

Impact of the prolonged slow expiratory maneuver on respiratory mechanics in wheezing infants*

Impacto da técnica de expiração lenta e prolongada na mecânica respiratória de lactentes sibilantes

Fernanda de Cordoba Lanza, Gustavo Falbo Wandalsen, Carolina Lopes da Cruz, Dirceu Solé

Abstract

Objective: To evaluate changes in respiratory mechanics and tidal volume (V_T) in wheezing infants in spontaneous ventilation after performing the technique known as the prolonged, slow expiratory (PSE) maneuver. **Methods:** We included infants with a history of recurrent wheezing and who had had no exacerbations in the previous 15 days. For the assessment of the pulmonary function, the infants were sedated and placed in the supine position, and a face mask was used and connected to a pneumotachograph. The variables of tidal breathing (V_T and RR) as well as those of respiratory mechanics—respiratory system compliance (Crs), respiratory system resistance (Rrs), and the respiratory system time constant (prs)—were measured before and after three consecutive PSE maneuvers. **Results:** We evaluated 18 infants. The mean age was 32 ± 11 weeks. After PSE, there was a significant increase in V_T (79.3 ± 15.6 mL vs. 85.7 ± 17.2 mL; $p = 0.009$) and a significant decrease in RR (40.6 ± 6.9 breaths/min vs. 38.8 ± 0.9 breaths/min; $p = 0.042$). However, no significant differences were found in the variables of respiratory mechanics (Crs: 11.0 ± 3.1 mL/cmH₂O vs. 11.3 ± 2.7 mL/cmH₂O; Rrs: 29.9 ± 6.2 cmH₂O · mL⁻¹ · s⁻¹ vs. 30.8 ± 7.1 cmH₂O · mL⁻¹ · s⁻¹; and prs: 0.32 ± 0.11 s vs. 0.34 ± 0.12 s; $p > 0.05$ for all). **Conclusions:** This respiratory therapy technique is able to induce significant changes in V_T and RR in infants with recurrent wheezing, even in the absence of exacerbations. The fact that the variables related to respiratory mechanics remained unchanged indicates that the technique is safe to apply in this group of patients. Studies involving symptomatic infants are needed in order to quantify the functional effects of the technique.

Keywords: Physical Therapy Modalities; Respiratory Mechanics; Infant; Respiratory Function Tests.

Resumo

Objetivo: Avaliar as alterações da mecânica respiratória e do volume corrente (VC) em lactentes sibilantes em ventilação espontânea após a realização da técnica de expiração lenta e prolongada (ELPr). **Métodos:** Foram incluídos no estudo lactentes com história de sibilância recorrente e sem exacerbações nos 15 dias anteriores. Para a avaliação da função pulmonar, os lactentes foram sedados e posicionados em decúbito dorsal com máscara facial acoplada a um pneumotacógrafo. As variáveis da respiração corrente – VC e FR – e da mecânica respiratória – complacência do sistema respiratório (Csr), resistência (Rsr) e constante de tempo (psr) – foram mensuradas antes e após a realização de três sequências consecutivas de ELPr. **Resultados:** Foram avaliados 18 lactentes, com média de idade de 32 ± 11 semanas. Houve um aumento significante no VC após ELPr ($79,3 \pm 15,6$ mL vs. $85,7 \pm 17,2$ mL; $p = 0,009$), assim como uma redução na FR ($40,6 \pm 6,9$ ciclos/min vs. $38,8 \pm 0,9$ ciclos/min; $p = 0,042$). Entretanto, não houve alterações significantes nos valores da mecânica respiratória (Csr: $11,0 \pm 3,1$ mL/cmH₂O vs. $11,3 \pm 2,7$ mL/cmH₂O; Rsr: $29,9 \pm 6,2$ cmH₂O · mL⁻¹ · s⁻¹ vs. $30,8 \pm 7,1$ cmH₂O · mL⁻¹ · s⁻¹; e psr: $0,32 \pm 0,11$ s vs. $0,34 \pm 0,12$ s; $p > 0,05$ para todos). **Conclusões:** Essa técnica de fisioterapia respiratória é capaz de induzir alterações significativas no VC e na FR de lactentes com sibilância recorrente, mesmo na ausência de exacerbações. A manutenção das variáveis da mecânica respiratória indica que a técnica é segura para ser aplicada nesse grupo de pacientes. Estudos com lactentes sintomáticos são necessários para quantificar os efeitos funcionais da técnica.

