Respiratory mechanics of neurological patients undergoing mechanical ventilation under heated humidifier and a heat exchanger filter model

Mecânica respiratória de pacientes neurocríticos sob ventilação mecânica submetidos à umidificação aquecida e a um modelo de filtro trocador de calor

Tiago Branco Siqueira[1], Juliana Cristina Gomes de Freitas Costa[1], Isnar Campos Tavares[2], Priscilla Muniz Torres[2], Maria do Amparo Andrade[3], Eduardo Ériko Tenório de França[4], Valdecir Castor Galindo Filho[5], Flávio Maciel Dias Andrade[6]

1. Physiotherapists; Cardiopulmonar Physiotherapy Specialization Students of the Faculdade Redentor – Campus Recife – Recife (PE), Brazil.
2. Physiotherapy Graduation Students of the Faculdade Integrada do Recife – FIR - Recife (PE), Brazil.
3. Physiotherapist; PhD, Professor for the Physiotherapy Course of Universidade Federal de Pernambuco – UFPE – Recife (PE), Brazil.
4. Physiotherapist; MSc, Professor for the Physiotherapy Course of the Universidade Católica de Pernambuco - UNICAP – Recife (PE), Brazil.
5. Physiotherapist; MSc, Professor for the Faculdade Integrada do Recife – FIR and Faculdade Pernambucana - FAPE - Recife (PE), Brazil
6. Physiotherapist; MSc, Professor for the Physiotherapy Course of the Universidade Católica de Pernambuco – UNICAP – Recife (PE), Brazil and Faculdade Integrada do Recife - FIR - Recife (PE), Brazil.

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Author for correspondence:
Flávio Maciel Dias de Andrade
Rua Francisco da Cunha, 1910 – apt. 1701-B - Boa Viagem
Zip Code: 51020-041 – Recife (PE), Brazil.
Email: flaviomaciel@pulmocardio.com.br / ftflaviomaciel@yahoo.com.br

ABSTRACT

Objectives: In mechanically ventilated patients, humidifier devices are used to heat and moisturize the inspired gas. Heating and humidifying inspired gas may prevent complications associated with the respiratory mucosa dryness such as mucus plugging and endotracheal tube occlusion. Two devices have been commonly used to this, either heated humidifier or the heat moisture exchange filter. This study aimed to compare the effects of the heated humidifier and a model of heat moisture exchange filter on respiratory mechanics in mechanically ventilated neurological patients.

Methods: This was a randomized crossover trial, involving 31 neurological patients under mechanical ventilation randomly assigned to the humidification devices. Expired tidal volume, peak inspiratory flow, peak expiratory flow, static compliance, dynamic compliance and respiratory system resistance were evaluated. Statistical analysis used the Kolmogorov-Smirnov test and Student's t test for paired samples, in which P values < 0.05 were considered significant.

Results: The heat moisture exchanger filter decreased expired tidal volume, peak inspiratory flow, peak expiratory flow ($p < 0.001$) and dynamic compliance ($p = 0.002$), and increased respiratory system resistance ($p < 0.001$).

Conclusion: In the studied population, the use of a heat moisture exchange filter model leaded to several changes on respiratory mechanics parameters.

Keywords: Mechanical ventilation; Artificial respiration; Mechanical ventilators; Intensive care units

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INTRODUCTION

Artificial airway (AAW) and mechanical ventilation (MV) are indicated in the presence of imbalance between demand and ventilatory capacity. Upper airways have a very important role for the inspired air heating, humidification and filtration, and are responsible for about 65% of alveolar gas humidity.(1,2)

Prolonged inhalation of inappropriately conditioned gases may lead to hypothermia, bronchial secretions thickening, airways epithelium destruction, atelectasis, tracheal wall inflammation, dysphagia, laryngeal narrowing, in addition to vocal cords, oral cavity and tracheal injuries.(1,3-5)

The use of an AAW contributes to inhalation of a large volume of gas at low temperature and poor humidity, being the use of humidifier system coupled to the inspiratory line of the mechanical ventilator to provide the inspired air conditioning.(1,4,6-9)

Two types of devices have been commonly used during MV aiming to humidify and heat the inspired air, namely heated humidifiers (HH) and heat moisture exchange filter (HMEF). HH promote inspired air heating and humidification by passing the air through a partially filled with heated distilled water chamber, while HMEF are devices adapted between the AAW and the ventilator circuit, and able to store part of the heat and water vapor from the exhaled air, rendering them available for a new inspiration.(1,8,10,11)

Some disadvantages are associated to the use of both humidifiers. During HH use, large amounts of condensate are frequent, increasing the incidence of ventilator-associated pneumonia, patient-ventilator asynchrony, requires electricity use, and constant water replacement. Thus, prolonged HMEF use (> 24 hours) may increase the respiratory workload due to the increased resistance to the inspired air, in addition to alveolar ventilation changes.(3,8,9,12-14)

Although some studies(3,8,10,12-16) analyzed the humidification systems effectiveness regarding viral and bacterial colonization and ability to provide appropriate humidification and heating, few studies(10,14,15) evaluated the effects of their use on respiratory mechanics and respiratory muscles workload.

