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Expiratory peak flow and respiratory system resistance in mechanically ventilated patients undergoing two different forms of manually assisted cough

Pico de fluxo expiratório e resistência do sistema respiratório de pacientes sob ventilação mecânica submetidos a duas formas de tosse manualmente assistida

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This study was conducted at the Intensive Care Units of Hospital da Restauração and Hospital Esperança - Recife (PE), Brazil.

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ABSTRACT

Objective: Mechanical ventilation is associated with retained airway secretions. Manually assisted cough contributes to the displacement of bronchial mucus, whereas positive end-expiratory pressure increases collateral ventilation and maintains airway patency. This study aimed to assess the effects of manually assisted cough, either alone or added to increased positive end-expiratory pressure and inspiratory time (optimized manually assisted cough), on the expiratory peak flow and respiratory system mechanics in mechanically ventilated patients.

Methods: In this controlled and randomized clinical trial, respiratory mechanics and expiratory peak flow were assessed in male and female patients undergoing either tracheal suctioning alone, manually assisted cough followed by tracheal suctioning or optimized manually assisted cough followed by tracheal suctioning.

Results: Thirty-five patients completed the trial. Respiratory system resistance was significantly reduced after optimized manually assisted cough (16.0 ± 3.6 versus 12.4 ± 3.1 $cmH_2O/L/s$; $p = 0.04$). The expiratory peak flow during optimized manually assisted cough was significantly higher in comparison with the values observed during manually assisted cough (112.3 ± 15.6 versus 95.8 ± 18.3 Lpm; $p < 0.05$). Both values were significantly higher than the values observed in the group undergoing tracheal suctioning alone (52.0 ± 7.6 Lpm; $p < 0.001$).

Conclusion: Optimized manually assisted cough increases the expiratory peak flow in comparison with manually assisted cough; in addition, this procedure reduces respiratory system resistance.

Keywords: Respiratory therapy/methods; Positive-pressure respiration; Respiration, artificial; Respiratory system/physiopathology

INTRODUCTION

Ineffective lower airway ciliated epithelium and coughing mechanisms are common in mechanically ventilated (MV) critically ill patients. Among the several causes, the following are particularly notable: the use of certain drugs (such as sedatives, anesthesia, or neuromuscular blockers), pain, missing compressive phase of cough, airway compression and obstruction, abdominal muscle weakness, inappropriate pulmonary expansion and inhalation of cold and dry gas.[1-5]

Secretion-removing techniques are essential for the displacement of secretions accumulated beyond the third airway generation using increased expiratory air flow and subsequent tracheal suctioning.[6] Manually assisted cough (MAC), also called quadcough,[7,8] manual chest compression,[9] manual chest pressure or squeezing,[10,11] is a maneuver that simulates the normal coughing mechanism and that is characterized by early expiratory vigorous chest and/or abdomen compression.[12,13]

A number of studies have shown that MAC is able to displace peripheral airway secretions toward the oropharynx, with positive effects on the respiratory mechanics and oxygenation; however it can be associated with reduced expiratory peak flow and early airway collapse in patients with obstructive diseases.[14,15]

Increased positive end-expiratory pressure (PEEP) and inspiratory time (Tins) can be useful for displacing bronchial secretions and maintaining airway patency and appropriate respiratory time constants, thereby promoting increased expiratory peak flow (EPF).[15-18]

With this rationale, this study aimed to assess the effects of MAC alone or in association with increased PEEP and Tins on the EPF values and respiratory mechanics of mechanically ventilated patients.

METHODS

This controlled randomized trial was conducted at the intensive care units of Hospital da Restauração and Hospital Esperança (Recife, PE, Brazil) from August 2008 to 2010. The clinical trial protocol was appropriately approved by the Fundação Altino Ventura Ethics Committee. A written informed consent form was signed by each subject entering the trial.

The subjects included male and female patients aged 18 years or above with different diseases, undergoing MV, using an artificial airway with an 8.5 mm diameter, having a history of airway hypersecretion confirmed by auscultation of rhonchi, respiratory system resistance (Rsr) ≥ 12 $cmH_2O/L/s$ and/or indented flow-volume curve along with an indication for respiratory physiotherapy and tracheal suctioning.

The study excluded patients with a history of intracranial hypertension, hemodynamic instability, chest stiffness, chronic obstructive pulmonary disease (COPD), pulmonary hyperinflation, smoking, bronchopleural fistula, acute respiratory distress syndrome, bronchial hyperreactivity, osteoporosis, vascular fragility, use of cardiac pacemaker or using PEEP > 10 cmH_2O.