Descritores: Modalidades de Fisioterapia; Mecânica Respiratória; Lactente; Testes de Função Respiratória.

* Study carried out at the Infant Pulmonary Function Laboratory, Allergy, Clinical Immunology, and Rheumatology Section of the Department of Pediatrics, *Universidade Federal de São Paulo/Escola Paulista de Medicina* – UNIFESP/EPM, Federal University of São Paulo/Paulista School of Medicine – São Paulo, Brazil.

Correspondence to: Fernanda de Cordoba Lanza. Rua Estado de Israel, 465, apto. 23, CEP 04022-001, São Paulo, SP, Brasil.

Tel. 55 11 5549-0542 or 55 11 98339-5002. E-mail: fclanza@uol.com.br

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Introduction

The prolonged, slow expiratory (PSE) maneuver is a respiratory therapy technique applied in infants with airway obstruction and accumulation of secretion.^(1,2) The benefits of different physiotherapy techniques have been described,⁽³⁾ and the same occurs with the PSE maneuver. During the use of this technique, it was possible to quantify the expiratory reserve volume mobilized, the induction of sighs and maintenance of peak expiratory flow was confirmed and a decreased respiratory distress was observed after application.^(4,5)

The evaluation of passive respiratory mechanics – respiratory system compliance (Cr_s), resistance (R_s) and its time constant (pr_s) – has been used in studies of various segments in infants, because in addition to obtaining reproducible measurements, it assists in longitudinal monitoring of lung function and evaluation of therapeutic interventions.⁽⁶⁾ Cr_s and R_s can also help confirm the benefits of respiratory physiotherapy due to altered pulmonary flow and lung volume after the elimination of secretion.^(7,8) Several studies on respiratory therapy in patients under mechanical ventilation in ICU used the evaluation of Cr_s and R_s.^(2,7-9) However, studies on patients breathing spontaneously are scarce. Evaluation of airway resistance can also help detect bronchospasm induced by respiratory therapy techniques. The application of chest vibration and “tapotement” (percussive tapping) in individuals with lung disease and hypersecretion resulted in no alteration in lung function, proving that this technique is safe and can be applied in subjects with bronchial hyperreactivity.^(10,11) This evaluation was not performed in patients undergoing PSE maneuver.

Evaluation of tidal volume (V_T) is one of the oldest and most simple techniques to measure lung function in infants.⁽¹²⁾ V_T has been studied as an outcome for evaluating the efficacy of unconventional techniques of respiratory therapy. The results so far, however, are controversial, with reports of increased V_T in some studies, and of maintenance in others.^(8,13-15)

The evaluation of respiratory mechanics and V_T in infants breathing spontaneously is not routinely measured in the clinical practice. These functional variables, however, can be studied in specialized laboratories, and we believe that these consist of objective outcomes and important factors in evaluating the effectiveness of respiratory therapy. The objective of this study was to

evaluate changes in respiratory mechanics and V_T in wheezing infants in spontaneous ventilation after the application of PSE maneuver.

Methods

We conducted a cross-sectional study evaluation wheezing infants referred for pulmonary function evaluation in the Infant Pulmonary Function Laboratory at the Allergy, Clinical Immunology, and Rheumatology Section of the Department of Pediatrics, Federal University of Sao Paulo, in São Paulo, Brazil. The study was approved by the local research ethics committee (Ruling no. 1054/07). Written informed consent was given by the parents or legal guardians. Data was collected between January 2008 and February 2009.

We included infants (between 4 and 24 months of age) with a history of recurrent wheezing (at least three episodes), without acute respiratory disease manifested in the preceding 15 days. Absence of acute respiratory disease was inferred from the absence of corresponding clinical symptoms (such as cough, wheezing and difficulty in breathing) and from the lack of consistent findings in the physical examination. We excluded those with upper airway obstruction, preterm infants (less than 37 weeks of gestational age), infants with gastroesophageal reflux disease, infants who underwent thoracic and/or abdominal surgery or who have been diagnosed with heart disease or neuropathy.

