DOI: 10.1590/1809-2950/220130311022EN

ORIGINAL RESEARCH

Minimal occlusive volume is a safe and effective method for adjusting cuff pressure in mechanically ventilated patients

O volume mínimo de oclusão é um método seguro e eficaz para o ajuste da pressão do cuff em pacientes ventilados mecanicamente

El volumen de oclusión mínimo es una técnica segura y eficaz para ajustar la presión del manguito en pacientes con ventilación mecánica

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ABSTRACT | The ideal cuff pressure (P_{cuff}) must prevent microaspiration of oropharyngeal secretions due to air leakage and avoid injury to the tracheal mucosa. Usually, monitoring consists of a manometer to keep the P_{cuff} between 20 and 30cmH_2O. The minimal occlusive volume (MOV) method minimally inflates the cuff using a syringe so that no leakage occurs. This study aims to evaluate the ability of the minimal occlusive method to individualize the P_{cuff} adjustment in mechanically ventilated patients. Cross-sectional prospective study with 25 adult patients with more than 48 hours of mechanical ventilation. Cuff pressure was measured at two moments: initial and by MOV. The prevalence of P_{cuff} outside the normal range was 76%. Leakage in the initial measurement occurred in 9 patients, 4 of whom were within the reference values. The other 5 patients presented P_{cuff}<20cmH_2O. In the adjustment by the MOV method, all patients presented P_{cuff} at the limit of normality. Patients without leakage with P_{cuff}>30cmH_2O had a reduction when adjusted for MOV (45.4±9.6 against 28.5±1.6cmH_2O; p<0.001). We can conclude that the minimal occlusive volume method was able to individualize the P_{cuff} within the reference values in all patients.

Keywords | Pneumonia, Ventilator-Associated; Airway Management; Intensive Care Units.

RESUMO | A pressão do cuff (P_{cuff}) ideal deve ser capaz de prevenir a microaspiração de secreções orofaríngeas por escapes aéreos e evitar lesão da mucosa traqueal. Normalmente, realiza-se a monitorização por meio de manômetro, buscando manter a P_{cuff} entre 20 e 30cmH_2O. O método do volume mínimo de oclusão (VMO) consiste em insuflar minimamente o balonete, utilizando uma seringa, para que não ocorram vazamentos. O objetivo deste estudo foi avaliar a capacidade do método do VMO de individualizar o ajuste da P_{cuff} em pacientes ventilados mecanicamente. Trata-se de um estudo transversal, prospectivo, com 25 pacientes adultos, com tempo de ventilação mecânica (VM) superior a 48 horas. A P_{cuff} foi medida em dois momentos: inicial e por VMO. A prevalência de P_{cuff} fora dos limites de normalidade foi de 76%. Ocorreu vazamento na medida inicial em nove pacientes, sendo que, para quatro, a medida estava dentro dos valores de referência. Os outros cinco apresentaram P_{cuff}<20cmH_2O. No ajuste pelo método VMO, todos os pacientes

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apresentaram P_{cuff} no limite de normalidade. Os pacientes sem vazamento com P_{cuff}>30cmH_2O tiveram redução quando ajustados pelo VMO (45,4±9,6 *vs* 28,5±1,6cmH_2O; p<0,001). Podemos concluir que o método do VMO foi capaz de individualizar a P_{cuff} dentro dos valores de referência em todos os pacientes.

Descritores | Pneumonia Associada à Ventilação Mecânica; Manuseio das Vias Aéreas; Unidades de Terapia Intensiva.

RESUMEN | La presión del manguito ($P_{manguito}$) ideal debería ser capaz de prevenir la microaspiración de secreciones orofaríngeas por el escape de aire y evitar daños en la mucosa traqueal. En general, la monitorización se da a través de un manómetro al buscar mantener la $P_{manguito}$ entre 20 y 30 cmH_2O. La técnica de volumen de oclusión mínimo (VOM) consiste en inflar al mínimo el manguito, utilizando una jeringa, para que no escape el aire. El objetivo de este estudio fue evaluar la capacidad de la técnica de VOM para individualizar el ajuste de la $P_{manguito}$ en pacientes con ventilación mecánica. Se trata de un estudio transversal, prospectivo, realizado con 25 pacientes adultos, con tiempo de ventilación mecánica (VM) superior a 48 horas. La $P_{manguito}$ se dio en dos momentos: inicial y por VMO. La prevalencia de la $P_{manguito}$ fuera de los límites normales fue del 76%. Se detectó el escape de aire en la medida inicial de nueve pacientes, entre los cuales cuatro tuvieron una medición dentro de los valores de referencia. Los otros cinco tenían una $P_{manguito}$<20cmH_2O. En el ajuste por la técnica de VMO, todos los pacientes tuvieron $P_{manguito}$ al límite de los valores normales. Los pacientes que no habían presentado escape de aire con $P_{manguito}$>30cmH_2O tuvieron una reducción cuando hubo un ajuste del VMO (45,4±9,6 vs 28,5±1,6cmH_2O; p<0,001). Se concluye que la técnica de VMO fue capaz de individualizar la $P_{manguito}$ dentro de los valores de referencia en todos los pacientes.

