Diaphragm ultrasound after manual rib cage stabilization maneuver in premature newborns: clinical trial

Ultrassom diafragmático após manobra de estabilização costal manual em recém-nascidos prematuros: ensaio clínico

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Abstract

Introduction: The manual rib cage stabilization maneuver (MRCSM) is a physical therapy intervention that promotes stabilization of the zone of apposition of the diaphragm, facilitating the contraction of this muscle and the work of breathing. **Objective:** To evaluate by diaphragm ultrasound the diaphragmatic excursion in premature newborns before and after MRCSM. **Methods:** Before-after clinical trial assessing by diaphragm ultrasound the effectiveness of MRCSM in the amplitude of diaphragmatic excursions. **Results:** The study sample consisted of 48 premature newborns born at a mean gestational age of 33.0 ± 2.8 weeks with a mean birth weight of 1,904.1 ± 708.9 grams. The newborns were classified in three groups: without respiratory distress syndrome (RDS; n = 26), with RDS (n = 15) and with apnea (n = 7) as a cause of admission to the neonatal intensive care unit (NICU). The measurements of diaphragmatic excursion and thickening were similar in newborns without or with RDS or apnea and there was a significant increase in the amplitude of diaphragmatic excursions after MRCSM ($p < 0.001$; effect size > 0.68) and less diaphragmatic thickening at exhalation in all of them. The diaphragm thickening fraction was 0.50 (0.33 - 0.72), and the diaphragm thickening rate was 0.04 (0.03 - 0.07). These measurements showed no significant variation with the presence or absence of RDS or apnea ($p > 0.05$). No significant variations in heart rate ($p = 0.30$), respiratory rate ($p = 0.79$), and peripheral oxygen saturation, considering newborns in ambient air ($p = 0.17$) compared with baseline. **Conclusion:** The MRCSM was effective, safe, and increased the amplitude of diaphragmatic excursion and thickness in premature newborns at one week of age, regardless of the presence or absence of RDS or apnea as a cause of admission to the NICU.

Keywords: Diaphragm. Newborn. Physical therapy modalities. Premature. Ultrasonography.

Resumo

Introducão: *A manobra manual de estabilização da caixa torácica (MRCSM) é uma intervenção fisioterapêutica que promove a estabilização da zona de aposição do diafragma, facilitando a contração deste músculo e o trabalho respiratório.* ***Objetivo:*** *Avaliar pela ultrassonografia do diafragma a excursão diafragmática em recém-nascidos prematuros antes e após MRCSM.* ***Métodos:*** *Ensaio clínico antes e depois avaliando por ultrassonografia do diafragma a eficácia do MRCSM na amplitude das excursões diafragmáticas.* ***Resultados:*** *A amostra do estudo foi composta por 48 recém-nascidos prematuros nascidos com idade gestacional média de 33,0 ± 2,8 semanas e peso médio ao nascer de 1904,1 ± 708,9 gramas. Os recém-nascidos foram classificados em três grupos: sem síndrome do desconforto respiratório (SDR; n = 26), com SDR (n = 15) e com apneia (n = 7) como causa de internação na unidade de terapia intensiva neonatal (UTIN) . As medidas de excursão e espessamento diafragmático foram semelhantes em recém-nascidos sem ou com SDR ou apneia e houve aumento significativo na amplitude das excursões diafragmáticas após MRCSM (p < 0,001; tamanho de efeito > 0,68) e menor espessamento diafragmático na expiração em todos eles. A fração de espessamento do diafragma foi de 0,50 (0,33 - 0,72) e a taxa de espessamento do diafragma foi de 0,04 (0,03 - 0,07). Essas medidas não apresentaram variação significativa com a presença ou ausência de SDR ou apneia (p > 0,05). Não houve variações significativas na frequência cardíaca (p = 0,30), frequência respiratória (p = 0,79), saturação periférica de oxigênio, considerando os recém-nascidos em ar ambiente (p = 0,17) em comparação com o valor basal.* ***Conclusão:*** *O MRCSM foi eficaz, seguro e aumentou a amplitude da excursão e espessura diafragmática em recém-nascidos prematuros com uma semana de idade, independentemente da presença ou ausência de SDR ou apneia como causa de admissão na UTIN.*

