

Effects of two respiratory physiotherapy protocols on respiratory mechanics and cardiorespiratory parameters of patients under mechanical ventilation: a pilot study

Efeitos de dois protocolos de fisioterapia respiratória na mecânica respiratória e parâmetros cardiorrespiratórios de pacientes em ventilação mecânica: estudo piloto

Efectos de dos protocolos de fisioterapia respiratoria en la mecánica respiratoria y parámetros cardiorrespiratorios de pacientes en ventilación mecánica: estudio piloto

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ABSTRACT | The aim of the study was to analyze the effects of two respiratory physiotherapy protocols on respiratory mechanics and cardiorespiratory parameters of patients under mechanical ventilation compared to a tracheal aspiration protocol. Pilot study with quasi-experimental design and 50 patients, randomized into GI group (n=16): control group, submitted to tracheal aspiration; GII (n=17): submitted to vibrocompression and tracheal aspiration; GIII (n=17): submitted to vibrocompression, aspiration, and ventilator hyperinflation. The variables analyzed were: heart rate (HR), respiratory rate, systemic blood pressure, peripheral oxygen saturation, static lung compliance, dynamic lung compliance, and airway resistance. These were recorded at three moments: before the procedures (M1), immediately after them (M2), and 15 minutes after them (M3). To compare the effect and analyze the interaction between measurement time and groups, we used Two-Way ANOVA and post hoc Tukey's test. The effect size was determined by calculating Cohen's f^2 and by statistical analysis using SPSS for Windows (version 20), with a significance level of 5%. In the intragroup comparison, no differences were observed, while in the comparison between groups the variable HR showed difference between GI and GII in M2 ($p=0.02$). Results suggest that the respiratory physiotherapy protocols evaluated had no favorable effects on respiratory

mechanics; however, they showed to be safe regarding cardiorespiratory parameters.

Keywords | Physiotherapy Modalities; Respiration, Artificial; Respiratory Mechanics; Intensive Care Units.

RESUMO | O objetivo deste estudo foi analisar os efeitos de dois protocolos de fisioterapia respiratória na mecânica respiratória e parâmetros cardiorrespiratórios de pacientes em ventilação mecânica comparando-os com um protocolo de aspiração traqueal. Estudo piloto com desenho quase-experimental com 50 pacientes, randomizados em grupo GI (n=16): grupo controle, realizado aspiração traqueal; GII (n=17): realizado vibrocompressão e aspiração traqueal; GIII (n=17): realizado vibrocompressão, aspiração e hiperinsuflação pelo ventilador mecânico. As variáveis analisadas foram: frequência cardíaca (FC), frequência respiratória, pressão arterial sistêmica, saturação periférica de oxigênio, complacência pulmonar estática, complacência pulmonar dinâmica e resistência das vias aéreas. Estas foram registradas em três momentos: antes dos procedimentos (M1), imediatamente após (M2) e 15 minutos após (M3). Para comparar o efeito e analisar a interação entre tempo de mensuração e grupos, utilizou-se a ANOVA Two-Way e post hoc de Tukey. O tamanho do efeito foi determinado pelo cálculo f^2 de Cohen e a

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análise estatística pelo programa SPSS para Windows (versão 20), nível de significância de 5%. Na comparação intragrupo não foram observadas diferenças, enquanto na comparação entre grupos a variável FC apresentou diferença entre o GI e GII no M2 ($p=0,02$). Os resultados sugerem que os protocolos de fisioterapia respiratória avaliados não promoveram benefícios quanto à mecânica respiratória, entretanto se mostraram seguros em termos de parâmetros cardiorrespiratórios.

Descritores | Modalidades de Fisioterapia; Respiração Artificial; Mecânica Respiratória; Unidades de Terapia Intensiva.