Considering the above discussed, this study aimed to evaluate the effects of HH and a HMEF model used on critically ill neurological patients under MV.

METHODS

This was a controlled, crossover, randomized study (randomized using ruffle card) involving critically ill neurological patients admitted in the intensive care unit from the Hospital da Restauração between October 2008 and October 2009.

This study was approved by the Institutional Ethic Committee and the legally accepted representatives of the subjects signed an informed consent form, according to the Brazilian Health Authorities requirements.

Inclusion criteria were patients older than 18 years; without previous pulmonary disease or neurological diagnosis; less than 72 hours under mechanical ventilation and sedation and absence of respiratory effort.

As exclusion criteria we considered: contraindications for HMEF use (i.e. abundant or thick tracheal secretion); increased minute volume (above 10 L/min); less than 300 mL or more than 1100 mL tidal volume; bronchopleural fistulae and hypothermia (temperature below 32ºC).(17,18)

The HH Misty-3® (Intermed®, São Paulo - Brazil), filled with 280 mL distilled water was used, adjusted on the device's level 5. The HMEF used was the Hygrobac "S"® (Mallinckrodt DAR® – Tyco Healthcare, Mirandola - Italy) electrostatic model, just unpacked, with dead space of 51 mL and weight of 28 g (according to information provided by the manufacturer).

The baseline patients' evaluation included personal data collection (name, age, gender), and clinical data (cause for intubation, comorbidities, and total MV time) obtained from the medical chart. The previously used ventilatory parameters and ventilation mode were directly checked on the mechanical ventilator (Inter 5-Plus® - Intermed®, São Paulo, Brazil).

All the patients were positioned in 30º elevated dorsal decubitus, which was measured with a goniometer (Carci®, São Paulo, Brazil), and underwent tracheal aspiration. After aspiration, were monitored the heart rate (HR), mean blood pressure (MBP) and peripheral oxygen saturation (SpO_2) using the DX 2010® (Dixtal®, São Paulo - Brazil) monitor.

All patients were initially ventilated in pressure controlled ventilation (PCV) mode for 15 minutes, pressure range of 20 cmH_2O (ΔP), respiratory rate (RR) of 12 ipm, inspiratory time (Tins) of 1 second, inspiratory sensitivity (Sens) set on -2cmH_2O, positive end-expiratory pressure (PEEP) and inspired oxygen fraction (FiO_2) kept on the previous level. After these parameters were obtained, the expired tidal volume (TVexp), peak expiratory flow (PEF), and peak inspiratory flow (PIF) were measured using the Inter-GMX Slim® monitor (Intermed®, São Paulo - Brazil).

Then, the ventilatory mode was changed to volume controlled ventilation (VCV) with square flow wave, tidal volume (TV) of 8 mL/kg from the predicted body weight (from the formulas 50 + 0.91 x [height (cm) – 152.4] for men and 45.5 + 0.91 x [height (cm) – 152.4] for women),(19) PIF 60 Lpm, inspiratory pause of 2 seconds, RR of 12 ipm, PEEP and FiO_2 kept on previous levels, obtaining a peak pressure (Ppeak) and plateau pressure (P_{plat}), and calculated the dynamic compliance – C_{dyn} (TV/P_{peak} – PEEP), static compliance – C_{stat} [$TV/(P_{plat} - PEEP)$] and respiratory system resistance – R_{rs} [$(P_{peak} - P_{plat})/ PIF$].(20)

Following C_{dyn}, C_{stat} and R_{rs} evaluations, the patients were ventilated in the PCV mode (parameters above mentioned), and the protocol repeated 15 minutes later, using the other humidification device.

For the statistical analysis, Kolmogorov-Smirnov test was used to measured variables normality, and for the inter-groups analysis the Student's t test for paired samples was applied. The GraphPad Prism 4 and Microsoft Excel 2007 softwares were used, and values with $p<0.05$ were considered significant.

