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Sensitivity Training of Residents to Pressure Improves the Management of Tracheal Tube Intracuff Pressure

You Zhi-jian[a]*, Xu Hong-xia[b]*, Wang Xue-mei[c]

[a,b]*Department of anesthesiology, First Affiliated Hospital of Medical College of Shantou University, Shantou, 515041, Guangdong Province, P. R. China*
[a,b,c]*Department of anesthesiology, Affiliated Hospital of Jiangsu University, Zhenjiang, 212001, Jiangsu Province, P. R. China*

Abstract

Insufficient cuff pressure of tracheal tube (TT) increases the risk of secretions aspiration and consequent pulmonary infection, whereas high pressure may cause tracheal injury. It is very important to control cuff pressure at the optimal status for air care providers. Volume control ventilation (VCV) is often applied to verify the cuff pressure. We used different volumes of syringe as simulated trachea, selected Proterx 7.0 tube to do the intubation, and recorded the volume of air ventilated and the corresponding intracuff pressure. The result indicated that pressures increased intensively when air volumes surpassed certain values, which suggested VCV method was not appropriate to control the intracuff pressure, and pressure control ventilation might be the better choice. In that case, air care providers have to improve their ability to control pressure. Herein, we enrolled 80 residents into sensitivity training for pressure. Trainees were required to palpate the pilot balloons of 12 tubes (Portex7.0) with different intracuff pressure repeatedly to sense the pressure, 1 hour/ day for 3 days. Trainees who could arrange tubes in turn and control the intracuff pressure at optimal range (20-30cm H2O) during intubation in model were considered eligible, the rest were trained continuously till eligible. Inappropriate percent —The proportion of residents who could not control intracuff pressure appropriately — were recorded before training, after training, one month, three months and six months after training. The results indicated that the training method was effective to improve the ability of residents to control the intracuff pressure, the inappropriate percent increased gradually over time, the average intracuff pressure surpassed the optimal value at six months post-training, suggesting six months should be time point for retraining.

Index Terms: incubation; intracuff pressure; pressure control ventilation; resident; tracheal tube

* Corresponding author.
E-mail address: [a]anesthesia_yzj@yahoo.com.cn

1. Introduction

The cuff of a tracheal tube (TT) can maintain the efficiency of ventilation support, and protect the lower airway from aspiration of secretions, and consequent pulmonary infection. Insufficient cuff pressure of TT could compromise the above functions, whereas high pressure may cause ischemia of tracheal mucosa, and possible serious complications because the cuff pressure is directly transmitted to the mucosa. Some papers have reported some complications including tracheal rupture [1-3], stenosis [reviewed in 4] and formation of tracheo-oesophageal fistula [5, reviewed in 6]. Even maintaining a slightly higher TT cuff pressure for only 2 hours may cause serious tracheal ciliary damage [7]. Therefore, it is very important to control the TT intracuff pressure at the appropriate level in patients with tracheal incubation for air care providers. The blood perfusion pressure is between 24-35 mmHg, or 20-30cm H2O. These values are considered safe to prevent ischemic injuries or other important tracheal mucosa changes which may be triggered by cuff overinflation.

Intracuff pressure should be controlled in order to prevent hyperintracuff pressure from tracheal mucosa injuries. There are usually three type of measure methods for intracuff pressure in clinic: volume control ventilation (VCV), and direct measurement of intracuff pressure by manometer, fingertip palpation. VCV is often applied to verify the cuff pressure, that is, certain volume of air is ventilated. However, accurate intracuff pressure might not be assured because there probably exist differences among patients, tracheal tube types. To investigate the exact correlation between volume of air and intracuff pressure, we used different volumes of syringe as simulated trachea, selected Proterx 7.0 tube to do intubation, ventilated the air of 1-16ml respectively, and recorded the volume of air and the corresponding intracuff pressure. The result indicated that pressures increased intensively when air volumes surpassed certain values, which suggested VCV method could not appropriately control the intracuff pressure, and pressure control ventilation (PCV) might be the better choice.

Although using pressure regulator or continuous pressure controller can control intracuff pressure at the appropriate level [8, 9], the method’s application is limited at the present because it depends on instruments which are not easy to carry about. Fingertip palpation is a common way of determining TT cuff pressure, has advantages of being fast and convenient. In that case, air care providers such as anesthesiologists, intensive care unit nurses have to improve their ability to control pressure. Chan et al. [10] reported that doctor/nurse with high seniority (≥5years) might do better than low seniority (＜5years). Herein, we investigated the ability of 80 residents (1-3 years graduated from medical college) to control the optimal intracuff pressure, and then trained their sensitivity to pressure by palpating the pilot balloon with different intracuff pressure of 5-60cm H2O, and recorded the inappropriate percent (The proportion of residents who could not control intrapressure appropriately) before training, after training, one month, three months and six months after training. The results indicated that our training method was effective to improve the sensitivity of trainees to intracuff pressure, and six months after training was the better time point to retrain.