Palabras clave | Neumonía Asociada al Ventilador; Manejo de la Vía Aérea; Unidades de Cuidados Intensivos.

INTRODUCTION

The accumulation of secretions above the cuff of the endotracheal tube and the microaspiration around the cuff are clearly implicated in the pathogenesis of ventilator-associated pneumonia (VAP)[1,2]. VAP prolongs the duration of mechanical ventilation (MV) and intensive care unit (ICU) hospitalization, increasing hospital costs[3-5]. VAP prevention bundles include interventions, such as controlling cuff pressure (P_{cuff}) and head-of-bed inclination, subglottic secretion drainage, oral hygiene care, among others[6]. P_{cuff} control minimizes and prevents complications; insufficient insufflations, however, can cause microaspiration of oropharyngeal secretions, leakage, and consequent patient-ventilator asynchrony[7]. On the other hand, high pressures increase the risk of tracheal injury[5,8-10].

Normally, intermittent monitoring of the P_{cuff} is performed by a manometer which should be maintained between 20 and 30cmH_2O[5,6,11,12]. As mentioned, the minimum pressure should be sufficient to prevent microaspiration, but excessive pressures can damage the tracheal mucosa. A maximum pressure of 30cmH_2O suggests a reduction in mucosal blood flow, but values greater than 50cmH_2O completely obstruct the tracheal blood flow, causing injury[12]. However, P_{cuff} values within normal limits may not guarantee sealing in all patients; similarly, pressures below 20cmH_2O may ensure sealing. Some authors recommend the minimal occlusive volume (MOV) technique to achieve a minimum pressure to obtain sealing[10]. The cuff must be deflated and re-inflated with a syringe until the tracheal sealing is restored. Leakage can be detected by pulmonary auscultation at level of the sternal furcula or by the difference between inspiratory and expiratory volumes. Thus, P_{cuff} management should consider the lowest volume of insufflation that promotes sealing, regardless of the pressure reached.

This study aims to verify the P_{cuff} obtained by the MOV method in mechanically ventilated patients and compare them with the reference values.

METHODOLOGY

Design and sample

This is a cross-sectional analytical study conducted with 25 adult patients, intubated or tracheostomized, with over 48 hours of MV time. All patients were on controlled MV via pressure- or volume-controlled ventilation and positive end-expiratory pressure (PEEP) between 5 and 8cmH_2O. Patients with tracheomalacia, tracheal stenosis, reported difficult airway, or maximum airway pressure higher than 30cmH_2O were excluded from the study. This airway pressure limit was defined to prevent high pressures from producing leakage, interfering with the results. The study was conducted from August to December

2019, in the ICU of the Hospital Geral de Guarus, Campos dos Goytacazes (RJ). The protocol of this hospital unit uses intermittent monitoring of the P_{cuff}. All those responsible for the patients signed the free and informed consent form.

Evaluation

P_{cuff} was verified in two occasions: initial measurement and measurement by the MOV method. Initially, the patients were put in supine position, with the bedside elevated at 30°, head centered, and subjected to tracheal aspiration. The measurements were always performed in the morning, after the nurses performed general and oral hygiene. After five minutes, P_{cuff} was verified by a cuff manometer, and this measurement was defined as the initial one. Simultaneously, the occurrence or absence of leakage was also verified and recorded. Leakage was verified by pulmonary auscultation at trachea level. With the cuff manometer still connected, P_{cuff} was adjusted by the MOV method. For this, the cuff was deflated and re-inflated to obtain the minimum volume of sealing, verified by auscultation. P_{cuff} was measured by the VBM Medizintechnick Gmbh cuff manometer, with a graduation from 0 to 120cmH_2O, which, when connected to the cuff, allows inflation and deflation. The reference values were considered normal between 20 and 30cmH_2O[6].