The study protocol was discontinued upon hemodynamic changes, i.e., 20 mmHg mean blood pressure (MBP) increase or decrease, 20 bpm heart rate (HR) increase or decrease, or peripheral oxygen saturation (spO_2) lower than 90% during the maneuvers (monitored with the multiparametrical monitors DASH 3000® (GE Medical Systems, Wisconsin, USA), SOLAR 8000® (GE Medical Systems, Wisconsin, USA) and DX2010® (Dixtal Biomedica, Manaus, Brazil).

The subjects' personal data were collected, including name, age, gender, height and estimated weight, calculated using the following formula: men = 50 + 0.91 (height - 152.4) and women = 45.5 + 0.91 (height - 152.4).[19] In addition, clinical and MV parameter data were collected.

After an initial evaluation, the patients were positioned with the bed head raised by 45º (measured with a goniometer Carci®, São Paulo, Brazil) and underwent 5 minutes of pressure-controlled ventilation mode (PCV), with controlled pressure (CP) = 20 cmH_2O above PEEP, Tins = 1 second, respiratory rate (RR) = 12 ipm, inspired oxygen fraction (FiO_2) = 40%, inspiratory sensitivity (sens) = -2 cmH_2O and PEEP = 5 cmH_2O, using the mechanical ventilators INTER-5® (INTERMED®, São Paulo, Brazil), BIRD 8400 (BIRD® Products Corp., Wisconsin, USA) or INTER-5 PLUS VAPS (INTERMED®, São Paulo, Brazil). The humidification system (heat exchanger filter) was removed, and the patients were subsequently randomized to one of 3 groups:

Control group: Previously adjusted PCV mode for 5 minutes followed by tracheal suctioning.

MAC group: Previously adjusted PCV associated with MAC (all maneuvers performed by a single professional), maintaining the hands positioned over the anterolateral surface of the hemithorax with early expiratory compression, promoting expiratory flow acceleration. This maneuver was repeated 10 times for each hemithorax with 2 ventilator cycle intervals between the maneuvers, for a total mean time of 5 minutes, followed by tracheal suctioning.

Optimized manually assisted cough (OMAC): MAC as described above in association with PCV with CP = 20 cmH_2O above PEEP, RR = 10 ipm, Tins = 2 seconds, FiO_2 = 40%, sens = -2 cmH_2O and PEEP = 15 cH_2O, followed by tracheal suctioning.

Tracheal suctioning was conducted as recommended by the American Association of Respiratory Care[20] using an open suctioning system with a number 12 suctioning catheter (Imbramed® São Paulo, Brazil) and was repeated 3 times with 2 minute intervals.

The respiratory mechanics were assessed before and after the maneuver and after tracheal suctioning. During these assessments, the patients were sedated with midazolam and fentanyl and kept at level 6 on the Ramsay scale, with no respiratory muscle effort. The cuff pressure was adjusted for the minimum occlusion volume, and the patients were ventilated with volume-controlled ventilation with a tidal volume = 8 mL/kg of anticipated weight, inspiratory flow = 60 lpm, with squared flow wave, RR = 12 ipm, PEEP = 5 cmH_2O, sens = -2 cmH_2O and FiO_2 = 40%. The plateau pressure was achieved using interruption of the inspiratory flow method with a 3-second inspiratory pause; the static compliance (Cst) and respiratory system resistance (Rsr) were calculated later.

For all of the groups, the EPF was observed after each ventilator cycle and directly read on the monitors TRACER V® and INTER GMX SLIM® (INTERMED®, São Paulo, Brazil), with the means calculated later.

Statistical analysis

The Kolmogorov-Smirnov test was used to test the variables' normality. A Chi-squared test was used to assess the differences in the ratios. Intergroup and intragroup variables were compared using a one-way analysis of variance (ANOVA) and Tukey's post-test. A significance level of 5% was used for all of the conclusions. The GraphPadPrism 4 and Microsoft Office Excel 2007 software packages were used for the analyses.

RESULTS

A total of 35 patients were assessed and randomized to one of the following groups: control (n = 12), MAC (n = 12) or OMAC (n = 11). Table 1 displays the overall patients' characteristics; the groups were not significantly different.

