Flavio Renato Antunes dos Santos[1], Luiz Carlos Schneider Júnior[2], Luiz Alberto Forgiarini Junior[3], Jefferson Veronezi[4]

Effects of manual rib-cage compression versus PEEP-ZEEP maneuver on respiratory system compliance and oxygenation in patients receiving mechanical ventilation

Efeitos da compressão torácica manual versus a manobra de PEEP-ZEEP na complacência do sistema respiratório e na oxigenação de pacientes submetidos à ventilação mecânica invasiva

1. Physiotherapist Graduate from the Centro Universitário Metodista IPA. Porto Alegre (RS), Brazil.
2. Physiotherapist from the Intensive Care Unit of the Hospital São Francisco at the Irmandade Santa Casa de Misericórdia de Porto Alegre. Porto Alegre (RS), Brazil.
3. Physiotherapist Postgraduate (Doctorate) in Lung Sciences at the Universidade Federal do Rio Grande do Sul – UFRGS - Porto Alegre (RS), Brazil. Researcher from the Hospital de Clinicas de Porto Alegre. Porto Alegre (RS), Brazil.
4. Master, Physiotherapist and Professor from the Centro Universitário Metodista IPA – Porto Alegre (RS), Brazil.

ABSTRACT

Objectives: Patients unable to perform breathing functions may be submitted to invasive mechanical ventilation. Chest physiotherapy acts directly on the treatment of these patients for the purpose of improving their lung function. The objective of this study was to evaluate the effects of manual rib-cage compression versus the positive end expiratory pressure-zero end expiratory pressure (PEEP-ZEEP) maneuver, on compliance of the respiratory system and oxygenation in patients under invasive mechanical ventilation.

Methods: A double centric, prospective, randomized and crossover study, with patients under invasive mechanical ventilation, in controlled mode for more than 48 hours was carried out. The protocols of chest physiotherapy were randomly applied at an interval of 24 hours. Data of respiratory system compliance and oxygenation were collected before application of the protocols and 30 minutes after.

Results: Twelve patients completed the study. Intragroup analysis, for both techniques showed a statistically significant difference in tidal volume ($p=0.002$), static compliance ($p=0.002$) and dynamic compliance ($p=0.002$). In relation to oxygenation, in the group of manual rib-cage compression, peripheral oxygen saturation increased with a significant difference ($p=0.011$).

Conclusions: Manual rib-cage compression and PEEP-ZEEP maneuver have positive clinical effects. In relation to oxygenation we found a favorable behavior of peripheral oxygen saturation in the group of manual rib-cage compression.

Keywords: Continuous positive airway pressure; Positive-pressure respiration; Physical therapy modalities; Respiration, artificial/methods; Respiratory therapy/methods

Received from the Centro Universitário Metodista IPA - Porto Alegre (RS), Brazil.

Submitted on October 10, 2008
Accepted on May 26, 2009

Author for correspondence:
Flavio Renato Antunes dos Santos
Rua Alcides Alfonsin, nº 452
CEP: 96760-000 – Tapes (RS), Brasil.
Phones: (51) 3672-2150 / 9852-3435
E-mail: flaviosantosfisio@bol.com.br

INTRODUCTION

Patients unable to perform respiratory functions may be submitted to invasive mechanical ventilation (IMV) to provide them with a ventilation and oxygenation system for adequate alveolar ventilation, restore acid-base balance and reduce respiratory work.(1)

These patients present various features that hinder clearance of lung secretion such as inadequate humidification, high fractions of oxygen, use of sedatives and or analgesics, basal lung disease and presence of an artificial airway mechanically hampering elimination of secretion next to the trachea.(2) Secretion retention contributes to episodes of hypoxemia, atelectasis and ventilator-associated pneumonia.(3) It is believed that bronchial hygiene may improve compliance of the respiratory system through increase of dynamic compliance (Cdyn) and static compliance (Cst).[4,5]

The airway clearance technique has been widely used in the treatment of patients under IMV aiming to improve their pulmonary function by bronchial clearance, expansion of collapsed lung areas and consequent balance of the ratio ventilation/perfusion. Currently, some studies have shown efficiency of physiotherapy for resolution of actelactasis and promotion of bronchial hygiene.[6,7] The physiotherapy techniques more often used to foster bronchial hygiene are postural drainage (PD), manual rib-cage compression (MRC), manual hyperinflation (MH) and tracheal suctioning, among others.[8]