RESUMEN | El objetivo de este estudio fue analizar los efectos de dos protocolos de fisioterapia respiratoria en la mecánica respiratoria y parámetros cardiorespiratorios de los pacientes en ventilación mecánica, comparándolos con un protocolo de aspiración traqueal. Estudio piloto con diseño cuasi-experimental con 50 pacientes, randomizados en grupo GI ($n=16$): grupo control, realizado una aspiración traqueal; GII ($n=17$): realizado vibrocompresión y aspiración traqueal; GIII ($n=17$): realizado vibrocompresión, aspiración y hiperinflación por el ventilador mecánico. Las variables analizadas fueron:

frecuencia cardiaca (FC), frecuencia respiratoria, presión arterial sistémica, saturación periférica de oxígeno, complacencia pulmonar estática, complacencia pulmonar dinámica y resistencia de las vías aéreas. Éstas se registraron en tres momentos: antes de los procedimientos (M1), inmediatamente después (M2) y 15 minutos después (M3). Para comparar el efecto y analizar la interacción entre el tiempo de medición y grupos, se utilizó el ANOVA Two-Way y post hoc de Tukey. Se determinó el tamaño del efecto mediante el cálculo f^2 de Cohen y el análisis estadístico por el programa SPSS para Windows (versión 20), nivel de significancia del 5%. En la comparación intragrupo no se encontraron diferencias, mientras que en la comparación entre grupos la variable FC presentó diferencia entre el GI y GII en el M2 ($p=0,02$). Los resultados sugieren que los protocolos de fisioterapia respiratoria evaluados no promovieron beneficios en cuanto a la mecánica respiratoria, sin embargo resultaron seguros en términos de parámetros cardiorespiratorios.

Palabras clave | Modalidades de Fisioterapia; Respiración Artificial; Mecánica Respiratoria; Unidades de Cuidados Intensivos.

INTRODUCTION

Maintenance of airway permeability by endotracheal intubation and institution of mechanical ventilation (MV) are the pillars of therapeutic intensive care and a breakthrough in the treatment of acute respiratory failure or acutized chronic respiratory failure¹. However, the application of positive pressure on lungs by use of prosthesis can generate systemic repercussions² and, as a result, prolong the length of hospitalization³, as well as increase the risk of death⁴. Among these repercussions, the most frequent are hemodynamic instability and respiratory infections caused by reduction of local defense mechanisms due to the presence of the tube. Moreover, patients under MV may have increased airway resistance impose greater burden to the respiratory system⁵.

The evaluation of respiratory mechanics has been studied in the MV context^{6,7}. A review study⁸ argues that there are differences for the values of Static Compliance ($C_{st,rs}$), Dynamic Compliance (C_{dyn}), and Airway Resistance (R_{aw}) when comparing patients under MV and under spontaneous ventilation.

Currently, physiotherapy has an important role in multi-professional teams assisting critical patients in most ICUs^{9,10}.

According to Siner¹¹, the advances in respiratory physiotherapy interventions contribute to reduce the accumulation of bronchial secretions in patients under MV. Physiotherapy procedures that aim to increase the permeability of the airways, optimize oxygenation, and improve respiratory mechanics are widely used in ICUs^{12,13}. Among these procedures, vibrocompression (VC), manual hyperinflation (MH), and ventilator hyperinflation (VH) are noteworthy.

Evidences of benefits resulting from MH and VC are referenced in the literature¹⁴⁻¹⁷; however, VH requires further research. Standardization is necessary to achieve the best mode of ventilation for hyperinflation and consensus regarding application parameters¹⁸. Furthermore, few studies compared VH, a relatively new technique¹⁹, with bronchial hygiene techniques such as VC, which, when combined, could enhance therapeutic effects. Possible benefits resulting from the combination of these techniques, to improve respiratory mechanics, would enable assessing their use as a means of feasible intervention to be applied on patients under MV.

Thus, the objective of this study was to analyze the effects of two respiratory physiotherapy protocols on respiratory mechanics and cardiorespiratory parameters of patients under MV, comparing them with a tracheal aspiration protocol.