Analysis

The patients were defined according to the presence of leakage and stratified according to the reference values for P_{cuff}. Initially, univariate data analysis was performed. The categorical variables of the study were based on absolute and relative frequencies; and the continuous variables were based on the mean and standard deviation, according to the analysis of the distribution of the data by the Shapiro-Wilk test. The tests chosen for the analysis of the main outcomes considered the normality of the sample within each group. The variables analyzed in the initial pressure and MOV methods were compared by the t-test for repeated samples or by the Wilcoxon test. For the analysis of variables that presented normal distribution, a 5% significance level was used. When one of the quantitative variables did not present a normal distribution, a 2.5% significance level was used, considering the penalty for the two groups in the analysis.

RESULTS

The sample consisted of 25 adult patients, of which 48% were male, with a mean age of 58.9 years. Of the total, 80% of the participants were intubated and 20% tracheostomized. The duration of mechanical ventilation was 8.9±5.8 days, ranging from 3 to 24 days, from 2 to 11 days in intubated patients, and from 16 to 21 days in tracheostomized patients. Table 1 shows the characteristics of the sample.

Table 1. Sample characteristics

	N=25
Age, years	58.9±10.6
Male, n (%)	12 (48.0)
Artificial airway, n (%)	
OTT	20 (80)
TCT	5 (20)
Duration of MV, days	8.9±5.8
Diagnosis, n (%)	
VAP	15 (60.0)
Sepsis	13 (52.0)
CVA	10 (40.0)
COPD	4 (16.0)
APE	4 (16.0)

OTT: orotracheal tube; TCT: tracheostomy; MV: mechanical ventilation; VAP: ventilator-associated pneumonia; CVA: cerebrovascular accident; COPD: chronic obstructive pulmonary disease; EAP: acute pulmonary edema. Data expressed as mean±standard deviation or absolute and relative frequency (%).

The initial P_{cuff} in the whole sample was 34.4±15.2cmH_2O, with lower and upper limits of 10 and 66cmH_2O, respectively. Leakage in the initial measure of P_{cuff} occurred in 36% (n=9) of the patients, and the P_{cuff} was 18.6±6.4cmH_2O (10–28cmH_2O). Of these nine patients, four had P_{cuff} in the normal range (24.5±3.3cmH_2O; 20–28cmH_2O) and five had P_{cuff} lower than 20cmH_2O (13.8±3.0cmH_2O; 10–18cmH_2O). The MOV method increased P_{cuff} (18.6±6.4 against 28.8±1.8cmH_2O; $p<0.001$).

Patients without leakage at initial measurement (n=16) presented a P_{cuff} of 43.4cmH_2O (95% CI: 39.0 to 47.8cmH_2O). Of these, only two had P_{cuffs} at the normal limit; the other 14 patients presented a P_{cuff} of 45.4cmH_2O

(95% CI: 41.4–49.4cmH_2O). In patients with a P_{cuff} within the normal range and without leakage, MOV reduced P_{cuff} (29.0±1.4 *vs* 24.5±0.7cmH_2O; p=0.035). Patients without leakage and with P_{cuff} higher than 30cmH_2O had a reduction when adjusted by MOV (45.4±9.6 against 28.5±1.6cmH_2O; p<0.001). When the P_{cuff} was adjusted by the MOV method, all patients presented P_{cuff} at the reference values (28.3cmH_2O; 95% CI: 27.5–29.1cmH_2O). Table 2 shows the data.

Table 2. Results

	Initial	MOV	p-value
Total (N=25)	34.4 (10–66) (95% CI: 28.1–40.7)	28.3 (24–30) (95% CI: 27.5–29.1	0.027
Without leakage (n=16)	43.4 (28–66) (95% CI: 39.0–47.8)	28.0 (24–30) (95% CI: 27.2–28.8)	0.001
20 to 30cmH_2O (n=2)	29.0 (28–30) (95% CI: 28.4–29.6)	24.5 (24–25) (95% CI: 24.2–24.8)	0.035
>30cmH_2O (n=14)	45.4 (34–66) (95% CI: 41.4–49.4)	28.5 (25–30) (95% CI: 27.8–29.2)	0.001
With leakage (n=9)	18.6 (10–28) (95% CI: 15.9–21.2)	28.9 (26–30) (95% CI: 28.3–29.5)	0.001
20 to 30cmH_2O (n=4)	24.5 (28–30) (95% CI: 23.1–25.9)	29.0 (28–30) (95% CI: 28.5–29.5)	0.001
<20cmH_2O (n=5)	13.8 (10–18) (95% CI: 12.6–15.0)	28.8 (26–30) (95% CI: 28.1–29.5)	0.001

MOV: minimal occlusive volume. Data expressed as mean (lower limit-upper limit), followed by 95% confidence interval (CI).

