥5 days group who presented accumulation of tracheobronchial secretion, similar studies in this population must be conducted to strengthen the achieved results. Contrariwise results suggest that in PTNB at acute stage of RDS and under PMV<5 days, techniques adopted in this study were not beneficial in Cdyn and in Raw, the benefits may not be lasting. Therefore, indication of these techniques for this population must be individualized and carefully assessed.

It must be explained that on the one hand, strong evidence must be reached in the area, on the other hand it is difficult to conduct studies proving the influence of certain airway clearance techniques on the clinical outcome of PTNB, as well as absence of an investigation and assessment method considered "ideal" to conduct clinical trials.[12] This is why, "lack of evidence" – that the airway clearance techniques in PTNB with RDS are not effective – must not be understood as " evidence of lack" of such effects. On the contrary, these must not be indiscriminately indicated nor carried out by unprepared professionals.

It must be highlighted that this study considered, within the possible negative impacts associated to the intervention described, changes in SpO2 and HR, analyzed during the technique did not envisage other complications, such as periventricular hemorrhage, which would require other studies.

Finally, intervention with airway clearance in PTNB under PMV must be individualized, carefully indicated and performed by qualified professionals caring for the

newborn, considering the specificity and instability of this population. Indications, contra-indications and non-indications of airway clearance in clinical practice must be discussed, studied, established and incorporated by a multiprofessional team, considering, at all times, the impacts – in the short, medium and long term – of interventions as well as their absence, on the clinical outcome of these patients.

CONCLUSION

It was concluded that physiotherapeutic techniques used in this trial benefited the Raw of both groups of PTNB under study, and such benefits were more evident in the PMV≥5, where Raw remained decrease in relation to the initial resistance at least up to 70 minutes after intervention. With regard to Cdyn, benefits were found in the short term in PTNB under PMV≥5 days.

RESUMO

Objetivos: O objetivo do trabalho foi avaliar as repercussões de técnicas fisioterapêuticas específicas na resistência média de vias aéreas e na complacência dinâmica de neonatos pré-termo em ventilação pulmonar mecânica .

Métodos: Dezoito neonatos pré-termo em ventilação pulmonar mecânica convencional foram submetidos a uma sessão de fisioterapia respiratória (compressão torácica manual durante a expiração + aspiração da cânula intratraqueal). Medidas de resistência média de vias aéreas e complacência dinâmica foram realizadas antes, 10, 40 e 70 minutos após as intervenções, por meio de um pneumotacógrafo com monitor gráfico (NewPort Navigator GM-250®), acoplado a um transdutor de fluxo (Varfley-Bicore®). Para análise dos resultados, os neonatos pré-termo foram divididos em dois grupos: tempo de ventilação pulmonar mecânica <5 dias e ventilação pulmonar mecânica ≥5 dias. Os resultados foram analisados pelo teste Friedman e pós-teste de Dunn de múltiplas comparações (p<0,05 significante).

Resultados: Observou-se no grupo ventilação pulmonar mecânica <5 redução significativa da resistência média de vias aéreas no 10º minuto após a intervenção (p<0,05), sem alterações significativas na complacência dinâmica. No grupo ventilação pulmonar mecânica ≥5 dias a resistência média de vias aéreas reduziu no 10º(p<0,001), 40º(p<0,05) e 70º(p<0,05) minutos após a intervenção. A complacência dinâmica melhorou significativamente no 10º minuto (p<0,05).

Conclusões: As técnicas para aumento do transporte de secreção traqueobrônquica utilizadas beneficiaram a resistência média de vias aéreas e complacência dinâmica dos neonatos estudados em ventilação pulmonar mecânica ≥5 dias, com melhores respostas na resistência média de vias aéreas.

Descritores: Recém-nascido; Mecânica respiratória; Modalidades de fisioterapia

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