METHODOLOGY

Pilot study with quasi-experimental, comparative design, conducted in an adult ICU of HUSM. It was approved by the local Ethics Committee under no. 220,812. Family members or guardians signed the Free and Informed Consent Form.

The study included patients of both sexes, aged over 18 years, hospitalized in the ICU, diagnosed with acute respiratory failure or acutized chronic respiratory failure, under MV (Inter 5-Plus® – Intermed®, São Paulo, Brazil; SERVOi, Maquet GmbH&Co, KG, Rastatt, Germany) for more than 48 hours, deep to light level of sedation (Richmond Agitation Sedation Scale – RASS), closed tracheal aspiration system, and intubation. We defined as a criterion for respiratory failure: oxygen arterial pressure lower than or equal to 50mmHg or carbon dioxide arterial pressure higher than or equal to 50mmHg, regardless of the cause²⁰. Patients under mild sedation (RASS-2) and pressure support ventilation were included provided they showed no asynchrony with the ventilator. Patients submitted to use of tracheostomy tube were excluded; as well as those with: spinal cord injury, hemodynamic instability, acute arrhythmias, fracture of ribs, intracranial hypertension, burns, undrained pneumothorax, and severe asthma.

We collected demographic and clinical data, as well as cardiovascular, ventilation and respiratory mechanics parameters. The variables measured were: heart rate (HR); mean arterial pressure (MAP), systolic blood pressure; diastolic blood pressure, and peripheral oxygen saturation, in a non-invasive manner by observing the multiparameter monitor DX2022 (Dixtal Biomédica, Manaus, Brazil). Respiratory rate (RR), plateau pressure (Pplat), and peak inspiratory pressure (Ppi) were observed in the mechanical ventilator display.

Cst,rs was obtained by dividing the tidal volume (TV) by Pplat subtracting the value of PEEP; Cdyn was obtained by dividing the TV by Ppi subtracting the value of PEEP; and Raw was obtained by dividing the

difference between the Ppi and Pplat by the inspiratory flow.

Variables were collected at three moments: baseline (M1), immediately after the interventions (M2), and 15 minutes after the interventions (M3). Patients were divided into three intervention groups, randomized by simple sortition conducted by a professional independent from the research, using envelopes containing the group to which they would be allocated, namely: Control group (GI) submitted to tracheal aspiration (TA); GII, vibrocompression (VC) maneuver followed by TA; or Group III, VC maneuver followed by TA and ventilator hyperinflation (VH). The protocols were applied by the same physical therapist in the three groups, in the afternoon, and evaluations were conducted by a physical therapist who did not know to which group the patient had been allocated.

In GI, TA was performed as recommended by the American Association for Respiratory Care²¹, as many times as necessary until no more secretion was observed in the suction probe.

In GII, VC was conducted for 10 minutes at the end of inspiration until the end of expiration²², with the patient supine and the physical therapist's hands flat on the rib cage. Next, TA was performed.

In GIII, VC and TA maneuvers were followed by the VH maneuver. This was performed with the increase in pressure or volume, depending on the ventilation mode in use, in order to achieve 40 cmH₂O of Ppi for 10 minutes²³.

At the time of application of the protocols, medical and nursing procedures were not carried out.

Sample calculation

Estimated to obtain a significance level of 5% ($p < 0.05$) and power of 80% (WinPepi version 10.5). Considering the standard deviation of the variable Cst,rs of the study by Lemes et al.²⁴, a sample of 23 individuals in each group was calculated.

Statistical analysis

Results presented with mean and standard deviation. Shapiro-Wilk test verified the normal distribution of the data. Anthropometric variables were compared between groups by one-way ANOVA and *post hoc* Tukey's test. To compare the effect

and analyze the interaction between measurement time and groups, we used two-way ANOVA and *post hoc* Tukey's test. Effect size was determined by using Cohen's f^2 for comparison between groups and classified as major, moderate, and minor²⁵. We used the Statistical Package for the Social Sciences (SPSS), version 20, with a level of significance of 5% ($p < 0.05$).