To perform the pulmonary function test, infants should be fasting for at least three hours. Chloral hydrate was administered (60-80 mg/kg), according to the laboratory routine and existing standardization.⁽¹⁶⁻¹⁹⁾ The infants were monitored using a pulse oximeter (DX 2405; Dixtal Biomedica, Manaus, Brazil) and SpO₂ and HR were evaluated. The infants were in the supine position with subtle cervical spine extension, using a small pad in the scapular region, without lateralization of the head. A face mask connected to a pneumotachograph (Hans Rudolph, Kansas City, MO, USA) was attached to the infants' face.

In technical phase, the PSE maneuver was performed with the infant in the supine position, with the hypothenar region of one of the therapist's hands positioned on the chest, precisely below the suprasternal notch, and the hypothenar region of the other hand placed on the abdomen above the umbilicus. At the end of the expiratory phase,

the compression of both hands was made, the hand on the chest being moved in craniocaudal direction and the hand on the abdomen and hand in the caudocranial direction. The next three or four inhalations subsequent to compression were restricted and squeezing motion in the expiratory phase was continued in accordance with the technical description.⁽²⁰⁾ There were three sequences of PSE maneuver (named A, B and C) in a continuous period of 120 s (Figure 1). The interval between the sequences was 30 s. The technique was always performed by the same evaluator, trained and qualified to do so. The PSE maneuver was performed during the evaluation of V_T , so the flow-volume curve was recorded constantly, allowing measurement of the V_T and its derivations—RR, PEF and the ratio between the time to reach the PEF (Tme) and expiratory time (Te).

Crs, Rrs and prs were the analyzed variables of respiratory mechanics using the airway occlusion technique, according to existing recommendations.^(17,19) For these measurements, the respiratory system is considered a one-compartment and linear model. The complete relaxation of the respiratory muscles in infants, necessary for the evaluation of the passive respiratory mechanics, is achieved by inducing the Hering-Breuer reflex,

triggered by the rapid airway obstruction (1 s) at the end of normal inhalation. The presence of the linear segment of at least 60% of the expiratory loop was inspected visually, as well as the lack of muscular activity by the plateau in the pressure-time curve with a standard deviation < 0.1 at 100 ms (Figure 1).^(16,17) At least three acceptable maneuvers were performed as recommended,⁽¹⁹⁾ and the average value was recorded.

All phases of the protocol were carried out during the measurement of V_T . Different variables can be obtained from the analysis of V_T , such as inspiratory time, Te, total respiratory time, PEF, Tme, RR and the Tme/Te ratio. For this group of patients, the evaluation was restricted to V_T , RR, PEF and the Tme/Te ratio, as these are variables that can be influenced by respiratory therapy techniques. The Tme/Te ratio is one of the most studied variables in V_T , as it may reflect airway obstruction.⁽¹⁸⁾

The protocol comprised three phases. The first phase (pre-technique) consisted of measuring the V_T and its derivations (RR, PEF and Tme/Te ratio) for 60 s. After the evaluation of the V_T , the measurement of respiratory mechanics was carried out. The second phase (technique phase) consisted of applying the PSE maneuver in three sequences of compression (A, B and C) for a

