

Impacts in the Respiratory Mechanics of the Ventilator Hyperinsufflation in the Flow Bias Concept: a Narrative Review

Impactos na Mecânica Respiratória da Técnica de Hiperinsuflação com Ventilador Mecânico no Conceito *Flow Bias* Cefálico: uma Revisão Narrativa

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Recebido em: 22/05/19

Aprovado em: 30/08/19

Abstract

Patients who require invasive ventilatory support are subject to the deleterious effects of this, mainly ventilator-associated pneumonia (VAP). The physiotherapist, a member of the multiprofessional team, assists the patient with the purpose of promoting the recovery and preservation of the functionality, being able to minimize / avoid secondary complications. This study aims to identify the repercussions of mechanical ventilation hyperinflation (MVH) in the flow bias concept in respiratory mechanics. This study is a narrative review. MVH is an important resource commonly used in clinical practice that involves the manipulation of mechanical ventilator configurations to provide larger pulmonary volumes, and the generated airflow gradient may play a relevant role in mucus transport, with the concept of flow bias the main factor responsible for its direction. For the mobilization of the mucus towards the cephalic direction to occur, there must be a predominant expiratory flow, guaranteeing the peak ratio of expiratory flow / inspiratory flow peak (EFP / IFP) greater than 1.11. Maintenance of mechanical ventilation assures the patient to maintain the positive end-expiratory pressure (PEEP) and the oxygen inspired fraction, avoiding the deleterious effects of the mechanical ventilator disconnection. MVH is able to improve lung compliance without, however, increasing airway resistance. MVH in the cephalic flow bias concept is effective for the mucus mobilization in the central direction, being able to improve pulmonary compliance and peripheral oxygen saturation.

Keywords: Respiration, Artificial. Intensive Care Units. Physical Therapy Department, Hospital.

Resumo

Os pacientes internados que necessitam de suporte ventilatório invasivo estão sujeitos aos efeitos deletérios deste, principalmente a pneumonia associada à ventilação mecânica (PAV). O fisioterapeuta, integrante da equipe multiprofissional, assiste o paciente com a finalidade de promover a recuperação e preservação da funcionalidade, podendo minimizar/evitar complicações secundárias. Este estudo consiste em identificar as repercussões da hiperinsuflação com ventilador mecânico (HVM) no conceito flow bias na mecânica respiratória. O presente estudo trata-se de uma revisão narrativa. A HVM é um importante recurso comumente utilizado na prática clínica que envolve a manipulação das configurações do ventilador mecânico para fornecer maiores volumes pulmonares, e o gradiente de fluxo de ar gerado pode desempenhar um papel relevante no transporte do muco, sendo o conceito de flow bias cefálico o principal fator responsável pelo direcionamento deste. Para que a mobilização do muco em direção cefálica ocorra, deve existir um fluxo expiratório predominante, garantindo a razão pico de fluxo expiratório/pico de fluxo inspiratório (PFE/PFI) maior do que 1,11. A manutenção da assistência ventilatória mecânica assegura ao paciente a manutenção da pressão positiva ao final da expiração (PEEP) e a fração inspirada de oxigênio (FiO₂), evitando os efeitos deletérios da desconexão do ventilador mecânico. A HVM é capaz de melhorar a complacência pulmonar sem, no entanto, aumentar a resistência das vias aéreas. A HVM no conceito flow bias cefálico é eficaz para a mobilização do muco em direção central, sendo capaz de melhorar a complacência pulmonar e saturação periférica de oxigênio (SpO₂).

Palavras-chave: Respiração Artificial. Unidades de Terapia Intensiva. Serviço Hospitalar de Fisioterapia.

1 Introduction

Patients hospitalized in intensive care units (ICU) require, in their majority, invasive ventilatory support and, thus, are subject not only to the benefits of the institution of this support, such as the gas exchange maintenance and reduction of respiratory work, but also to the deleterious effects associated with it, such as the transport mechanism involvement, the mucociliary depuration and cough ineffectivity¹⁻⁴.