RESULTS

Of the 58 patients eligible for the study, three were excluded because of hemodynamic instability, and five because of use of tracheostomy tube. The remaining 50 were divided into three groups: GI (n=16), GII (n=17), and GIII (n=17). Subsequently, follow-up was lost for five patients, so the study was completed with 45 patients (Figure 1).

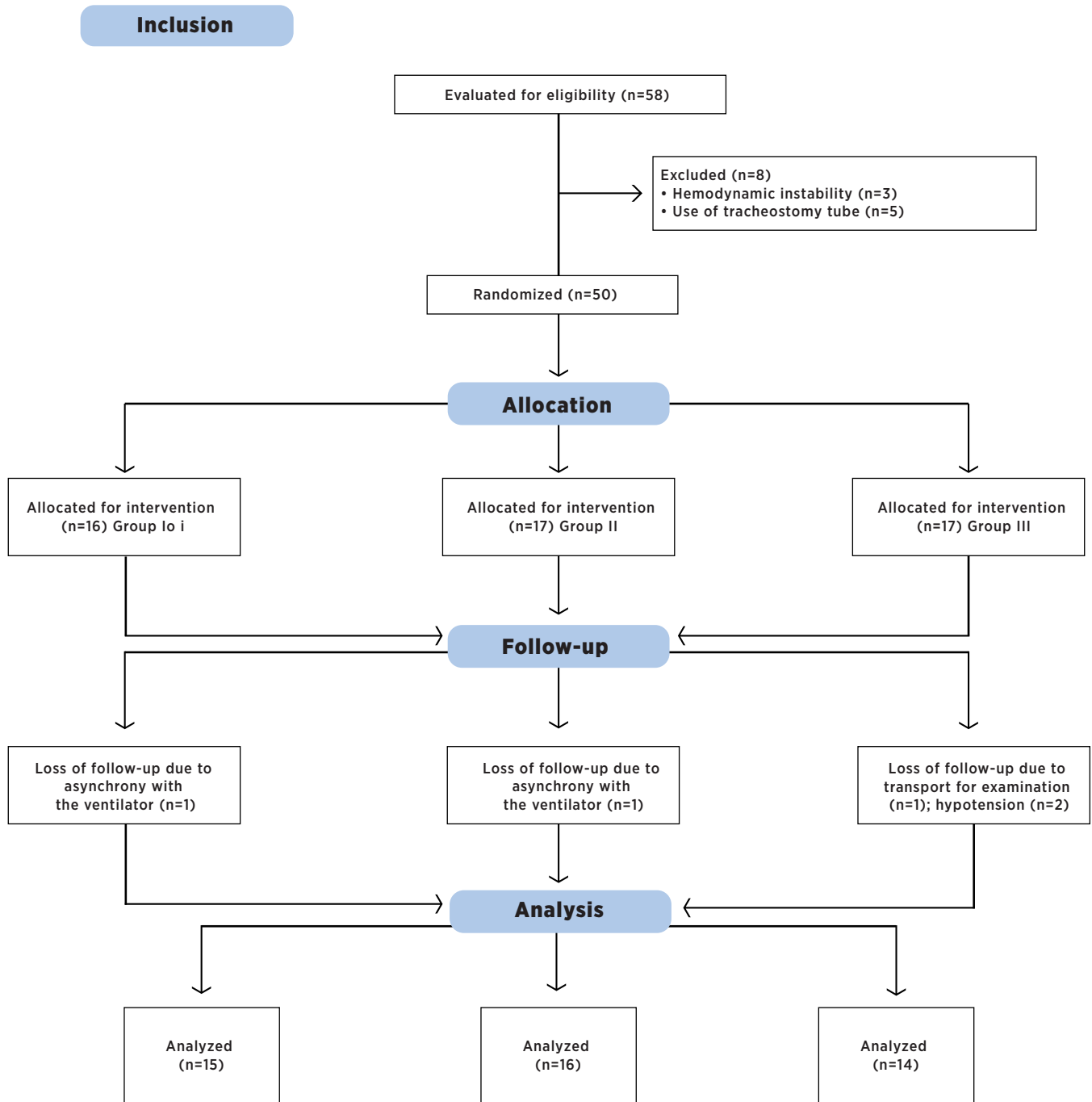


Figure 1. Study Flow Chart

Table 1 shows the characteristics of the sample, and we did not observe differences between groups.