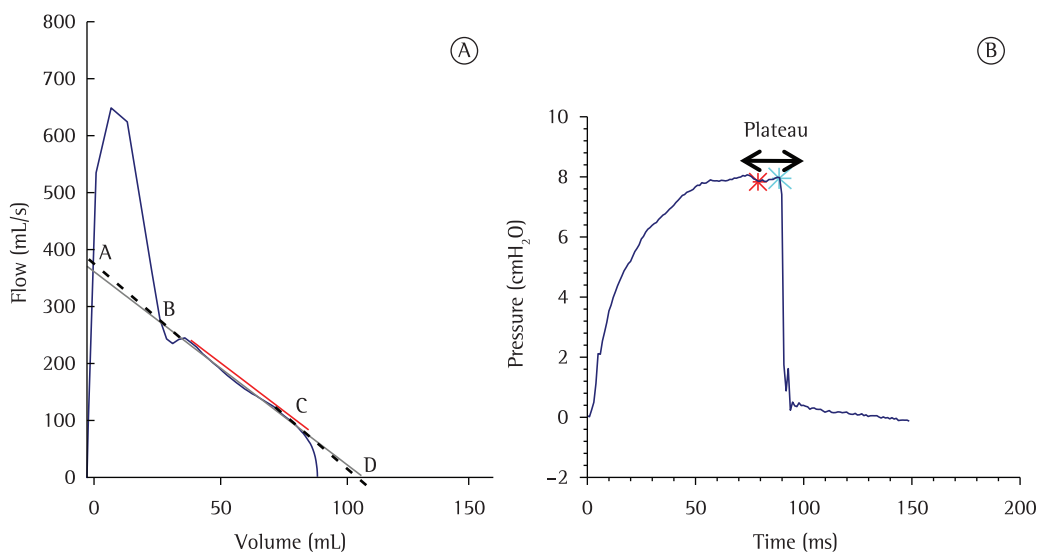


Figure 1 – Representation of the acceptability criteria of the expiratory curve obtained in the evaluation of passive mechanics of the respiratory system by the technique of single occlusion. In A, flow-volume curve: segment AD - extrapolation for calculation of the time constant of the respiratory system; segment BC - linear portion of the curve \geq 60% of the total, meaning the relaxation of respiratory muscles during expiration. In B, the pressure-time: 100 ms plateau in the expiratory phase. These are the eligibility criteria for the evaluation of respiratory mechanics.

period of 120 s. The technique was performed during the measurement of V_T (Figure 2). The third phase (post-technique) consisted of the reevaluation of the V_T for 60 s immediately after the application of the PSE maneuver, followed by the evaluation of the respiratory mechanics.

All continuous variables analyzed presented normal distribution and were evaluated using the Shapiro-Wilk test and therefore are presented as mean and standard deviation. The mean of the 60 s of evaluation of the V_T and the three measurements of respiratory mechanics were used for pre- and post-technique comparison. We used the Student t test for dependent samples for the analysis of the tidal breathing (V_T and RR) and respiratory mechanics (Crs, Rrs and prs) variables between the pre and post technique phases. The rejection level for the null hypothesis was set at 5%. The program used for the analysis was the Statistical Package for the Social Sciences, version 14.0 (SPSS Inc., Chicago, IL, USA).

Results

Of the 22 infants who started the protocol, 4 did not complete the study: one by coughing during the examination and 3 by technical difficulties (early awakening and insufficient sedation). The mean age of the infants who completed the study was 32.2 ± 11.4 weeks. Nine were female. The initial data of the population are described in Table 1.

During the protocol, no infant showed signs of respiratory distress or expiratory grunting. The SpO_2 remained over 93% throughout the tests, and HR remained between 110 and 150 bpm in all infants evaluated.

When comparing the pre and post technique phases, we observed a statistically significant mean increase in V_T ($p = 0.009$, Figure 3) and V_T corrected by height ($p = 0.01$, Table 2). A reduction was observed in RR from 40.6 ± 6.9

breaths/min to 38.8 ± 5.9 breaths/min after the technique ($p = 0.04$, Table 2). We also observed a significant increase in the Tme/Te ratio ($p = 0.007$). There was no significant change in the mean value of PEF when compared to the pre and post-technique phases (Table 2). Regarding respiratory mechanics, there was no statistically significant changes in Crs, Rrs and prs (Table 2).

Discussion

The PSE maneuver is a respiratory therapy technique described to promote bronchial clearance in infants.^(1,4) The scientific arguments that prove the effectiveness of the PSE maneuver were based, for a long time, on the evaluation of indirect variables, such as HR and SpO_2 .^(1,2,5,20) Only recently has the variation in expiratory reserve volume during PSE maneuver been described more objectively using the evaluation of pulmonary function variables.⁽⁴⁾ However, there are still questions about variations in V_T and passive respiratory mechanics immediately after the application of the PSE maneuver in subjects breathing spontaneously. After having studied the variations in volume and respiratory wheezing in infants breathing spontaneously, we observed a significant increase in V_T and maintenance of the variables Crs and Rrs and after application of the PSE maneuver.

Table 1 - Demographic characteristics of infants studied ($n = 18$).^a

Variables	Results
Age, weeks	32.2 ± 11.4
Height, cm	68.0 ± 4.3
Weight, kg	8.3 ± 1.0
Number of wheezing attacks	4.8 ± 1.9
Sex male/female, n/n	9/9

^aValues expressed as mean \pm SD, except where otherwise indicated.