RESULTS

Thirty one patients with different neurological conditions were evaluated. The subjects' characteristics, including gender, age, anthropometric data and intubation days are shown on table 1.

Table 2 shows the means ± standard deviations for the respiratory mechanic parameters evaluated in this study. It can be seen that patients under HMEF significantly reduced TV_{exp} ($p<0.001$), PEF ($p<0.001$), PIF ($p<0.001$), and C_{dyn} (0.002). Regarding R_{rs}, a significant increase was seen in the HMEF group ($p<0.001$). C_{est} was not significantly different between groups.

Table 1 – Demographic characteristics

Variables	Results
Clinical diagnosis	
Head injury	12 (38.9)
Hemorrhagic stroke	7 (22.5)
Post-operative Neurosurgery	6 (19.3)
Ischemic stroke	5 (16.1)
Spinal trauma	1 (3.2)
Gender	
Male	17 (54.8)
Female	14 (45.2)
Age (years)	47.61 ± 15.99
Height (m)	1.66 ± 0.10
Ideal weight (Kg)	61.33 ± 11.38
Intubation time (days)	1.83 ± 0.73

The data are expressed as number (percents or mean ± standard deviation).

DISCUSSION

The use of HMEF has increased in the last years due to their reduced operational costs, easy handling and possible clinical benefits such as reduced circuit condensate volume and the incidence of ventilator-associated pneumonia.(21,22) However, its use may be associated with increased resistance and dead space, and consequently increased respiratory muscle workload, reduced minute volume and carbon dioxide (CO_2) retention.(10, 23-25)

These HMEF adverse effects have been described with its partial obstruction by tracheobronchial secretions and prolonged use, and are associated to its increased hygroscopicicity and weight, not expecting major changes, while using the dry filter.(23,24)

In this study we chose to evaluate a HMEF effect over the respiratory mechanics just after starting its use, and found a mean R_{rs} increase according to the manufacturer recommendation (±2.5 $cmH_2O/L/sec$, with PIF = 60 Lpm), reaching a mean value above (14.84 $cmH_2O/L/sec$) to the considered acceptable for mechanically ventilated patients (12 $cmH_2O/L/sec$), which could be even greater with longer duration of use.

In our sample composed of critically ill neurological patients, a significant TV_{exp} was identified with HMEF used during assisted-controlled ventilation mode in neurological patients.

Special attention should be available to the control of alveolar ventilation in this population, and in hypercapnic patients while using HMEF, particularly COPD patients and those with a history of bronchospasm, in order to avoid unwanted $PaCO_2$ fluctua-

Table 2 – Ventilatory mechanics parameters during both humidification devices

Parameters	HH	HMEF	p value*
TVexp (ml)	673.90 ± 165.50	584.20 ± 141.50	0.001
PEF (Lpm)	49.65 ± 9.45	42.84 ± 7.40	0.001
PIF (Lpm)	64.23 ± 8.75	59.55 ± 8.56	0.001
C_{stat} (ml/cmH_2O)	55.95 ± 17.29	55.12 ± 14.87	0.571
C_{dyn} (ml/cmH_2O)	29.75 ± 12.12	26.29 ± 9.94	0.002
R_{sr} ($cmH_2O/L/s$)	11.71 ± 5.36	14.84 ± 5.28	0.001

HH – heated aqueous humidifier; HMEH - heat mositure exchange filter; TV_{exp} – expired tidal volume ; PEF – peak expiratory flow; PIF – peak inspiratory flow; C_{stat} - static compliance; C_{dyn} – dynamic compliance; R_{rs} – respiratory system resistance. Results were expressed as mean ± standard deviation. * t-Student paired samples test.

tions and cerebral hemodynamics changes.(26-28)

Patients undergoing weaning from MV may have respiratory muscles overload while using HMEF due to increased resistance. Several studies compared the effects of HMEF in patients weaning from MV, observing reduced TV, increased $PaCO_2$ and respiratory rate, and minute volume.(4,10,15,23)

In our study the PIF, PEF and C_{dyn} values were significantly reduced, while R_{rs} increased significantly using the HHEF. These results showed an increased airflow resistance, which may increase the ventilatory demand and consumption oxygen, difficult the mechanical ventilation weaning process.(10,23,29,30)

Chiaranda et al. reported significant R_{sr} increase in 83% of the HMEF users after 24 hours.(31) However, in a randomized controlled trial, Ricard et al. evaluated the effect of usage time on the HMEF performance in 45 mechanically ventilated patients, and observed increased R_{rs} after the initial moment of its use, not observing differences in the R_{rs} after 7 days to the first day of use.