2. Methods

Determining the relation between the volume of ventilated air and intracuff pressure

We selected 5ml, 10ml and 20ml syringe outer tube as simulated trachea, with 2.0mm, 1.5mm and 1.3mm of diameter respectively, placed one Protex 7.0 tube into syringe outer tube, then ventilated air till intracuff pressure reached above 135cmH2O. The volume of ventilated air and corresponding intracuff pressure were recorded

Trainees

80 residents from multiple departments such as intensive care unit (ICU), cardiovascular medicine, respiratory medicine, cardiothoracic surgery, neurosurgery, gynecology, paediatrics, emergency in our hospital were enrolled into the training program. These residents have graduated 1-3 years from medical college.

Training method

After examining the appropriate percent of trainees to control the intracuff pressure at the optimal range in simulated model. We did the training for trainees. Firstly, we ventilated 12 Protex 7.0 tube to make their intracuff pressure at 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60 cm H2O. Secondly, residents were required to palpate the pilot balloons repeatedly, and sense the pressure. The time of training is one hour/day for three days. After three days' training, the ability of trainees to control the optimal intracuff pressure was examined.

Examination

Before training, after training, 1 month, 3 months, 6 months after training, the training effect on residents were examined. The residents who could reach the following standards were judged qualified: 1) be able to arrange accurately the ventilated Protex 7.0 tubes according to the gradient of intracuff pressure; 2) be able to control the intracuff pressure between 20-30 cm H2O determined by manometer when doing tracheal incubation in the simulation model. The rest were trained continuously till qualified.

Statistics analysis

All values were expressed as mean±SD. Statistic analysis was done by SPSS 16.0 (SPSS, Inc., Chicago, IL, USA). The differences between groups were analyzed by one way ANOVA.

3. Results

The relation between the volume of ventilated air and intracuff pressure

We recorded the volume of ventilated air and the corresponding intracuff pressure, and made the volume-pressure curve to analyze the relation between the volume of ventilated air and intracuff pressure (Fig 1). The result indicated that there existed flex points in volume-pressure curve. The linear fitness equations and the coefficient of determination between volume and intracuff pressure in no incubation, 5ml, 10ml and 20ml of syringe outer tubes were shown in Table 1. The coefficient of determination for no incubation, 5ml, 10ml and 20ml were respectively 0.75, 0.94, 0.74 and 0.66, which suggested the intracuff pressures was not linear correlated with the volume of ventilated air.

Table 1 The linear fitness equation from volume-pressure curve *and R2

	Equation	**R2**
No incubation	$y = -22.73 + 7.10x$	0.75
5ml	$y = -20.79 + 44.47x$	0.94
10ml	$y = -22.75 + 24.27x$	0.74
20ml	$y = -26.94 + 12.91x$	0.66

* Volume-pressure curve seen in Figure 1

y:Intracuff pressure; x: volume of air ventilated

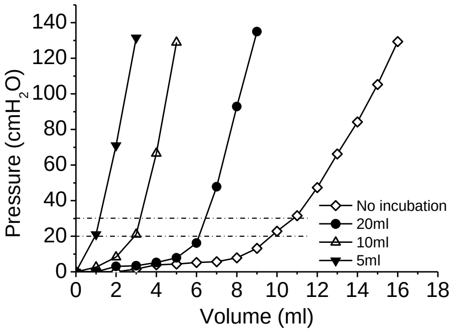

Fig 1. The diagram indicating the relation between the volume of air and intracuff pressure. 5ml, 10ml and 20ml syringe outer tube were used as simulated trachea, Protex7.0 tube was selected to intubate into 5ml, 10ml and 20ml syringe outer tube, no intubation as control. The volume of ventilated air and the corresponding intracuff pressure were recorded

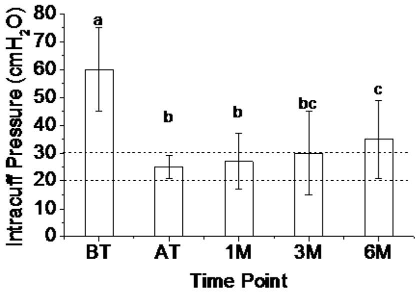

Fig 2 The changes of intracuff pressure controlled by residents before training (BT), after training (AT), 1 month (1M), 3 months (3M) and 6 months (6M) after training. One way ANOVA was used to analyze the differences between groups. Values are expressed as mean±SD. Means not sharing a common superscript letter are significantly different (P＜0.01)

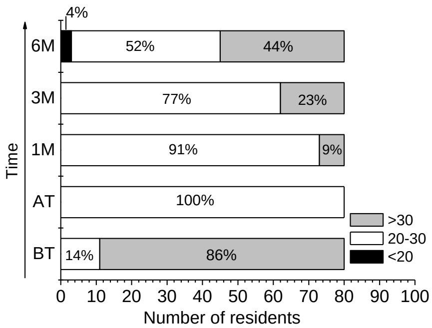

Fig 3 The number and proportion of residents in different range of intracuff pressure at different time point: before training (BT), after training (AT), 1month, 3months and 6months after training (1M, 3M and 6M). >30, 20-30, <20 mean range of intracuff pressure (cmH2O). The intracuff pressure between 20 and 30 cmH2O was considered appropriate

The changes of intracuff pressure controlled by residents receiving training

The time history of intracuff pressure controlled by residents receiving training was shown in Fig 2. The average intracuff pressure after training was significantly lower than before, which indicated that the training method was effective for inhibiting the tendency to overinflation of endotracheal tube cuffs in residents. The average intracuff pressure controlled by residents increased gradually over time. Six months after training, the average pressure was higher than 30cmH2O, also significantly higher than that after training and 1 month after training. This result suggested that it was necessary to train the air provider termly.