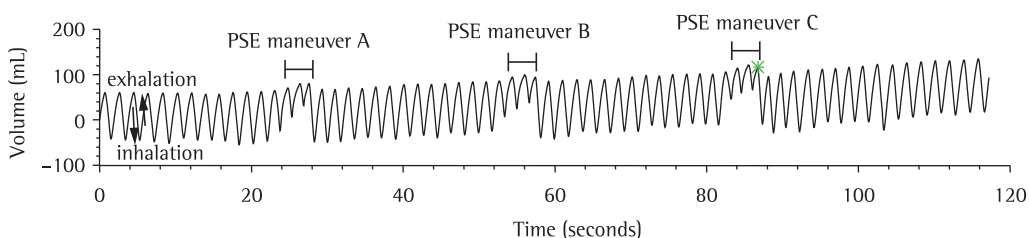
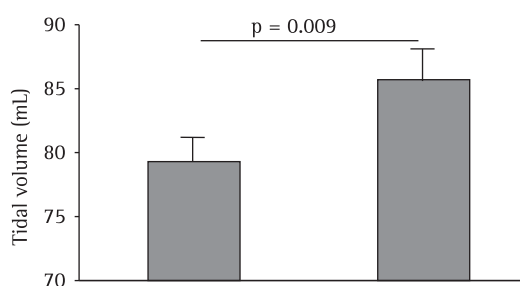


Figure 2 - Representation of three sequences (A, B, and C) of the technique prolonged, slow expiratory (PSE) maneuver.

Table 2 – Variables derived from tidal breathing and respiratory mechanics observed in the pre-and post-technique protocol.^a

Variables	Phases		p
	Pre-technique	Post-technique	
PEF, mL/s	140.5 ± 19.2	143.5 ± 20.6	0.3
V _T , mL	79.3 ± 15.6	85.7 ± 17.2	0.009
V _T , % previsto	111.6 ± 18.7	120.1 ± 17.7	0.013
V _T , mL/cm	1.16 ± 0.20	1.21 ± 0.22	0.010
Tme/Te ratio	0.33 ± 0.11	0.35 ± 0.11	0.007
RR, breaths/min	40.6 ± 6.9	38.8 ± 5.9	0.04
Crs, mL/cmH ₂ O	11.0 ± 3.1	11.3 ± 2.7	0.4
Rrs, cmH ₂ O · mL ⁻¹ · s ⁻¹	29.9 ± 6.2	30.8 ± 7.1	0.4
prs, s	0.32 ± 0.11	0.34 ± 0.12	0.3

V_T: Tidal volume; Tme: time to reach PEF; Te: expiratory time; Crs: Respiratory system compliance; Rrs: respiratory system resistance; prs: time constant of the respiratory system. ^aValues expressed as mean ± SD.

**Figure 3** – Graphical representation of the variation in tidal volume before (pre-technique) and after (post-technique) applying the slow and progressive expiration.

One possible explanation for the increase in V_T is the reduction of airway obstruction. It has been described that the reduction in the Tme/Te ratio is an indirect form to determine airway obstruction.⁽¹⁸⁾ Thus, we infer that there was a decrease in bronchial obstruction in the patients studied by the increase in the Tme/Te ratio (> 0.30) after the PSE maneuver. This reduction in the obstructive process is due to the thoracoabdominal compression performed during the PSE maneuvers, where the aim is to prolong the expiratory phase and eliminate the trapped air. If this process is successful, the reduction of the expiratory reserve volume is expected, and it is able to allow an increase in V_T. In addition to finding an increase in the Tme/Te ratio, our group has previously described that the PSE maneuver contributes in removing over 50% of the expiratory reserve volume,⁽⁴⁾ confirming the results of the decrease in obstruction.