Table 2 shows the cardiorespiratory and respiratory mechanics parameters in the three groups and the intragroup and intergroup comparison. In the

intragroup comparison, no differences were observed, while in the intergroup comparison variable HR had a difference between GI and GII at M2 ($77.4 \pm 12.7 \rightarrow 87.3 \pm 20.6$ bpm; $p=0.02$), with major effect size (Cohen's $f^2=0.39$).

Table 1. Characterization of the sample

Variables	GI (n=15)	GII (n=16)	GIII (n=14)	p
Male, n (%)	10 (66.7)	13 (81.2)	7 (50)	0.19
Age (years)	56.5±15.4	52.3±14.0	58.5±17.0	0.40
MV time (days)	4.3±2.6	6.9±5.4	5.4±4.3	0.51
PEEP (cmH ₂ O)	6.7±1.6	6.6±1.3	7.6±2.9	0.79
FI _{O₂} (%)	48.1±7.7	43.1±6.8	46.8±10.1	0.27
Reason for hospitalization				
Surgery, n (%)	4 (26.7)	4 (20.0)	5 (35.7)	0.79
Trauma, n (%)	5 (33.3)	3 (18.8)	1 (7.1)	0.20
Lungs, n (%)	1 (6.7)	5 (31.2)	3 (21.4)	0.22
Nervous system, n (%)	3 (20.0)	2 (12.5)	3 (21.4)	0.78
Infection, n (%)	1 (6.7)	2 (12.5)	2 (14.3)	0.78
Heart, n (%)	1 (6.7)	0 (0)	0 (0)	0.36
Mode of ventilation				
PCV, n (%)	12 (80.0)	12 (75.0)	13 (82.2)	0.42
PSV, n (%)	1 (6.7)	1 (6.2)	0 (0.0)	0.62
VCV, n (%)	1 (6.7)	3 (18.8)	1 (7.1)	0.48
Medication				
Antibiotic, n (%)	6 (40.0)	7 (43.8)	5 (35.7)	0.90
Sedation, n (%)	15 (100.0)	16 (100.0)	14 (100.0)	0.35
Vasopressor, n (%)	7 (46.7)	5 (31.2)	10 (71.4)	0.08
Corticoid, n (%)	4 (26.7)	8 (50.0)	9 (64.3)	0.12

Values expressed as Mean±SD and percentages. GI: tracheal aspiration; GII: vibrocompression and tracheal aspiration; GIII: vibrocompression, tracheal aspiration, and ventilator hyperinflation; MV: mechanical ventilation; PEEP: positive end expiratory pressure; FI_{O₂}: fraction of inspired oxygen; PCV: pressure controlled ventilation; PSV: pressure support ventilation; VCV: volume controlled ventilation

Table 2. Cardiorespiratory variables, respiratory system compliance variables, and airway resistance variables