The application of positive pressure in the lungs, by means of a prosthesis, can generate systemic repercussions and, as a

result of these prolong the hospitalization time, as well as increase the morbidity-mortality⁵⁻⁷. Just as the mechanical ventilation, the immobility imposed on the patient for sedation and generalized muscle weakness contributes to the retention of secretions in the airways, resulting in partial or total obstruction, with consequent alveolar hypoventilation, development of atelectasis, hypoxemia and increased respiratory work⁸⁻¹⁰. The anesthetics/sedatives often used in these conditions also lead to hypoventilation and hypoxemia, changing the pulmonary compliance, thereby inhibiting the physiological mechanism of cough^{11,12}, favoring the

development of micro-organisms in these non-ventilated areas and resulting in pneumonia associated with mechanical ventilation (VAP)^{13,14}. VAP is one of the main factors that contribute to the increase of mortality, duration of ICU stay, duration of hospitalization and costs related to health^{10,15}. The estimate of mortality attributed to this infection varies in different studies, but approximately 33% of patients with VAP die as a direct result of this, being translated into the prolongation of hospitalization for around 12 days and in increased costs around \$40,000 per episode⁶.

Among the complications, respiratory dysfunction is an important disease in ICU. Physiotherapy operates with the objective of promoting the pervious airways management, retain or recruit lung volumes, optimize oxygenation and prevent secondary respiratory complications^{17,18}. The hyperinflation technique is employed to treat the retention of secretions, reversal of atelectasis, optimize the pulmonary oxygenation, and has been routinely used by physiotherapists from the beginning of years 1970^{19,20}. The manual hyperinflation uses the resuscitation balloon and was described for the first time in the decade of 1960, while the hyperinflation with mechanical ventilator (HVM) is by comparison a relatively new technique and was first described in 2002, and again in 2006²¹⁻²³.

Therefore, the objective of this study is to identify the MVH repercussions in the cephalic flow bias concept on respiratory mechanics.

2 Development

2.1 Methodology

The present study is a narrative review on hyperinflation with mechanical ventilator in the cephalic flow bias concept and its impacts/effectiveness. The search for articles was performed in electronic databases *Medline*, *Bireme*, *Lilacs*, *SciELO*, *PubMed* and *PEDro*, covering both Portuguese and English languages and using the following descriptors: "Intensive Care Unit", "*Flow Bias*", "Static Complacency", "Airway Resistance", "Mechanical Hyperinflation" and "Secondary Pulmonary Complications". Through the search procedure 84 publications were identified, initially, (in Portuguese language and English 64) potentially eligible for inclusion in this review.

The references that met the inclusion criteria were evaluated, regardless of the journal, namely: (a) sample should include patient belonging to the intensive therapy unit mechanically ventilated; (b) use of the HVM and pulmonary complications; (c) national/international data collection; (d) article/book of original research with humans - including review articles; (e) approval of the corresponding relevant ethics committee - for those who need them. Theses, Dissertations and Monographs are excluded, since the implementation of a systematic search of the same is impossible logistically.

2.2 Discussion

According to Dennis et al.²⁴ the physiotherapeutic intervention in the ICU is based on clinical reasoning after a complete and systematic evaluation is an integral component of the support for the management of these patients, boasting wide diversity of practices/techniques. However, currently in agreement with Dias et al.⁸, Cerqueira et al.²⁵ and Sricharoenchai et al.²⁶ it has been debated extensively about the safety of the procedures application.

Since the decade of 1980, however, evidences emerged that the transport of secretions in the airways is influenced not only by the expiratory flow, but also by the relationship established between the inspiratory and expiratory flows, i.e., by the *flow bias*²⁷, and may change the layer of secretion covering the airways. In normal conditions, the diameter of the flexible airways increases during inspiration and decreases during expiration. This dynamic airways during the respiratory cycle causes acceleration of the expiratory air flow in relation to generating inspiratory flow, therefore, a *cephalic flow bias*, i.e., from distal to proximal direction²⁸.