Table 2 displays comparative intragroup and intergroup Cst analysis during different study times;

Table 1 - Overall sample characteristics

Variables	Control (N = 12)	MAC (N = 12)	OMAC (N = 11)	p value
Age (years)	59.50 ± 24.93	48.92 ± 27.27	55.64 ± 21.82	0.57
Height (m)	1.67 ± 0.07	1.69 ± 0.11	1.68 ± 0.10	0.82
Ideal weight (Kg)	60.61 ± 7.97	63.54 ± 11.97	61.37 ± 11.49	0.78
Female	8 (66.7)	6 (50.0)	8 (72.7)	0.50
Orotracheal tube	7 (58.3)	10 (83.3)	7 (58.3)	0.38
Diagnosis				
Stroke	7 (58.3)	8 (66.6)	7 (63.7)	0.84
CHF	2 (16.7)	2 (16.7)	1 (9.0)	0.87
HT	3 (25.0)	2 (16.7)	3 (27.3)	0.87
VAP	12 (100)	12 (100)	11 (100)	1.00

MAC - manually assisted cough; OMAC - optimized manually assisted cough; CHF - congestive heart failure; HT - head trauma; VAP - ventilator-associated pneumonia. The results were expressed as the means ± standard deviation or absolute figures. One-way ANOVA and Chi-squared tests.

Table 2 - Respiratory system compliance and resistance at different protocol times

	Times			p value
	Initial	Before aspiration	After aspiration	
Respiratory system compliance				
Control	57.4 ± 26.6	48.8 ± 16.8	51.3 ± 15.7	0.57
MAC	51.8 ± 15.1	59.0 ± 26.7	51.2 ± 15.2	0.57
OMAC	42.1 ± 11.9	46.1 ± 29.4	43.3 ± 11.6	0.88
P value	0.17	0.16	0.79	
Respiratory system resistance				
Control	15.0 ± 4.4	14.0 ± 3.3	12.6 ± 3.0	0.28
MAC	15.5 ± 7.5	19.9 ± 8.5	14.1 ± 8.8	0.22
OMAC	16.0 ± 3.6	16.0 ± 4.1	12.4 ± 3.1	0.04
p value	0.92	0.06	0.73	

MAC - manually assisted cough; OMAC - optimized manually assisted cough. One-way ANOVA and Tukey's post-test.

no statistically significant difference was observed. The Rsr was significantly reduced after OMAC (16.0 ± 3.6 versus 12.4 ± 3.1 cmH2O/L/s; $p = 0.04$). (Table 2)

Figure 1 displays the means ± standard deviation for EPF during the study protocol, with statistically higher EPF values observed during MAC (95.8 ± 18.3 Lpm) and OMAC (112.3 ± 15.6 Lpm) in comparison with control group values (52.0 ± 7.6 Lpm) ($p < 0.001$) and for OMAC in comparison with MAC ($p < 0.05$).

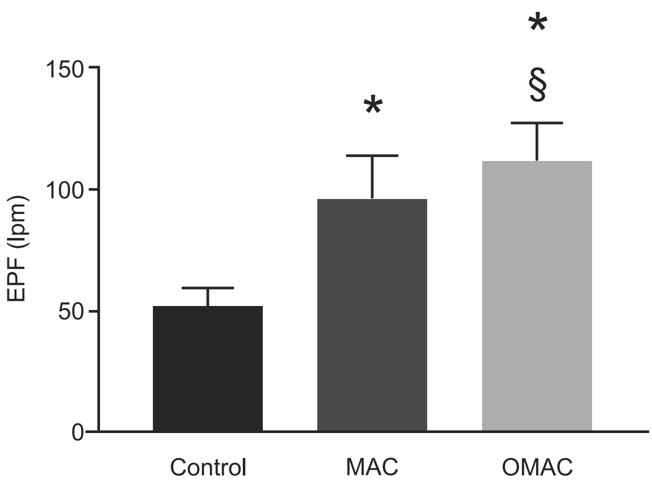

Figure 1 - Mean (standard deviation) of expiratory peak flow during the maneuvers.

EPF – expiratory peak flow; MAC - manually assisted cough; OMAC - optimized manually assisted cough; * $p < 0.001$ versus Control; § $p < 0.05$ versus MAC Group; One-way ANOVA and Tukey's post-test.

DISCUSSION

In this study, higher EPF values were observed during MAC in association with increased Tins and PEEP in comparison with MAC alone. This result likely suggests protective PEEP effects.