	HR (bpm)	RR (rpm)	MAP (mmHg)	SpO ₂ (%)	Cst,rs (mL/cmH ₂ O)	Cdyn (mL/cmH ₂ O)	Raw (cmH ₂ O/L/s)	
Group I	M1	73.7±9.7	14.9±1.8	93.8±17.2	96.9±3.4	42.3±12.8	25.6±7.3	13.0±6.5
	M2	77.4±12.7	15.4±1.9	93.6±16.3	97.5±2.6	43.4±19.3	26.1±7.5	12.4±6.8
	M3	77.5±12.2	14.9±1.8	94.3±12.6	97.5±2.6	47.3±19.8	26.8±7.5	12.8±6.1
	p-value ^α	0.58	0.73	0.39	0.78	0.72	0.9	0.95
Group II	M1	83.4±21.0	16.6±4.4	91.1±15.7	98.0±3.2	45.1±14.7	27.4±8.3	12.2±5.9
	M2	87.3±20.6	16.7±3.1	98.2±14.1	98.4±2.2	47.2±16.9	29.7±9.2	10.9±7.1
	M3	86.9±21.3	16.0±2.8	92.9±12.2	98.2±2.0	48.4±16.9	29.8±9.4	11.0±6.8
	p-value ^α	0.85	0.84	0.34	0.91	0.85	0.69	0.82
Group III	M1	84.2±18.6	16.1±2.4	92.6±13.4	98.1±1.6	42.1±16.5	25.5±7.7	12.2±6.0
	M2	83.4±18.1	15.9±2.2	87.4±16.3	98.1±1.8	46.6±17.1	28.7±11.8	12.1±6.2
	M3	85.1±19.4	15.7±2.4	94.3±12.1	97.6±2.1	48.7±18.3	30.2±13.3	11.8±6.6
	p-value ^α	0.97	0.92	0.4	0.73	0.59	0.54	0.98
p-value ^β	0.02*	0.06	0.64	0.19	0.76	0.33	0.6	
Effect size ^β	0.39	0.33	0.07	0.26	0.04	0.17	0.28	

^αIntragroup comparison. ^βIntergroup comparison. Values expressed as Mean±SD. HR: heart rate; RR: respiratory rate; MAP: mean arterial pressure; SpO₂: peripheral oxygen saturation; Cst,rs: static compliance of the respiratory system; Cdyn: Dynamic compliance of the respiratory system; Raw: airway resistance; * Significant difference between Group I and II at M2 (two-way ANOVA)

DISCUSSION

Currently, there has been discussion about the safety of the application of respiratory physiotherapy procedures in critically ill patients^{16,26,27}; however, there are few studies evaluating their effect on cardiorespiratory parameters. In this study, although HR was different between GI and GII at M2, it is emphasized that it was within normal limits and, thus, no clinical relevance was evident on the finding, indicating that the protocols adopted showed to be hemodynamically safe in these patients.

Despite the lack of evidence of the effects of VH combined with VC on cardiorespiratory parameters of critically ill patients, it is important to mention the study of Castro et al.²², who evaluated the hemodynamic repercussions of VC in tracheostomy patients, observing that VC promoted reduction in MAP. In the study of Cerqueira Neto et al.¹⁶, it was observed that VC combined with acceleration of expiratory flow (AEF) did not alter the MAP in TBI patients under MV. Hemodynamic variables were maintained during VC and AEF; however, there was an increase in MAP, intracranial pressure, HR, and pulmonary artery pressure during TA. All values returned to baseline levels 10 minutes after the procedure.

In this study, the respiratory mechanics variables did not change at any of the moments evaluated, suggesting that the protocols, as applied, were not effective to evidence, to date, the recovery of complacencies and the reduction of resistance. Importantly, the values of C_{dyn}, C_{st}, R_s, and R_{aw} were out of the normal parameters since M1 and remained like this at the other evaluated moments. It is also important to highlight that these findings were evidenced in the intragroup and intergroup comparisons.

Most studies on the effects of bronchial hygiene resources on respiratory mechanics of patients under MV analyzed VH alone or compared to MH, and there are few that analyzed the effects of VH combined with VC maneuvers, as in this study. By comparing VH to MH, Dennis et al.²⁸ found that there was no difference in relation to compliance and current volume. However, a similar study conducted by Berney et al.¹⁹ showed increased pulmonary compliance after application of both hyperinflation techniques. Among the few studies that combined VH with manual bronchial hygiene techniques, there is the study of Guimarães et al.²⁹, who used a technique that is similar to VC combined with

hyperinflation using pressure support, observing no improvement in respiratory mechanics.