Palavras-chave: *Diafragma. Recém-nascido. Modalidades de fisioterapia. Prematuro. Ultrassonografia.*

Introduction

The manual rib cage stabilization maneuver (MRCSM) is a physical therapy intervention that promotes stabilization of the zone of apposition of the diaphragm by offering this muscle a fixed point, facilitating its contraction and providing better respiratory work, which can be observed by abdominal movement or by diaphragm ultrasound.[1-3] The diaphragm is responsible for 70-80% of the inspiratory work. While contracting together with the external intercostal muscles, the diaphragm expands the thoracic cavity, decreases the intrathoracic pressure, and causes air to enter the lungs; while relaxing, causes the air to passively be exhaled from the lungs by elastic recoiling.[4,5]

The movement of the diaphragm contributes to changing lung volumes; the more efficient the diaphragmatic contraction, the greater the mobilized volume.[4-6] An assessment by physical therapists of the diaphragm function and force of contraction in healthy adults has indicated a good correlation between the diaphragm's function, excursion amplitude, and thickness, with the inspiratory strength measured using spirometry.[7,8] A recent systematic review published by López-Fernández et al.[2] assessed how manual physical therapy directed to the diaphragm affects the musculoskeletal system in adults; the review included nine clinical trials and showed an immediate and significant effect of the manual therapy on diaphragmatic mobility.

The MRCSM is a safe physical therapy technique that causes no pain or respiratory discomfort and has no effect on vital signs or clinical stability of the newborn.[9,10] The diaphragm can be safely visualized by ultrasonography starting from the fetal period and can be evaluated in terms of anatomy, thickness, and excursions.[1,11,12]

Based on the considerations above, the primary aim of this study was to evaluate, using diaphragm ultrasound, the diaphragmatic excursions in premature newborns before and after MRCSM and diaphragmatic thickness. Another aim of the study was to evaluate the response of the newborns according to the presence or absence of RDS or apnea as a cause of admission to the NICU, in terms of vital signs, clinical stability, pain, and respiratory effort after MRCSM.

Methods

This was an uncontrolled, before-after clinical trial conducted at a tertiary Neonatal Intensive Care Unit (NICU) between September and December 2021. The objective was to assess the effectiveness of the MRCSM by measurement of diaphragmatic excursions and thickness using ultrasonography before and after the maneuver. The research was approved by the Hospital das Clínicas/Universidade Federal do Paraná's ethics committee (number 36202920.2.0000.0096) and is registered in the Brazilian Clinical Trials Registry (protocol RBR-6vnftw). Parents and guardians of all newborns signed an informed consent form.

The study included 48 premature newborns, comprising all who met the inclusion criteria: a) with gestational age less than or equal to 37 weeks; b) having been admitted to the CHC NICU; c) on the sixth day of life; d) whose parents allowed participation in the research by signing the Free and Informed Consent Form (TCLE). During the period of data collection, 81 babies were born prematurely, all of which were included in the study, except for 33 that meet the exclusion criteria listed below.

A premature newborn was excluded if having one or more of the following: a) contraindication for MRCSM (chest drain, immediate postoperative period of abdominal or thoracic surgery, cardiopathy, or a Silverman-Andersen score (SAs) > 3,[13] or critically ill; b) contraindication for respiratory physical therapy (pulmonary hemorrhage, diaphragmatic hernia, severe pulmonary hypertension, undrained pneumothorax, thrombocytopenia, omphalocele, or uncorrected gastroschisis); c) need for invasive mechanical ventilation support on the day of data collection; d) malformation of the central nervous system; e) need for respiratory isolation; f) transference to another service or discharge from the NICU before the sixth day of life; or g) clinical procedures scheduled for the same time as the MRCSM.

The newborns were classified in 3 groups: without respiratory distress syndrome (RDS) (n = 26), with RDS (n = 15) and with apnea (n = 7) as a cause of admission to the NICU. The 15 newborns who presented RDS were either on room air or receiving oxygen through a nasal cannula or continuous positive airway pressure (CPAP) on the day of the intervention.