In the positive end expiratory pressure - zero end-expiratory pressure (PEEP-ZEEP), theoretically when PEEP rises, gas is redistributed through collateral ventilation, reaching adjacent alveoli previously collapsed by mucus. This redistribution eases reopening of small airways by removing the mucus adhering to their walls. Later, when PEEP is reduced to 0 cmH_2O, the expiratory flow pattern is changed aiding transport of secretions from smaller airways to those more central.[9,10]

Recent studies have not found a statistically significant difference when comparing MRC to isolated tracheal suction. These studies however, presented some limitations.[11-13] To the contrary, Stiller et al.[14-15] concluded that this technique, associated to body positioning, sighs and suctioning increases efficacy of treatment, for resolution of acute lobar actelactasis. Comparison of MRC with PEEP-ZEEP was elected because both techniques aim for airway clearance by changing the airflow. Furthermore, MRC requires physical effort from the physiotherapist while the other makes use of changes in the ventilator parameters, to displace bronchial secretions.

In this study it was hypothesized that MRC and PEEP-ZEEP may improve compliance of the respiratory system and oxygenation of patients under IMV. As such, Cdyn and Cst, tidal volume (TV) and peripheral oxygen saturation (SpO_2) were measured. This study proposed to assess behavior of the respiratory system compliance and of oxygenation for use of the MRC and PEEP-ZEEP techniques in patients under mechanical ventilation.

METHODS

This study was carried out from January to May 2008 in the Intensive Care Unit (ICU) of the Policlínica Santa Clara da Irmandade Santa Casa de Misericórdia de Porto Alegre and in the ICU of the" Hospital Parque Belém. Research was approved by the Resarch Ethics Committee of the Centro Universitário Metodista IPA and of the hospitals mentioned. Family members or those responsible signed an informed consent.

Inclusion criteria were patients under IMV in controlled mode for more than 48 hours. Exclusion criteria were rib fracture, presence of thoracic tube, hemodynamic instability (mean arterial pressures < 89 mmHg), severe bronchospasm, intracranial hypertension (intracranial pressure > 10mmHg), non drained pneumothorax, tracheostomy, use of ventilation support with high PEEP levels (above 12 cmH_2O) and closed suction system. No change in the individual adjustment of the ventilator was carried out for the proposed study.

Study design

A bicentric, prospective, randomized and crossover study was carried out. Patients were randomly chosen for the two types of treatment: MRC and PEEP-ZEEP, both followed by endotracheal suction.

After patient inclusion in the study the sequence of application of MRC and PEEP-ZEEP were randomly defined. Brown envelopes were used for allotment in blocks of 10. The interval between application of each protocol was set at 24 hours, to avoid interference with the first protocol used. Body hygiene, chest X-rays, administration of drugs, bronchodilators and tracheal suction procedures were not performed for at least one hour prior to application of the techniques. To avoid interference in the various measurements, the same criteria were used until the last data was recorded (thirty minutes after application of the technique). Protocols were analyzed separately (intragroup) and also together (intergroup) for comparison of the two protocols.

Physiotherapy techniques

Manual rib-cage compression

Manual compression at expiratory phase of the ventilatory cycle on the anterolateral region of the chest at the level of the six last ribs was carried out. .Each compression was interrupted at the end of each expiratory stage to release inspiration. The maneuver was performed for 10 minutes.

PEEP-ZEEP maneuver

At the inspiration phase of the ventilatory cycle, PEEP was raised to 15 cmH_2O, limiting the peak inspiratory pressure (PIP) to 40 cmH_2O. After the patient performed five ventilatory cycles, at expiration phase, PEEP was suddenly reduced to zero pressure and at inspiration phase, PEEP was returned to the previously adjusted values. After waiting for two ventilatory cycles, the maneuver was repeated for 10 minutes.

Procedures

Initially all individuals in the sample were placed in supine position with the head at zero degrees with head, trunk and lower limbs stretched and in neutral position, this instant was defined as moment zero (MO). While patients were in this position for twenty minutes variables of respiratory system compliance and oxygenation were collected. This first data collection was defined as moment one (M1).