Another factor that would justify the increase in V_T in the infants studied here is the induction

of sighs, characterized as breaths in which there is an increase greater than 100% in V_T. Recently, we have shown that the PSE maneuver favors the induction of sighs,⁽⁴⁾ and that it is already known that sighs act by recruiting alveoli and increasing the V_T.^(16,18) It is important to point out that the variation observed in our study in the values of V_T, albeit small, is probably clinically relevant. The instability of the rib cage, routinely observed in infants, makes those more susceptible to lung volume reduction, and maneuvers that increase V_T become clinically relevant.^(21,22) We observed an increase of nearly 10% in V_T after applying three sequences of the PSE maneuver. In the clinical practice, however, physical therapists, when using the PSE maneuver technique, perform a greater number of maneuvers, basing the number of repetitions on the improvement in pulmonary auscultation.⁽⁵⁾ Thus, it is unlikely that the actual increase of V_T determined by the PSE maneuver technique in the daily practice be much more expressive than the one found in our study.

Rrs in our study was maintained after the application of the PSE maneuver, in disagreement with studies in patients on mechanical ventilation.^(2,8,9) This finding can be explained by evaluating patients breathing spontaneously, without hypersecretion and therefore without change in the Rrs at the beginning of the protocol.

Another benefit of measuring Rrs is the detection of bronchospasm. It is described that techniques with intense mechanical vibrations in the chest, such as “tapotement” (percussive tapping) and vibration, can aggravate bronchospasm, evidenced by the reduction in

FEV₁ and PEF.⁽²³⁻²⁵⁾ There is no description of the unconventional techniques of physiotherapy favoring bronchospasm, due to the fact that these techniques cause no abrupt mechanical vibrations in the chest. In our study, we observed no change in either Rrs or PEF, confirming that PSE maneuver did not induce bronchospasm in this group of wheezing infants, and we consider it a safe technique to perform even in individuals prone to bronchospasm. A group of authors, when evaluating unconventional techniques of respiratory therapy similar to that applied in this study, observed no significant changes in PEF.⁽²⁶⁾

The maintenance of the values of Crs in this study can be justified due to fact that the initial values were within normal limits,^(17,18) and to the lack of pulmonary hypersecretion. Authors who observed that variation in respiratory function after physical therapy in mechanically ventilated patients described the secretion clearance as the main reason.^(7,9,20,21)

Our study was limited by the fact that patients are not in exacerbation or presented hypersecretion. Individuals with hypersecretion were not selected, due to the fact that, in addition to the interference of this condition in the variables analyzed, the secretion could also compromise the safety of the infant, since the sedation associated with hypersecretion aggravates airway obstruction in patients breathing spontaneously. The short application time of PSE maneuver (three sequences) and functional reevaluation soon after its completion are other limitations to our study. This, however, could hardly be altered due to the short time of sedation induced by chloral hydrate. Even with a small evaluation time, we observed significant changes in V_T and we can speculate that the performance of a greater number of sequences of the PSE maneuver could increase the differences found. We conclude that the application of PSE maneuver in wheezing infants is able to induce changes in pulmonary function with increased V_T and reduced RR. These facts are probably secondary to the reduced bronchial obstruction. The maintenance of the airway resistance values demonstrates that the PSE maneuver technique is safe for application in infants with propensity to bronchospasm.

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About the authors

Fernanda de Cordoba Lanza

Adjunct professor. Graduate Program in Rehabilitation Sciences, *Universidade Nove de Julho* – UNINOVE, Nove de Julho University – São Paulo, Brazil.

Gustavo Falbo Wandalsen

Adjunct Professor. Allergy, Clinical Immunology, and Rheumatology Section of the Department of Pediatrics, *Universidade Federal de São Paulo/Escola Paulista de Medicina* – UNIFESP/EPM, Federal University of São Paulo/Paulista School of Medicine – São Paulo, Brazil.

Carolina Lopes da Cruz

Master's Student. Allergy, Clinical Immunology, and Rheumatology Section of the Department of Pediatrics, *Universidade Federal de São Paulo/Escola Paulista de Medicina* – UNIFESP/EPM, Federal University of São Paulo/Paulista School of Medicine – São Paulo, Brazil. And Physiotherapist. Department of Pediatrics and Neonatology, *Hospital Israelita Albert Einstein*, São Paulo, Brazil.

Dirceu Solé

Full Professor. Allergy, Clinical Immunology, and Rheumatology Section of the Department of Pediatrics, *Universidade Federal de São Paulo/Escola Paulista de Medicina* – UNIFESP/EPM, Federal University of São Paulo/Paulista School of Medicine – São Paulo, Brazil.