DISCUSSION

The results showed that P_{cuff} adjustment by the MOV method was effective in preventing leakage and maintaining P_{cuff} in the reference values in all patients analyzed. We observed a high prevalence of excessive insufflation of the cuff. Of the nine patients who presented leakage in the initial measure, four presented P_{cuff} within normal limits.

Excessive insufflation of the tracheal cuff can damage the mucosa of the tracheobronchial wall. On the other hand, leakage may lead to microaspiration of oronasal secretions, which directly implies the pathogenesis of VAP[13]. VAP prevention bundles aim to identify and correct risk factors associated with the development of infections directly related to ventilatory support[14,15]. The increase in invasive ventilatory support time is a risk factor for morbidity and mortality and increased hospital costs[3,16]. Thus, monitoring of P_{cuff} should be a routine activity in ICUs, as well as a well-established practice in respiratory care for mechanically ventilated patients[17].

Excessive P_{cuff} is a relevant factor in tracheal lesions[5]. High pressure is transmitted to the tracheal mucosa and can generate ischemia. In an experimental study, Castilho et al.[18] histologically analyzed the tracheal mucosa of dogs submitted to P_{cuff} adjustment by MOV or fixed value at 25cmH_2O. The authors observed that both methods caused epithelial lesions equally. Perfusion pressure of the tracheal mucosa is between 25 and 35mmHg or 34 and 47cmH_2O. In this study, the initial measurement was 34.4±15.2cmH_2O, but with values up to 66cmH_2O. After adjustment by MOV, all patients presented protective values for ischemia of the tracheal mucosa. Although necessary to facilitate ventilatory support, orotracheal intubation can cause damage to the oropharynx, larynx, and trachea, thus promoting harm to local defense mechanisms by keeping the epiglottis open, altering cough and the mucociliary system, and by modify the phenotype of tracheobronchial cells, leading to bacterial attachment and inoculation of the lower respiratory tract with the endogenous oropharyngeal flora[19,20].

The leakage of contaminated subglottic secretion is the main vector of pathogenic microorganisms in mechanically

ventilated patients. In this context, endobronchial bacterial colonization results in pulmonary infections[21]. While P_{cuff} monitoring by MOV has promoted ideal P_{cuff} results, it is impossible to ensure the complete sealing and prevention of microaspirations. Factors such as PEEP, change in patient positioning and bedside angulation modify airway permeability even at recommended levels for P_{cuff}[11]. Ono et al.[22] observed that the reduction of the bedside inclination from 30° to 0° reduced P_{cuff} by 16.9%; when elevated from 30° to 60°, they observed an average reduction of 18.8%. Thus, they verified that the pressure undergoes frequent oscillations, allowing gas leakage. Another factor that can influence the alteration of the P_{cuff} is the inner diameter of the trachea. The volume of air required to inflate the cuff depends on the relation between the inner diameter of the trachea and the outer diameter of the orotracheal tube, so that the choice of the tube depends on the glottic space[23]. This may explain the leakage found in four patients who presented a P_{cuff} in the normal range, which was corrected by the MOV technique. This characterizes the effectiveness of the technique as a way to individualize P_{cuff} to prevent air leakage regardless of the size of the trachea or the diameter of the artificial airway.

The MOV technique proved to be safe and low cost to monitor P_{cuff}, and can be performed in any hospital unit since it depends only on a syringe and a stethoscope for the auscultation of leakage in the trachea. Furthermore, leakage can be observed in the mechanical ventilator by the difference between the inspiratory and expiratory tidal volume.

The study presented as a limitation the generalization of the results without stratification of the sample according to sex and height of the patient and the diameter of the artificial airway. This information could determine a relationship between the inner diameter of the trachea and the outer diameter of the artificial airway. Moreover, determining whether patients had any degree of tracheal injury, especially those with longer duration of artificial airway. Another limitation is air leakage during disconnection of the cuff manometer or syringe from the cuff after the measurements performed. Finally, a more expressive sample could increase the generalization capacity of the results.

CONCLUSION

The MOV method promoted the lowest P_{cuff} needed to prevent leakage, keeping it within the reference values in all patients. On the other hand, the adjustment for the normality range did not guarantee sealing. Moreover, it is an efficient and low-cost method that can be used extensively in clinical practice. Further studies should be conducted to evaluate the effects this method may have on the incidence of VAP or tracheal injury.

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