Next, patients were submitted to one of the physiotherapy techniques, with an approximate duration of ten minutes. Afterwards a tracheal suction was carried out according to recommendations of the American Association of Respiratory Care.[16] Thirty minutes after end of the procedure a new data collection was made and defined as moment two (M2).

Twenty four hours later the patient was submitted to the other technique, according to the random order established at study onset following the model (Figure 1).

After conclusion of this study all patients received the physiotherapeutic care prescribed by the physician according to the ICU routine, without changes due to the survey.

Data collection

Collection of ventilatory parameters, vital signs and physiotherapeutic care was carried out by a single researcher, for standardization. The variables of compliance of the respiratory and cardiorespiratory systems: minute volume (MV), TV, PEEP, intrinsic positive end-expiratory pressure (iPEEP) controlled pressure (CP) peak of inspiratory pressure (PIP) plateau pressure (PlateauP), heart rate (HR), mean arterial pressure (MAP) and SpO_2 were collected.

Value of MV was collected, coupling the ventilometer (Ohmeda RM 121) to the expiratory valve of the mechanical ventilator and an arithmetic mean of the three consecutive means was determined. TV was calculated by dividing MV by respiratory rate (RR), measured during MV collection. PEEP and PIP were collected on the manometer of the mechanical ventilator. PEEP was collected by occlusion of the expiratory valve of the ventilator, immediately before start of the next inspiration and PlateauP was collected by occluding the expiratory valve for five seconds at end- inspiration, both shown on the ventilator manometer.

For calculation of Cdyn and Cst the following formulas were used: TV divided by the result of PIP subtracted from PEEP and iPEEP; TV divided by the result of PlateauP subtracted by the PEEP and iPEEP.

All patients who participated in the study were ventilated with Servo 900C (Siemens-Elema, Solna, Sweden) or Sechrist 2200B (Anahein, California). Vital signs were collected by the non-invasive method, with a multiparametric modular monitor model Compact Monitor Eagle 1000 (Marquete Hellige Medical System, Germany). A module of the pulse oxymeter with sensor to read SpO_2 was used, placed on the extremity of one of the upper limbs; a module with chest electrodes placed on the patient was used to read HR also, a module to measure non- invasive arterial pressure, placing a cuff on the proximal end of one of the upper limbs.

Statistical Analysis

Data with normal distribution was presented as mean ± standard deviation (SD) or absolute frequency (n) and percentage (%). The variable with asymmetric distribution (time of MV) was presented as median (minimum-maximum). For intragroup and intergroup comparison, the Wilcoxon test was used for paired samples. Were considered as statistically significant $p<0.05$ values.

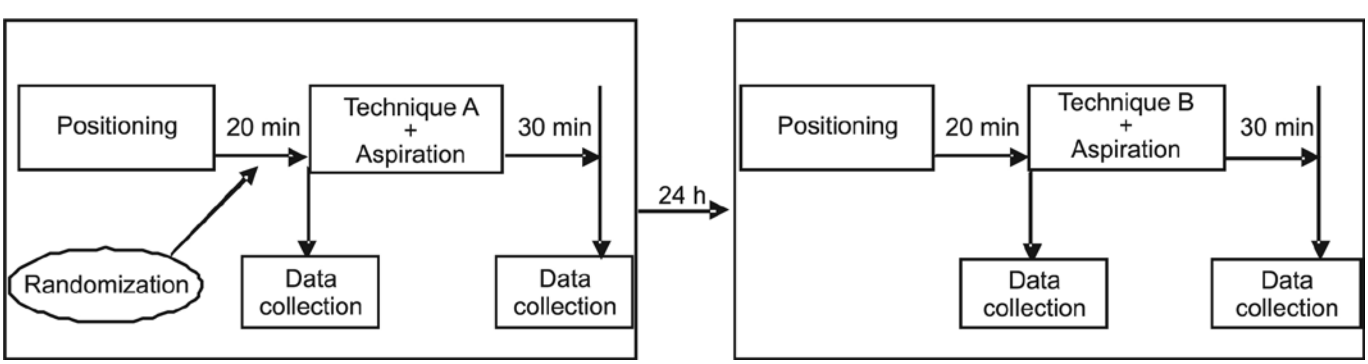

Figure 1- Study protocol.

RESULTS

From January to May 2008, 14 patients were selected, 2 were excluded due to change of the ventilation mode, therefore 12 completed the study. Table 1 shows the initial characteristics of studied patients.