HVM involves the manipulation of the mechanical ventilator settings to provide higher lung volumes. However, during mechanical ventilation, the air flows can play an important role in the transport of mucus and the concept of *flow cephalic bias* consisting of the expiratory flow acceleration in relation to the inspiratory flow, in virtue of the airway compression during expiration, which assists in the mucus displacement in the direction of the trachea²⁸⁻³⁰.

The series of studies conducted in the decade of 1980 identified as critical threshold for the *flow bias*, the ratio between the expiratory flow (PEF) and the inspiratory flow peak (PFI) (ratio PEF/PFI) equal to 1.11. Being the ration PEF/PFI greater than 1.11 determines the secretion displacement toward the mouth (distal to proximal) and, less than 1.11 determines the secretion displacement toward inside the lungs (proximal to distal). This threshold can still be interpreted in another way, i.e., the mucus displacement occurs when one of the workflows achieves at least a value 10% higher than the other, and the direction of travel shall be determined by the flow of greater value or a difference of $PEF - PFI \geq 17$ L/min²⁷. And according to Thomas³¹, in addition to the latter, there is also the reason $PFI/PEF \leq 0.9$ and $PEF \geq 40$ L/min.

HVM in the cephalic bias concept consists of increasing the current volume (VT) in the proportions of 10 to 20ml/kg based on the calculation of the weight predicted until the VT target or the limit of 40 cmH₂O of prolonged P_{peak}, inspiratory time (T_{insp}), constant flow, respiratory frequency (RF) of 6 - 8, FiO₂ and unchanged PEEP^{12,20,27,30,32}. The goal is to generate the as high as possible PEF (by means of the adjustment of high current volume)²⁷ and smaller PFI (through the increase of inspiratory time and the use of the square flow wave)^{12,30}.

Knowing only the respiratory system mechanics does not guarantee the safety of the technique, making it necessary

the knowledge of the hemodynamic impacts of the technique used. Thus, some authors who studied HVM concluded that it produces no significant hemodynamic changes^{22,33}. Savian, *et al.*²³ and Dennis *et al.*²⁰ also corroborate the previous findings and affirm that HVM is safe and effective. Regarding the evaluation of SpO₂ showed an increase after the HVM, which may explain this finding due to the increased area available for gas exchanges³³.

Regarding the respiratory mechanics, studies have demonstrated a significant increase in lung compliance after the HVM^{23,34}. Other similar findings were found, attributing this increase in lung compliance due to the fact that the hyperinflation distributes better air flow, resulting in the collapsed lung re-expansion units²³. On the other hand, RaW showed no statistically significant variations³².

The dynamics of the inspiratory and expiratory air flow generated by the inspiratory and expiratory adjustments in the mechanical ventilator can contribute substantially in the mucus movement, however this has little relevance in the clinical environment and deserves more recognition. So that the mucus mobilization in the cephalic direction occurs, there must be a predominant expiratory flow. In contrast, the persistent caudal migration can result in clinical consequences, because the relationship PEF/PFI lower than 1.11 favors the secretion displacement to the lungs interior²⁹.

Although it is not always possible to adjust an *expiratory flow bias*, it seems, at least interesting to seek to avoid or minimize the occurrence of an *inspiratory flow bias*, with the potential to promote the secretions movement toward inside the lungs. Therefore, some researchers suggest that the flow curves of the mechanical ventilator should also be analyzed/monitored in relation to the *flow current* in force and its possible action on the pulmonary secretions displacement³⁵⁻³⁷.

Studies in animals and pulmonary models have demonstrated consistently that the bias of inspiratory or expiratory flow may result in liquid migration of mucus in the direction of the flow bias³⁸⁻⁴⁰. Thus, Volpe *et al.*¹², reaffirms that the bias of flow obtained with the fan settings can clear or incorporate the mucus during the mechanical ventilation.