After a period of minimal handling for three days to minimize the risk of periventricular hemorrhage, care for the newborns was initiated. The maneuver was administered twice a day, and data collection took place on the sixth day for newborns with a gestational age of less than 36 weeks and 6 days. Four physiotherapists underwent training to proficiently execute the newborn maneuvers. The ultrasound scans were consistently conducted by a research physiotherapist who had received prior training from the thesis advisor physician. The MRCSM was performed with the physical therapist resting the palm of one hand on the newborn's upper abdomen, and thumb and index fingers on the lower ribs bilaterally to allow the ribs to be directed to a normal position (Figure 1).

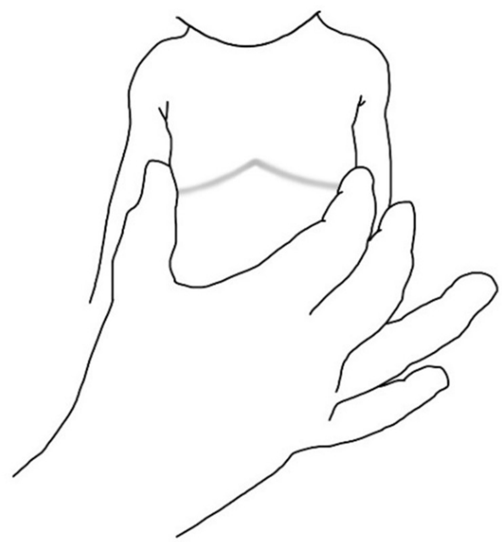

Figure 1 - Illustration of the manual rib cage stabilization maneuver (MRCSM).

During expiration, the physical therapist pulled the ribs downward gently, with light pressure towards the umbilical scar, and maintained this movement until inspiration. This procedure was performed for 5 to 8 respiratory cycles and repeated for 5 to 8 minutes. The maneuver results in increased movement in the upper abdomen during inspiration, reflecting improved lung compliance.[1-3,14-17]

Data sources

The newborns were evaluated before MRCSM in the morning or afternoon, while clinically stable, with normal vital signs, and at least 1 hour after feeding. During the MRCSM, the newborns were continuously monitored, and when necessary, bronchial hygiene and aspiration of airway secretions were performed.

Diaphragm ultrasound (SonoSite M-turbo, Gorham St., Canada) was obtained in all newborns using a 5 MHz transducer for evaluation of diaphragmatic excursions and a 10 MHz transducer for measurement of diaphragmatic thickness. Measurements were taken before and after the maneuver was performed, immediately before and after. The ultrasound was performed while the newborn rested calmly and, if necessary, after soothing with non-nutritive suction. Initial visualization of the diaphragm was performed using the two-dimensional (2D) mode, while measurements were obtained using the motion (M) mode. For assessment of diaphragmatic excursions (2D mode), the transducer was positioned on the newborn's right mammary line in the upper abdomen and subcostal region. The transducer was oriented toward the head, and the liver was used as the right acoustic window. The M mode was used for visualization and measurement of the amplitude of the craniocaudal diaphragmatic excursion during quiet breathing. The values of three consecutive respiratory cycles were recorded. For measurement of diaphragmatic thickness, the transducer was positioned on the axillary line, between the 8th and 11th intercostal space, in the zone of diaphragm apposition.[18-23]

The assessments included the diaphragm's amplitude and thickness, and the diaphragm thickening fraction and rate. The diaphragm thickening rate was calculated as the difference between the diaphragm thickness during inspiration and expiration. The diaphragm thickening fraction was calculated using the following equation: (Thick insp-Thick exp)/(Thick exp*100). We were unable to measure the diaphragm thickness in 19 newborns due to other conflicting clinical procedures scheduled for the same time as the ultrasonography.[18-23]

The evaluated variables were diaphragmatic excursion before and after the MRCSM, and diaphragm thickening. The occurrence of pain, evaluated using the Neonatal Infant Pain Score (NIPS),[24] and signs of respiratory distress,[25] evaluated using the SAs,[13] were determined before and after the MRCSM. Other variables evaluated included demographic (sex, gestational age in weeks[26]), anthropometric (weight in grams, newborn size classification[27]), and clinical (heart rate, respiratory rate, peripheral oxygen saturation[25]) characteristics, as well as the Apgar score at 5 minutes.[28]

Study size

The sample size was estimated considering a significance level of 5%, a type II error of 5%, and an effect magnitude of 0.10 mm of amplitude of diaphragmatic excursions, and the minimum estimated size was 35 cases. All statistical analyses were carried out using the software Statistica 4.0 (StatSoft Power Solutions, Inc., Palo Alto, California, USA). P values < 0.05 were considered significant.