Essentially, the reason for mechanical ventilation was pneumonia in eight patients (66.7%). Among comorbidities, chronic obstructive pulmonary disease was the most common, found in six patients (50%). Variables related to ventilation mode and to drug therapy at the moment prior to application of the physiotherapy techniques did not present a significant difference among groups (p=1.0). None of the patients made use of bronchodlitaors.

Table 1 – Characteristics of the patients studied

Variables	Results (N=12)
Age (years)	54.9 ± 19.3
Gender	
Male	6 (50).0
Female	6 (50.0)
MV days	6 (2 – 13)
Cause of ARF	
Pneumonia	8 (66.7)
Acute pulmonary edema	2 (16.7)
Intestinal obstruction	1 (8.3)
Acute arterial obstruction	1 (8.3)
Ventilation therapy	
PCV	12 (100)
PEEP	6.4 ± 1.3
FiO_2	42.9 ± 8.9
CP	18.6 ± 4.8
Medical treatment	
Antibiotic	10 (83.3)
Vasopressor	6 (50.0)
NSAI	7 (58.3)

MV- mechanical ventilation; ARF – acute respiratory failure; PCV – pressure controlled ventilation; PEEP – positive end expiratory pressure l; FiO_2 – fraction of inspired oxygen; CP – controlled pressure; NSAI – non-steroid anti-inflammatory. Results expressed in mean± standard deviation; median (minimum-maximum) or N(%).

Variables related to compliance of the respiratory system, TV, Cst and Cdyn did not significantly change in intergroup analysis at any of the assessed moments. Yet, intergroup analysis shows statistically significant changes 30 minutes after application of the techniques. In both groups there was an increase of TV, Cst and Cdyn (Table 2).

Hemodynamic variables, when analyzed between groups did not present a statistically significant difference at any of the assessed moments (Table 3).

Table 3 – Hemodynamic variation in the manual rib-cage compression and the PEEP-ZEEP maneuver

	HR (bpm)		MAP (mmHg)	
	MRC	PEEP-ZEEP	MRC	PEEP-ZEEP
Before	88±12	86±14	82±18	84±16
30 min	92±14	88±15	84±16	88±14

HR – heart rate; MAP mean arterial pressure; MRC manual rib-cage compression; PEEP-ZEEP - PEEP-ZEEP maneuver Values expressed in mean ± SDDP * p <0,05 when compared with the moment before protocol application.

Regarding oxygenation, SpO_2 did not present a significant difference when analyzed between groups, at the moment before (p=0.469) or 30 minutes after (p=0.191). In the MRC group, SpO_2 increased with a significant difference and in the PEEP-ZEEP group it increased, however with no statistically significant difference (Figure 2).

Table 2 – Variables of the respiratory system compliance

		Before (N=12)		After30 min (N=12)		p Value**
TV (mL)	MRC	547	(380 – 705)	615	(427 – 842)	0.002
	PEEP-ZEEP	561	(336 – 661)	610	(446 – 689)	0.002
	p*	0.248		0.209		
Cst (L/cmH_2O)	MRC	51.5	(29 – 68)	62	(36 – 71)	0.002
	PEEP-ZEEP	49	(34 – 69)	54.5	(45 – 74)	0.002
	p**	0.683		0.637		
Cdyn (L/cmH_2O)	MRC	39.5	(20 – 47)	47	(25 – 53)	0.002
	PEEP-ZEEP	35	(19 – 46)	41	(25 – 52)	0.002
	p**	0.455		0.373		

TV – tidal volume; Cst – static pulmonary compliance; Cdyn – dynamic pulmonary compliance; MRC – manual rib-cage compression; PEEP-ZEEP = positive end expiratory pressure/zero end expiratory pressure. p* - paired Wilcoxon test intragroups (before and after 30 min). p** - Paired Wilcoxon test between groups (MRC and PEEP-ZEEP).