In our study we used one single HMEF hygroscopic model. Lucato et al. evaluated the effects of different types of HMEF (hygroscopic x hydrophobic x mixed), and found a significant R_{sr} increase in the hygroscopic HMEF, which was correlated to the excessive humidity accumulation and increased filter weight.(14) Our study did not allow a comparison of several hygroscopic filters, preventing the extrapolation of our results to other models commercially available.

Iotti et al. noted that the increased R_{rs} from the HMEF may promote increased RR, decreased expiratory time, auto-PEEP development, and consequently increased respiratory workload.(29) Auto-PEEP is associated with increased intrathoracic pressure and reduced cerebral venous return,(32) predisposing to intracranial pressure increase in extensive brain injury patients.(27,28)

Conti et al., evaluating healthy volunteers that spontaneous breathing, noted that HMEF lead to increased R_{sr}, and that the respiratory muscles workload may be reduced by expiratory time prolongation.(33)

In this study we found no clinical signs of increased respiratory work, as all patients were under sedation and/or anesthesia, and controlled ventilation.

In previous studies, the effect of using HMEF on C_{dyn} is controversial. Iotti et al. did not observed significant change in C_{dyn} in patients using HMEF,(29) while Morán et al. found significant reduction in C_{dyn} during employment of HMEF due to an increased restrictive pressure,(34) similarly to our results.

Reduction in PEF found in this study during HMEF use may difficult bronchial secretions displacement to upper airways in mechanically ventilated patients. According to Gosselink et al and Volpe et al., increase PEF is associated to center of mass displacement and better removal of bronchial mucus excess, thus contributing to lower risks of pulmonary complications such as atelectasis and respiratory infections.(35,36)

In this study, HMEF did not cause significant change in the Cdyn. Macintyre et al., studied 26 patients under mechanical ventilation using HMEF more than 24, also found no significant changes in C_{est}, which could be explained due to no change in alveolar pressure during during application of HMEF.(37)

Although changes in respiratory mechanics have been observed in our sample, it is not possible to assess the clinical impact, because we did not analized its effect on variables as such mechanical ventilation time and ICU length of stay and hospital mortality. Further more studies should be addressed using others HMEF models (hygroscopic, hydrophobic and mixed) to assess alveolar ventilation and cerebral hemodynamics in critically ill neurological patients, and the respiratory muscles workload in patients weaning from mechanical ventilation.

CONCLUSION

Our results suggest that the use of a HMEF model may lead to significant changes in the respiratory mechanics (TVexp, PIF, PEF, C_{dyn} and R_{sr}) in mechanically ventilated neurological patients.

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RESUMO

Objetivos: Em pacientes sob ventilação mecânica, dispositivos de umidificação são utilizados para aquecer e umidificar o gás inspirado. O aquecimento e umidificação do gás inspirado podem prevenir complicações associadas ao ressecamento da mucosa respiratória, como a formação de tampão mucoso e oclusão do tubo endotraqueal. Com esse objetivo, dois dispositivos têm sido comumente utilizados: os umidificadores aquosos aquecidos e os filtros trocadores de calor e umidade. O objetivo deste estudo foi comparar o efeito da utilização do umidificador aquoso aquecido e de um modelo de filtro trocador de calor e umidade sobre a mecânica respiratória de pacientes neurocríticos sob ventilação mecânica.

Métodos: Trata-se de um ensaio clínico, cruzado e randomizado, onde 31 pacientes neurocríticos sob ventilação mecânica foram submetidos de forma aleatória às duas formas de umidificação. Foram avaliados o volume corrente expirado, pico de fluxo inspiratório, pico de fluxo expiratório, complacência estática, complacência dinâmica e resistência do sistema respiratório. Para análise estatística dos resultados obtidos foram utilizados os testes de Kolmogorov-Smirnov e t-Student para amostras pareadas, considerando-se a significância estatística quando observado um valor de $p < 0,05$.

Resultados: A utilização de um modelo de filtro trocador de calor e umidade promoveu a redução do volume corrente expirado, pico de fluxo inspiratório, pico de fluxo expiratório ($p < 0,001$) e complacência dinâmica ($p = 0,002$), além do aumento da resistência do sistema respiratório ($p < 0,0001$).

Conclusão: Na população estudada, a utilização de um modelo de filtro trocador de calor e umidade promoveu a modificação de diversos parâmetros da mecânica respiratória.

Descritores: Mecânica respiratória; Respiração artificial; Ventiladores mecânicos; Unidades de terapia intensiva

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