Statistical methods

Variables with normal distribution are presented as mean and standard deviation, while those with asymmetric distribution are presented as median and interquartile range. The Shapiro-Wilk test was used to test for normality.[29]

To obtain the mean of the most adjusted measurements, the three diaphragm measurements were evaluated for differences using the Bland-Altman Method (which assesses the degree of difference and agreement between measurements), one-sample t-test (which verifies whether differences between measurements are different from zero), and Lin's coefficient of agreement (which verifies the reproducibility of the measurements, with a value of 1 indicating maximum agreement). The decision of which measurements to use to calculate the mean measurement was based on the assessment by these three methods, with priority given to Lin's coefficient of agreement.[29]

Student's t test for dependent samples was applied to estimate the difference between symmetric continuous variables. Friedman's ANOVA followed by Wilcoxon post hoc test were applied to assess possible differences in diaphragmatic measurements according to classes of gestational age and presence of ventilatory support during the MRCSM. McNemar's test was applied to estimate the difference between categorical variables.[29]

Results

Of the 48 newborns included, 26 (51%) were girls. The newborns were born at a mean gestational age of 33.0 ± 2.8 weeks and with a mean birth weight of 1,904.1 ± 70.9 grams. An Apgar score > 7 was recorded in 47.9% and 85.4% of the newborns at 1 minute and 5 minutes, respectively. The anthropometric measures at birth were (in centimeters) length: 41.8 ± 4.5; head circumference: 30.2 ± 3.0; thoracic circumference: 26.9 ± 3.8; abdominal circumference: 25.3 ± 3.7. The measurements of diaphragmatic excursion and thickening were similar in newborns with or without RDS or apnea, and there was a significant increase in the amplitude of diaphragmatic excursions after MRCSM ($p < 0.001$) (Figure 2).

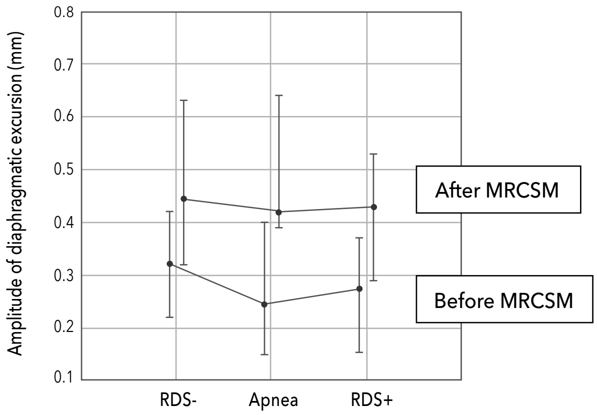

Figure 2 - Amplitude of diaphragmatic excursions according to the presence (+) or absence (-) of respiratory distress syndrome (RDS) or apnea.

Note: MRCSM = manual rib cage stabilization maneuver. Kruskal-Wallis ANOVA, Mann-Whitney post hoc test before vs after (n = 48). MRCSM: p < 0.001. Friedman ANOVA, Wilcoxon post hoc test between groups: p > 0.05. Effect size: RDS: 0.75; apnea: 0.57 RDS+: 0.68.

Diaphragmatic thickening was less during expiration regardless of the presence or absence of RDS or apnea ($p < 0.001$; effect size: RDS: 0.87; apnea: 0.61; RDS+: 0.90), Therefore, the diaphragmatic inspiration was of 0.13 (0.12 - 0.19), 0.13 (0.09 - 0.16) and 0.1 (0.05 - 0.1) in the presence of RDS, absence of RDS and apnea groups, respectively. The diaphragm thickening fraction was 0.50 (0.33 - 0.72), and the diaphragm thickening rate was 0.04 (0.03 - 0.07). These measurements showed no significant variation with the presence or absence of RDS or apnea ($p > 0.05$). There was no correlation between any diaphragmatic measurement and birth weight, birth length, gestational age, or head, thoracic or abdominal circumference ($r < 0.10$). There was significant increase in the amplitude of diaphragmatic excursions after MRCSM ($p < 0.001$) regardless of gestational age (Table 1). In Figure 3 we present a comparative US image showcasing diaphragmatic excursion before and after MCRSM treatment. The image illustrates a noticeable increase in the amplitude of diaphragm movement following the procedure.