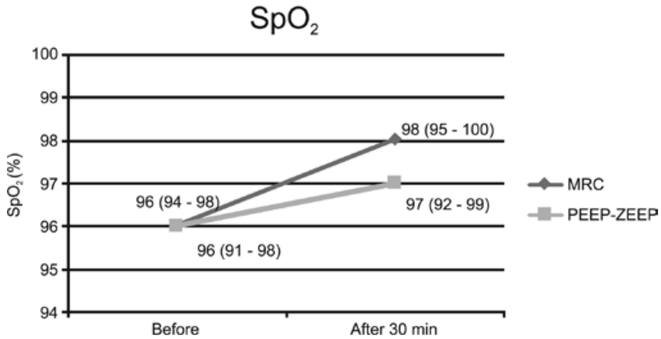

Figure 2 – Peripheral oxygen saturation (SpO_2). Values expressed in median (minimum- maximum). p=0.011 when compared with the moment before application of manual rib-cage compression. MRC - manual rib-cage compression; PEEP-ZEEP – positive end expiratory pressure-zero end expiratory pressure maneuver.

DISCUSSION

Techniques o bronchial clearance are often used in patients under IMV to prevent hypoxemia, atelectasis, and ventilator- associated pneumonia.[3] However, some techniques such as MRC, continue to be controversial about their effects. Regarding PEEP-ZEEP, although it is disseminated among Brazilian physiotherapists, it was found in few publications on standardization of the methods and influence on compliance of the respiratory and cardiovascular systems.[9,10]

When using the open suction system, no loss of lung volume and hypoxemia were disclosed at the collection carried out after thirty minutes. Furthermore, prior to suctioning patients were hyperoxygenated at a hundred percent during thirty seconds.[16] Studies have shown that after suction there is a quick decrease in the airway pressures and consequent loss of lung volume due to the negative pressure generated in the airway that may also cause hypoxemia.[17-19]

In this study MRC and PEEP-ZEEP were carried out for 10 minutes, without a statistically significant difference of TV between maneuvers. Differently from our outcome, Unoki et al.[13] made a crossover study in 31 patients with various diseases, compared endotracheal suction with and without association of MRC for 5 minutes, concluding that there was no significant difference in the intragroup analysis of MRC (p=0.93) in Cdyn, possibly due to the short time of application of the technique. Another study did not detect a significant difference of Cdyn after application of MRC, which may be associated to the variety of base diseases.[20]

The Cst increased significantly after 30 minutes of application of both techniques (p=0.002), when compared to the respective MO. Another study that used PEEP-ZEEP found a decrease of Cst after 30 minutes. However, the maneuver was carried out waiting for five ventilatory cycles and only then PEEP was reduced to a zero pressure level, associated to MRC. Then, the patient was disconnected from the ventilator and endotracheal suctioning was performed. The maneuver was then repeated three times.[9]

In our study, for the intergroup analysis there was no statistically significant difference of TV between maneuvers, nevertheless, at intragoup analysis there was a statistically significant increase (p=0.002) in both techniques. In another study, using MRC for 10 minnutes, TV did not significantly change, however, patients were submitted to different ventilation modes.[20]

SpO_2 increased significantly after MRC, and did not exhibit the same behavior when carried out with PEEP-ZEEP. Likewise, Rodrigues[9] did not find significant change after application of PEEP-ZEEP in patients with bronchial hypersecretion. Rosa et al.[20] carried out MRC for tem minutes and MH, disclosing a significantly increased SpO_2 (p=0.01) immediately after application of the technique, remaining above the base value for 120 minutes. Although values obtained in our study showed a significant increase after application of MRC, this difference was not clinically relevant considering that values are in accordance with the normality of SpO_2 parameters. However, this increase may have taken place due to airway clearance, fostering expansion of the collapsed areas and consequently, better oxygenation

It was decided to standardize PEEP-ZEEP with PEEP levels up to 15 cmH_2O for five ventilation cycles. Values above 15 cmH_2O would induce alveolar hyperdistension and therefore drop of compliance.[21] PEEP-ZEEP was performed for ten minutes to avoid hemodynamic variations., Pressurization with 15 cmH_2O for 15 minutes may change the cardiac index in patients at postoperrative of cardiac surgery.[22] PIP did not exceed the recommended safe threshold values, patients did not present clinical evidence of injury to the respiratory system, since no case of barotrauma was found in our study notwithstanding use of PIP up to 40 cmH_2O. The 3rd Brazilian Consensus on Mechanical Ventilation (2007) advocated the PIP<50 cmH_2O and PlateauP<35 cmH_2O values as maximum safety thresholds, capable of minimizing risk of barotrauma.[23]

In both techniques, when comparing the moment before care, all assessed variables presented an increase, suggesting that both techniques promote efficient bronchial hygiene detaching secretions from the smaller airways to the central ones, so that a greater volume of secretion is removed by tracheal suctioning. In literature no studies analyzing the deleterious effects and the complications derived from application of the techniques were found.