For physiological explanation of the technique HVM, Chaves *et al.*³², is based on the principle of presence of the Hering-Breuer reflex that allows the use of momentary current volumes higher than those recommended in the literature, generating a more effective expiratory flow peak for the removal of secretions in the airways of intubated and mechanically ventilated patients. The results of this study showed that the HVM increased the expiratory flow without modifying hemodynamic parameters of patients hospitalized in the ICU. Conversely, smaller PFI is resulting from increased inspiratory time and the use of square wave flow²⁷. However, the square wave flow is restricted to volumetric modes.

It is important to remember that the mechanical properties of the respiratory system can exert some influence in the PFI only during the ventilatory modes at pressure³⁷ and

depend mainly on the impedance which, in turn, is directly proportional to the airways resistance³¹. During the pressure modes, the reduction of PFI can be obtained by means of decrease in inspiratory pressure (pressure delta) and by slowing the speed of the inspiratory flow (reduction of rail, *slope* or *rise time* - depending on the fan). However, the first adjustment reduces the current volume, which also reduces the PEF, and may annul the effect of inspiratory pressure reduction on the resulting *flow bias* and can also generate discomfort to the patient. Another unfavorable factor is that in spontaneous ventilation, the patient exercises control over the inspiratory and expiratory flows; therefore, undertakes the maintenance of a cephalic *flow bias*²⁷.

There is a variety of ventilation modes used for the HVM Dennis *et al.*²⁴ and Hayes *et al.*¹⁹. However, Thomas³¹ conducted a limited survey to guide the selection of the HVM settings to optimize their application for the secretions mobilization, analyzing the PFI and PEF generated during the HVM performed in different ventilation modes, in order to provide recommendations to guide the application of the technique. The results suggest that the SIMV-V mode is more successful than the PSV and SIMV-P, by achieving the ratio bias PFI/Pef ≤ 0.9 , this being this the main factor in comparison with other modes, generating gradients of desired flows, in addition to gathering a greater proportion of tests with characteristics of ideal flows (PFI/PEF $\leq 0.9 = 80\%$; PEF -PFI ≥ 5.30 L/min = 47%, PEF ≥ 40 L/min = 69% and all the three previous properties = 47% of the samples).

Regarding the PEEP, since the inspired volume is maintained, its setting does not influence the PEF therefrom, with the exception of patients with unstable airways, in which PEEP may result in an increase of the PEF by preventing the collapse of dynamic airways³⁰. When the use of high PEEP and FiO₂ are necessary, the HVM should preferably be used in detriment of the technique of manual hyperinflation Ortiz *et al.*⁴¹ In severe patients, the physiotherapist must monitor the pressures, volumes and flows used during the technique, thus allowing a better adjustment of the same Berney and Deneby⁴². Beyond the control of ventilatory parameters, especially the mean pressure, current volume and peak pressure, the HVM when used properly is a safe alternative to allow the patients' maintenance in mechanical ventilation throughout the maneuver, assuring the FIO₂ and PEEP Guimarães and Lemes⁴³ and avoiding the adverse effects of disconnecting the fan, such as the loss of functional residual capacity (FRC), decreased oxygenation and increased shear stress of distal lung units^{19,44-46}. Another factor to be considered is that when performing the HVM the professional assistant prevents the contamination associated with the disconnection of the ventilatory circuit⁴⁷, as well as reducing the chances of transmissions of infection both for the patient and for the care team^{20,24}.

3 Conclusion

HVM in the *cephalic flow bias* is safe and effective when performed in a thorough and concise way, allowing a cephalic expiratory flow gradient and contributing with the secretion carriage. After the completion of the HVM there was an increase in lung compliance, inferring about the recruitment of previously collapsed areas by atelectasis and/or secretion.

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