We consider as limitations of the present study the heterogeneity of the sample in relation to clinical reasons for hospitalization and the impossibility of using methods to quantify the volume of the tracheobronchial secretion eliminated.

Thus, our findings should be interpreted with caution. The continuation of the study, to reach the planned sample size, as well as the conduct of randomized clinical trials, may clarify the potential benefits of the interventions analyzed here and commonly used in the clinical practice of respiratory physiotherapy in ICU. At this time, the practical applicability of the research refer to the absence of negative implications regarding the investigated physiotherapy procedures, considering both hemodynamic and cardiorespiratory perspectives, evidence being required as for whether these procedures are favorable to the recovery of complacencies and reduction of airway resistance in patients under MV.

CONCLUSION

The respiratory physiotherapy protocols had no favorable effects on respiratory mechanics; however, they showed to be safe concerning cardiorespiratory parameters and, from this point of view, can be used safely.

REFERENCES

1. Laghi F, Tobin MJ. Indications for mechanical ventilation. In: Tobin, MJ, editor. Principles and Practice of Mechanical Ventilation. 2. New York: MacGraw-Hill Co. 2006:129-62.
2. Carvalho CRR. Ventilator-associated pneumonia. J Bras Pneumol. 2006;32(4):xx-ii.
3. Esteban A, Anzueto A, Frutos F, Alía I, Stewart TE, Benito S, et al. Characteristics and outcomes in adult patients receiving mechanical ventilation: a 28-day international study. J Am Med Assoc. 2002;287(3):345-55.
4. Esteban A, Frutos-Vivar F, Muriel A, Ferguson ND, Peñuelas O, Abaira V, et al. Evolution of mortality over time in patients receiving mechanical ventilation. Am J Respir Crit Care Med. 2013;188(2):220-30.
5. Smith BK, Gabrielli A, Davenport PW, Martin AD. Effect of training on inspiratory load compensation in weaned and unweaned mechanically ventilated ICU patients. Respir Care. 2014;59(1):22-31.
6. Alotaibi GA. Effect of pressure support level, patient's effort, and lung mechanics on phase synchrony during