Our study presents some limitations, that made generalization of results unfeasible. Collection was not performed by a single evaluator who did not know to which group the patients belong. Base diseases were varied and may have interfered in the outcomes. Furthermore, it was not possible to analyze the subgroup according to base disease, due to the small number of the sample, which also may have biased results. It must be taken into consideration that pulse oxymetry for parameters above 94% of SpO_2 an approximate variation of 4% may take place.[21] Consequently, comparison between effects of MRC versus PEEP-ZEEP according to diagnosis or mechanical ventilation mode must be clarified in the future. Therefore, care must be taken in an attempt to generalize our assumptions for all patients under mechanical ventilation.

CONCLUSION

MRC and PEEP-ZEEP have positive effects on the respiratory function and do not differ one from another in relation to compliance of the respiratory system, expressed by Cdyn, Cst and TV after 30 minutes of application of the techniques. Regarding oxygenation a favorable behavior of SpO_2 was found in the MRC group however not in the PEEP-ZEEP. Studies about each technique are needed for a better understanding of their effects thereby allowing consensus regarding the techniques that may be used and which are the expected benefits of their application.

RESUMO

Objetivos: Os pacientes com incapacidade de desempenhar suas funções ventilatórias podem ser submetidos à ventilação mecânica invasiva. A fisioterapia respiratória atua no tratamento destes pacientes com a finalidade de melhorar sua função pulmonar. O objetivo do estudo foi avaliar os efeitos da compressão torácica manual versus a manobra de pressão expiratória final positiva-pressão expiratória final zero (PEEP-ZEEP) na complacência do sistema respiratório e na oxigenação de pacientes em ventilação mecânica invasiva.

Métodos: Foi realizado um estudo bicêntrico, prospectivo, randomizado e crossover, incluindo pacientes em ventilação mecânica invasiva em modo controlado por um período superior a 48 horas. Os protocolos de fisioterapia respiratória foram realizados de forma aleatória, com intervalo de 24 horas entre eles. Dados da complacência do sistema respiratório e da oxigenação foram coletados antes da aplicação dos protocolos e 30 minutos após a aplicação dos mesmos.

Resultados: Doze pacientes completaram o estudo. Na análise intragrupo, em ambas as técnicas houve aumento estatisticamente significativo do volume corrente (p=0,002), da complacência estática (p=0,002) e complacência dinâmica (p=0,002). Com relação à oxigenação, no grupo compressão torácica manual, a saturação periférica de oxigênio aumentou com diferença significativa (p=0,011).

Conclusões: A compressão torácica manual e a manobra de PEEP-ZEEP têm efeitos clínicos positivos e não diferem entre si. Em relação à oxigenação encontramos um comportamento favorável da saturação periférica de oxigênio no grupo compressão torácica manual.

Descritores: Pressão positiva contínua nas vias aéreas; Respiração com pressão positiva; Modalidades de fisioterapia; Respiração artificial/métodos; Terapia respiratória/métodos