MAC in patients with COPD was associated with reduced EPF and is correlated with premature small airway collapse.[21] Darbee et al., using a helium dilution technique, observed an improved gas mix, concluding that PEEP is associated with improved airway patency and collateral ventilation, leading to increased EPF by easing air inflow to airways obstructed by secretion.[22] Perry et al. noted that an association of PEEP and high-frequency chest compression prevented reductions in the end-expiratory volume and promoted oscillation expiratory flow in six voluntary COPD patients.[16]

The role of PEEP-generating devices in increasing the volume of expectorated secretions is not clear. Two studies have shown increased amounts of cough-expectorated secretions following the use of PEEP-generating devices.[23,24]

In an experimental trial, Volpe et al.[6] have shown that increased EPF, EPF/inspiratory peak flow (IPF) ratio and EPF-IPF difference cause improved mucus displacement. Biphasic flow mechanisms, based on the generation of high expiratory flow rates, lead to the disorganization of glycoprotein molecules and reduced mucus viscosity, thereby improving the secretion mobility.[25-29]

Studies have shown that inverting the Tins/expiratory time relationship (< 0.9), obtained via increasing Tins, promotes EPF increase, especially if associated with low IPF. In this case, EPF should be at least 10% higher than IFP.[6,29,30] In our study, the patients were under PCV mode ventilation during the use of both forms of MAC. This condition yielded high and variable IPFs, predisposing to low EPF/IPF rates and EPF-IPF differences; these differences were not monitored.

Avena et al.[31] performed MAC in sixteen intubated patients undergoing volume-controlled MV with squared flow wave, observing a non-significant increase in resistance pressure and respiratory system resistance immediately following the maneuver with a tidal volume = 8 mL/kg body weight. The IPF was not informed. In our study, a significant Rsr drop was observed following OMAC.

Potential MAC benefits in MV patients are not fully understood. Unoki et al.[32] assessed the role of MAC in the treatment of mechanically ventilated patients. Improved ventilation and oxygenation and reduced retention of tracheal secretions were found.

The use of PEEP is correlated with improved pulmonary compliance and arterial oxygenation. In our study, no significant Cst change was observed during increased PEEP and Tins in association with MAC. Berney & Denehy[30] have found that the use of inspiratory pressures as high as 40 cmH_2O, maintained for 3 seconds, delivered using a manual inflator or mechanical ventilator, led to improved Cst in mechanically ventilated patients.

In this study, we could not use any methods to measure the volume of secretions removed from the airway or analysis of the mucus mass displacement. These techniques are considered to be more objective ways to assess the technique's effects;[6,30,33] this lack may have limited the assessment of the possible benefits from this technique. Considering that this study had a small sample size and only assessed short-term outcomes, larger sample sizes and assessment of long-term clinical outcomes are required before our findings can be extrapolated.

CONCLUSION

Optimized manually assisted cough increases the expiratory peak flow compared with manually assisted cough; in addition, this technique reduces respiratory system resistance.

RESUMO

Objetivo: A ventilação mecânica associa-se à retenção de secreções traqueobrônquicas. A tosse manualmente assistida contribui para o deslocamento do muco brônquico, enquanto a pressão positiva ao final da expiração incrementa a ventilação colateral e mantêm a patência da via aérea. O objetivo deste estudo foi analisar os efeitos da aplicação da tosse manualmente assistida isoladamente ou associada ao incremento da pressão expiratória final positiva e do tempo inspiratório (tosse manualmente assistida otimizada) sobre o pico de fluxo expiratório e a mecânica do sistema respiratório de pacientes em ventilação mecânica.

Métodos: Ensaio clínico controlado e randomizado, em que foram avaliados a mecânica respiratória e o pico de fluxo expiratório de pacientes de ambos os sexos submetidos à aspiração traqueal isolada, tosse manualmente assistida seguida de aspiração traqueal e tosse manualmente assistida otimizada seguida de aspiração traqueal.

Resultados: Trinta e cinco pacientes completaram o estudo. A resistência do SR (Rsr) reduziu significativamente após a realização da tosse manualmente assistida otimizada (16,0 ± 3,6 *vs* 12,4 ± 3,1 $cmH_2O/L/s$; p = 0,04). O pico de fluxo expiratório durante a realização da tosse manualmente assistida otimizada foi significativamente maior que o observado durante a tosse manualmente assistida (112,3 ± 15,6 *vs*95,8 ± 18,3 Lpm; p < 0,05)e ambas foram significativamente maiores que aquele observado no grupo submetido à aspiração traqueal isoladamente (52,0 ± 7,6 Lpm; p < 0,001).

Conclusão: A tosse manualmente assistida otimizada aumenta o pico de fluxo expiratório quando comparada à tosse manualmente assistida, promovendo redução da resistência do sistema respiratório.

Descritores: Terapia respiratória/métodos; Respiração com pressão positiva; Respiração artificial; Sistema respiratório/fisiopatologia

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