- pressure support ventilation. *Middle East J Anaesthesiol.* 2014;22(6):573-82.
7. Valentini R, Aquino-Esperanza J, Bonelli I, Maskin P, Setten M, Danze F, et al. Gas exchange and lung mechanics in patients with acute respiratory distress syndrome: comparison of three different strategies of positive end expiratory pressure selection. *J Crit Care.* 2015;30(2):334-40.
 8. Henderson WR, Sheel AW. Pulmonary mechanics during mechanical ventilation. *Respir Physiol Neurobiol.* 2012;180(2-3):162-72.
 9. França EET, Ferrari F, Fernandes P, Cavalcanti R, Duarte A, Martinez BP, et al. Fisioterapia em pacientes críticos adultos: recomendações do Departamento de Fisioterapia da Associação de Medicina Intensiva Brasileira. *Rev Bras Ter Intensiva.* 2012;24(1):6-22.
 10. Sommers J, Engelbert RH, Dettling-Ihnenfeldt D, Gosselink R, Spronk PE, Nollet F, et al. Physiotherapy in the intensive care unit: an evidence-based, expert driven, practical statement and rehabilitation recommendations. *Clin Rehabil.* 2015 Feb 13. [Epub ahead of print]
 11. Siner JM. An exogenous cough. *Crit CareMed.* 2013;41(3):929-30.
 12. Castro AA, Calil SR, Freitas SA, Oliveira AB, Porto EF. Chest physiotherapy effectiveness to reduce hospitalization and mechanical ventilation length of stay, pulmonary infection rate and mortality in ICU patients. *Respir Med.* 2013;107(1):68-74.
 13. Naue Wda S, Forgiarini Junior LA, Dias AS, Vieira SR. Chest compression with a higher level of pressure support ventilation: effects on secretion removal, hemodynamics, and respiratory mechanics in patients on mechanical ventilation. *J Bras Pneumol.* 2014;40(1):55-60.
 14. Jones AY. Secretion movement during manual lung inflation and mechanical ventilation. *Respir Physiol Neurobiol.* 2002;132(3):321-7.
 15. Paulus F, Binnekade JM, Vroom MB, Schultz MJ. Benefits and risks of manual hyperinflation in intubated and mechanically ventilated intensive care unit patients: a systematic review. *Crit Care.* 2012;16(4):R145.
 16. Cerqueira Neto ML, Moura AV, Cerqueira TC, Aquim EE, Reá-Neto A, Oliveira MC, et al. Acute effects of physiotherapeutic respiratory maneuvers in critically ill patients with craniocerebral trauma. *Clinics.* 2013;68(9):1210-4.
 17. Ferreira LL, Valenti VE, Vanderlei LC. Chest physiotherapy on intracranial pressure of critically ill patients admitted to the intensive care unit: a systematic review. *Rev Bras Ter Intensiva.* 2013;25(4):327-33.
 18. Hayes K, Seller D, Webb M, Hodgson CL, Holland AE. Ventilator hyperinflation: a survey of current physiotherapy practice in Australia and New Zealand. *N Z J Physiother.* 2011;39(3):124-30.
 19. Berney S, Denehy L. A comparison of the effects of manual and ventilator hyperinflation on static lung compliance and sputum production in intubated and ventilated intensive care patients. *Physiother Res Int.* 2002;7(2):100-8.
 20. Batista CC, Goldbaum Júnior MA, Sztiler F, Goldim JR, Fritscher CC. Medical futility and respiratory failure: a prospective cohort study. *Rev Bras Ter Intensiva.* 2007;19(2):151-60.
 21. Restrepo RD, Brown JM, Hughes JM. AARC Clinical Practice Guidelines. Endotracheal suctioning of mechanically ventilated patients with artificial airways 2010. *Respir Care.* 2010;55(6):758-64.
 22. Castro AAM, Rocha S, Reis C, Leite JRO, Porto EF. Comparação entre as técnicas de vibrocompressão e de aumento do fluxo expiratório em pacientes traqueostomizados. *Fisioter Pesqui.* 2010;17(1):18-23.
 23. Dennis D, Jacob WJ, Samuel FD. A survey of the use of ventilator hyperinflation in Australian tertiary intensive care unit. *Crit Care Resusc.* 2010;12(4):262-8.
 24. Lemes DA, Zin WA, Guimarães, FS. Hyperinflation using pressure support ventilation improves secretion clearance and respiratory mechanics in ventilated patients with pulmonary infection: a randomised crossover trial. *Aust J Physiother.* 2009;55(4):249-54.
 25. Lindenau JD, Guimarães LSP. Calculando o tamanho de efeito no SPSS Revista HCPA. 2012;32(3):363-81.
 26. Dias CM, Siqueira TM, Faccio TR, Gontijo LC, Salge JA, Volpe MS. Efetividade e segurança da técnica de higiene brônquica: hiperinsuflação manual com compressão torácica. *Rev Bras Ter Intensiva.* 2011;23(2):190-8.
 27. Srirachoenchai T, Parker AM, Zanni JM, Nelliot A, Dinglas VD, Needham DM. Safety of physical therapy interventions in critically ill patients: a single-center prospective evaluation of 1110 intensive care unit admissions. *J Crit Care.* 2014;29(3):395-400.
 28. Dennis D, Jacob W, Budgeon C. Ventilator versus manual hyperinflation in clearing sputum in ventilated intensive care unit patients. *Anaesth Intensive Care.* 2012;40(1):142-9.
 29. Lopes AJ, Constantino SS, Lima JC, Canuto P, Menezes S. Expiratory rib cage in mechanically ventilated subjects: a randomized crossover trial. *Respir Care* 2014;59(5):678-85.