Table 1 - Amplitude of diaphragmatic excursions according to the gestational age

Excursions	< 30 weeks	30-35 weeks	> 35 weeks	p-value
Before MRCSM	0.28 (0.20 - 0.38)	0.39 (0.38 - 0.47)	0.22 (0.19 - 0.47)	< 0.001
After MRCSM	0.45 (0.35 - 0.60)	0.66 (0.45 - 0.88)	0.48 (0.28 - 0.56)	

Note: Values are presented as median and interquartile range (n = 48). Kruskal-Wallis ANOVA, Mann-Whitney post hoc test before vs after manual rib cage stabilization maneuver (MRCSM): p < 0.001. Friedman ANOVA, Wilcoxon post hoc test between gestational ages: p > 0.05. Effect size: < 30 weeks: 0.76; 30-35 weeks: 0.94; > 35 weeks: 0.82; RDS+: 0.50.

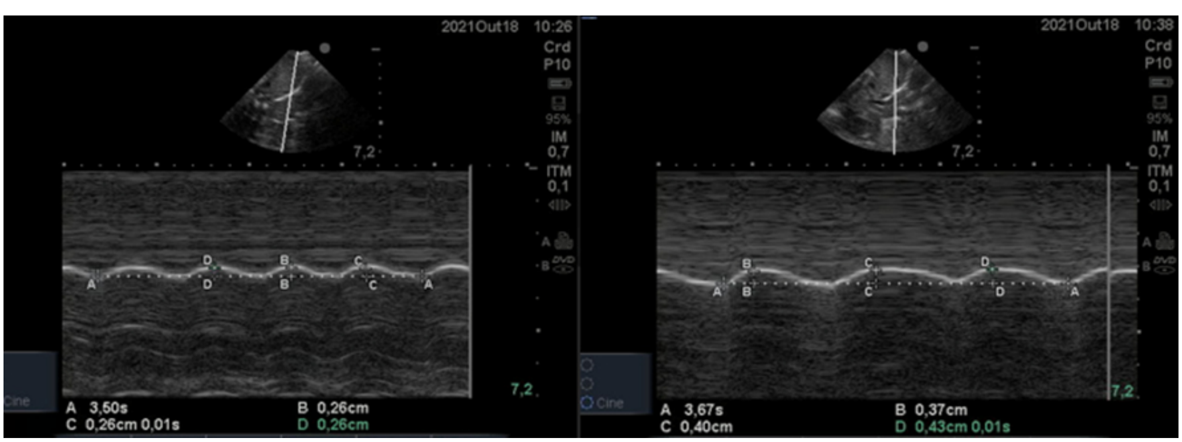

Figure 3 - Diaphragmatic excursion by ultrasound image before (left image) and after (right image) manual rib cage stabilization maneuver.

No significant variations in heart rate (p = 0.30), respiratory rate (p = 0.79), peripheral oxygen saturation (p = 0.17), considering only newborns in ambient air, NIPS score (p = 0.98) or SAs (p = 0.93) were observed after the MRCSM compared with baseline (Table 2).

Table 2 - Vital signs, Silverman-Andersen score (SAs) and Neonatal Infant Pain Score (NIPS) before and after the manual rib cage stabilization maneuver (MRCSM)

Parameters	Before MRCSM	After MRCSM	p-value
Heart rate	144.8 ± 15.4	142.5 ± 16.5	0.30[1]
Respiratory rate	49.1 ± 12.0	48.7 ± 11.2	0.79[1]
Peripheral O_2 sat.	96.1 ± 2.2	96.9 ± 2.3	0.17[1]
NIPS (%)			
0-2	47 (97.9)	48 (100)	
3-4	1 (2.1)	0 (0.0)	0.98[2]
> 4	0 (0.0)	0 (0.0)	
SAs (%)			
0-1	45 (93.8)	47 (97.9)	0.95[2]
2-3	3 (6.2)	1 (2.1)	

Note: [1]Student's t test for dependent samples; [2]McNemar's test (n = 48). Effect size < 0.20.