The distribution of intracuff pressure and proportions at different time points

To investigate the ability of residents to control intracuff pressure, we further analyzed the distribution of the intracuff pressure and the proportions of residents in different range of pressure (<20, 20-30, >30) before and after training (Fig 3). The results showed that all residents could control the pressure between 20 and 30 cmH2O after training (the appropriate percent-the proportion of residents could control the intracuff pressure at the optimal pressure- reached 100%). The appropriate percent decreased gradually over time, while the inappropriate percent increased gradually. Six months after training, the appropriate percent was only 52%, almost decreased to a half of 100%.

4. Discussion

Intubation is widely used in many medical circumstances, such as apnoea, respiratory failure, airway protection, airway obstruction and haemodynamic instability. The tube's intracuff pressure higher or lower than the optimal level (20-30cmH2O) can cause adverse consequence. It is therefore important to control the intracuff pressure at the optimal level. Two methods controlling the intracuff pressure were usually used: volume control ventilation (VCV) and pressure control ventilation (PCV).

Our results showed the coefficients of linear fitness between volume and intracuff pressure in different circumstances (no incubation, 5ml, 10ml and 20ml syringe) were all low, which suggested the volume was not linear correlated with the corresponding pressure. There were flex points in volume-pressure curves. When volume surpassed the flex point, the subtle increase of volume would contribute to the intensive increase of pressure, which made difficult to control the optimal intracuff pressure by determining certain volume. The results also indicated that different volumes of air were required to be ventilated to obtain certain target pressure in different trachea different diameters. Clinically, air care providers are required to select the tube according to weight, age and gender of patients. However, the diameter ratio between trachea and tube may be influenced by personal differences of patients and the habit of doctors. Many doctors often select the tracheal tube with low diameter in the circumstance of difficult intubation. Our result has showed the volume ventilated to obtain target pressure decreased when the diameter ratio between trachea and tube decreased. VCV may cause hyper- or hypo- intrapressure because of uncertainty in ratio of diameter between trachea and tube in the clinical practice, which made difficult for doctor to control intracuff pressure, PCV may be the better choice.

Using manometer or continuous controller could keep the optimal pressure [8, 9]. Several cuff pressure regulators have been introduced in clinical practice in order to limit cuff pressure and to maintain cuff pressure by continuously inflating and deflating [9, 11-13]. However, Weiss et al. reported that rapid pressure compensation by automated cuff pressure controller worsened sealing in tracheal tubes [14]. Besides, pressure controllers are not easy to carry about, while patients were distributed in different departments of hospital, which limit the application of controller. Determining intracuff pressure by fingertip palpation is still common way in clinical practice. In that case, doctors are required to have good ability to control the intracuff pressure at the optimal level. We chose 80 residents with 1-3 years of seniority from our hospital, examined their ability to control intracuff pressure at the optimal range, and found 86% failure rate. Residents usually worry about aspiration and corresponding infection induced by insufficient intracuff pressure, thus ventilate excessive air, resulting in hyperintracuff pressure. Our results showed the average intracuff pressure controlled by residents was much higher than the optimal pressure, which was consistent with the previous study [10]. However, the previous study only observed the effect of their training methods within 1 month, and did not indicate the time to reexamine and retrain the trainees. Trained by our method, 80 residents were all qualified, which suggested our training method was effective. The intracuff pressure increased overtime, suggesting the effectiveness was gradually impaired. 6 months after training, the average intracuff pressure was significantly higher than 30cmH2O, which suggested 6 months might be the appropriated time for residents to be examined and retrained.

In this study, there is a tendency to overflation of endotracheal tube cuff in residents even after training. Interestingly, operation time's increase often means experience's increase, which was supposed to improve the ability of controlling the intracuff pressure in residents. The results indicated the adverse result. Chen et al. [10] reported doctors with seniority of < 5 years made the pressure higher than the optimal level, those with seniority of >5 years could control appropriately the intracuff pressure. However, Hoffman et al. reported experienced emergency medicine physicians could not safely inflate or estimate endotracheal tube cuff pressure by palpation [15]. Wujtewicz et al. also even reported that overinflation of TT cuff was still common in highly experienced anaesthesiologists. These differences might result from small sample size and different examination methods. Future study may be done to examine the ability of doctors with high seniority to control the optimal level of intracuff pressure.

In conclusion, PCV may be better than VCV. The training method we designed is effective to improve the ability of residents to control the intracuff pressure at the optimal range. The appropriate percent of residents decreases overtime. The time point-six months after training-is the right moment to reexamine and retrain the residents.

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