REFERENCES

1. Knobel E, Barbas CSV, Scarpinella-Bueno MA, Rodrigues Júnior M. Terapia intensiva: pneumologia e fisioterapia respiratória. 2a ed. São Paulo: Atheneu; 2004.
2. Scanlan CL, Wilkins RL, Stoller JK. Fundamentos da terapia respiratória de Egan. 7a. ed. São Paulo: Manole; 2000.
3. Judson MA, Sahn SA. Mobilization of secretions in ICU patients. Respir Care. 1994;39(3):213-26.
4. Ciesla ND. Chest physical therapy for patients in the intensive care unit. Phys Ther. 1996;76(6):609-25.
5. Selsby D, Jones JG. Some physiological and clinical aspects of chest physiotherapy. Br J Anaesth. 1990;64(5):621-31. Comment in: Br J Anaesth. 1991;66(1):146-7.
6. Berney S, Denehy L, Pretto J. Head-down tilt and manual hyperinflation enhance sputum clearance in patients who are intubated and ventilated. Aust J Physiother. 2004;50(1):9-14.
7. Paratz J, Lipman J, McAuliffe M. Effect of manual hyperinflation on hemodynamics, gas exchange, and respiratory mechanics in ventilated patients. J Intensive Care Med. 2002;17(6):317-24.
8. Stiller K. Physiotherapy in intensive care: towards and evidence-based practice. Chest. 2000;118(6):1801-13.
9. Rodrigues MVH. Estudo do comportamento hemodinâmico, da troca gasosa, da mecânica respiratória e da análise do muco brônquico na aplicação de técnicas de remoção de secreção brônquica em pacientes sob ventilação mecânica. [tese]. São Paulo: Faculdade de Medicina da Universidade de São Paulo; 2007.
10. Kaneko M, Murakami SH, Silva AB. Fisioterapia na ventilação mecânica convencional. In: Knobel E. Condutas no paciente grave. 2a ed. São Paulo: Atheneu; c1999.p. 1599-609.
11. Unoki T, Mizutani T, Toyooka H. Effects of expiratory rib cage compression combined with endotracheal suctioning on

gas exchange in mechanically ventilated rabbits with induced atelectasis. Respir Care. 2004;49(8):896-901. Comment in: Respir Care. 2004;49(8):894. Respir Care. 2005;50(3):387; author reply 387-8.

12. Unoki T, Mizutani T, Toyooka H. Effects of expiratory rib cage compression and/or prone position on oxygenation and ventilation in mechanically ventilated rabbits with induced atelectasis. Respir Care. 2003;48(8):754-62.
13. Unoki T, Kawasaki Y, Mizutani T, Fujino Y, Yanagisawa Y, Ishimatsu S, et al. Effects of expiratory rib-cage compression on oxygenation, ventilation, and airway-secretion removal in patients receiving mechanical ventilation. Respir Care. 2005;50(11):1430-7.
14. Stiller K, Jenkis S, Grant R, Geake T, Taylor J, Hall B. Acute lobar atelectasis: a comparison of five physiotherapy regimens. Physiother Theory Pract. 1996;12:197-209.
15. Stiller K, Geak T, Taylor J, Grant R, Hall B. Acute lobar atelectasis. A comparison of two chest physiotherapy regimens. Chest. 1990;98(6):1336-40. Comment in: Chest. 1991;100(6):1741.
16. AARC clinical practice guideline. Endotracheal suctioning of mechanically ventilated adults and children with artificial airways. American Association for Respiratory Care. Respir Care. 1993;38(5):500-4.
17. Maggiore SM, Lellouche F, Pigeot J, Taille S, Deye N, Durrmeyer X, et al. Prevention of endotracheal suctioning-induced alveolar derecruitment in acute lung injury. Am J Respir Crit Care Med. 2003;167(9):1215-24.
18. Cereda M, Villa F, Colombo E, Greco G, Nacoti M, Pesenti A. Closed system endotracheal suctioning maintains lung volume during volume-controlled mechanical ventilation. Intensive Care Med. 2001;27(4):648-54.
19. Fernández MD, Piacentini E, Blanch L, Fernández R. Changes in lung volume with three systems of endotracheal suctioning with and without pre-oxygenation in patients with mild-to-moderate lung failure. Intensive Care Med. 2004;30(12):2210-5.
20. Rosa FK, Roese CA, Kusiak F, Savi A, Dias AS, Monteiro MB. Comportamento da mecânica pulmonar após a aplicação de protocolo de fisioterapia respiratória e aspiração traqueal em pacientes com ventilação mecânica invasiva. Rev Bras Ter Intensiva. 2007;19(2):170-5.
21. Presto B, Presto LDN. Fisioterapia respiratória: uma nova visão. 2a. ed. Rio de Janeiro: Bruno Presto; 2005.
22. Auler JO Jr, Carmona MJ, Barbas CV, Saldiva PH, Malbouisson LM. The effects of positive end-expiratory pressure on respiratory system mechanics and hemodynamics in postoperative cardiac surgery patients. Braz J Med Biol Res. 2000;33(1):31-42.
23. Jerre G, coordenador. Fisioterapia no paciente sob ventilação mecânica. III Consenso Brasileiro de Ventilação Mecânica. J Bras Pneumol. 2007;33(Supl 2):142-50.