Discussion

In the present study, we observed an increased amplitude of diaphragmatic excursion after MRCSM, independent of the newborn's gestational age at birth, presence or absence of RDS or apnea as a cause of admission to the NICU, along with greater diaphragm thickness during inspiration. The MRCSM did not cause pain or require respiratory effort, and the newborns maintained their vital signs within the normal limits after the maneuver. There is a gap in the literature that evaluates physiotherapy maneuvers with ultrasound.

The newborn's thoracic anatomy and physiology – horizontalized ribs, weak intercostal muscles, lungs less complacent than the rib cage, and narrow airways – contribute to increasing the work of breathing, which can easily lead to muscle fatigue.[4-7] Compared with adults, newborns have a more rounded thorax, which results in a reduced zone of apposition of the diaphragm, reducing the ability to generate force and leading to distortions during respiratory work.[7,14]

An increase in diaphragm contractility leads to mobilization of greater lung volumes.[6,20] The fixation of the zone of apposition of the diaphragm by a physical therapist facilitates the contraction of this muscle, increasing the volume of air entering the lungs, making the respiratory work of the newborn more efficient.[1,14,16]

Roussenq et al.[9] and Oliveira et al.[10] also observed an increase in peripheral oxygen saturation among newborns subjected to thoracic manipulations for stimulation of diaphragmatic contraction. Increased oxygen saturation during compression of the last ribs has also been observed in a study in adults, although ultrasonographic measurements were not performed to evaluate the amplitude of diaphragmatic excursions.[1]

Easy to learn and perform, non-invasive, and inexpensive, ultrasonography has been widely used for diagnosis in intensive care, including for the evaluation of diaphragmatic dysfunctions in critically ill patients.[18-23] However, there is still no consensus on the standardization of its technique and the influence that the position of the transducer, type of ventilation, and patient position may have on the results obtained with this evaluation. In a non-systematic review by Lippi et al.,[21] including nine clinical trials or comparative studies, the most used ultrasonographic variables for assessment of the outcomes of hypotrophy, diaphragmatic dysfunction, and endotracheal extubation failures were diaphragmatic excursion, diaphragmatic thickness, and thickening fraction.

The use of mechanical ventilation has been pointed out as one of the main factors associated with decreased diaphragmatic force (also known as ventilator-induced diaphragmatic dysfunction), which is associated with the duration of the mechanical ventilation. This dysfunction also seems to be strongly associated with extubation failure, determined by the imbalance between the mechanical load imposed by spontaneous breathing and the diaphragm's ability to deal with it.[21] This potential influence of mechanical ventilation on outcomes was a limitation of the present study, as we evaluate only newborns on room air or receiving supplemental oxygen through a nasal cannula or continuous positive airway pressure (CPAP) at the time of MRCSM.

The use of diaphragm ultrasound in intensive care seems to be well established,[21-23] especially for monitoring patients treated with mechanical ventilation. In the present study, it proved to be useful in showing the benefits of MRCSM in strengthening the diaphragmatic respiratory mechanics among premature newborns. This study opens up various research possibilities, including the evaluation of the diaphragm during different maneuvers performed by neonatal physiotherapists, as well as promoting the integration of ultrasound into the daily practice of neonatal physiotherapy.

Conclusion

The MRCSM was effective, safe, and led to an increase in the amplitude of diaphragmatic excursions in premature newborns at one week of age regardless of the presence or absence of RDS or apnea as a cause of admission to the NICU. It kept vital signs within normal limits, as well as did not causing causes pain or respiratory distress.

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Authors' contributions

MGA, SV and MNL were responsible for the literature search and data collection. MNL analyzed the data; MGA, CNB, RPGVCS and MNL prepared the manuscript. All authors were responsible for the study design, manuscript review and approval of the final version.

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