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Impact of supra-cuff suction on ventilator-associated pneumonia prevention

Impacto da aspiração supra-cuff na prevenção da pneumonia associada à ventilação mecânica

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ABSTRACT

Critically ill patients are intubated or tracheostomized because, in most cases, these individuals require invasive mechanical ventilation. The cannulae that are used include the cuff, which can act as a reservoir for oropharyngeal secretions, predisposing to ventilator-associated pneumonia. Studies have revealed that the suction of subglottic secretions through the dorsal suction lumen above the endotracheal tube cuff delays the onset and reduces the incidence of ventilator-associated pneumonia. The aim of this review is to assess published studies regarding the significance of using suction with a supra-cuff device for the prevention of ventilator-associated pneumonia in critically ill patients treated with orotracheal intubation or tracheostomy. Therefore, by searching national and international databases, a literature review was undertaken of studies published between the years 1986 and

2011. Few results were found relating the suction of subglottic secretions to decreased duration of mechanical ventilation and length of stay in the intensive care unit. The suction of subglottic secretions is ineffective in decreasing mortality but is effective in reducing the incidence of early-onset ventilator-associated pneumonia and hospital costs. Techniques involving continuous suction of subglottic secretions may be particularly efficient in removing secretions; however, intermittent suction appears to be the least harmful method. In conclusion, cannulae with a supra-cuff suction device enable the aspiration of subglottic secretions, providing benefits to critically ill patients by reducing the incidence of ventilator-associated pneumonia and, consequently, hospital costs - with no large-scale adverse effects.

Keywords: Subglottic aspiration; Suction; Pneumonia, ventilator-associated; Intensive care

INTRODUCTION

The critically ill patient is usually dependent on mechanical ventilation enabled by prostheses, including the endotracheal tube and tracheostomy cannula. Both devices contain a cuff, which is a balloon that seals the lower airways during mechanical ventilation.⁽¹⁾ The cuff should be examined every four hours, and its inflation should be maintained at an ideal pressure of 20 to 30 cmH₂O to avoid bronchoaspiration (when using reduced pressure) and tracheal wall injury (when using increased pressure).⁽²⁻⁴⁾

There are two types of cuff: the high-volume, low-pressure cuff and the low-volume, high-pressure cuff. The high-volume, low-pressure cuff, which is the oldest type of cuff and is also called "red rubber," has a small contact area

Conflicts of interest: None.

Submitted on August 28, 2012
Accepted on November 8, 2012

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with the trachea when inflated and deforms into a circular shape. Thus, prolonged use of this device leads to ischemia and, consequently, tracheal wall injury. However, the high-volume, low-pressure cuff has a lower cost, provides stronger sealing of the trachea, and is effective against bronchoaspiration. The low-volume, high-pressure cuff is a more recently developed device that has a thin wall, which (when inflated) easily adapts to the irregular edges of the tracheal wall, preventing injuries.⁽⁵⁾

However, the cylindrically shaped, high-volume, low-pressure cuff does not fully protect the airways from aspiration of secretions, food, and gastric contents⁽⁶⁾ because it acts as a reservoir of oropharyngeal secretions,^(7,8) as upper airway secretions, saliva, and food that are above the cuff tend to drip from the sides of the trachea⁽⁶⁻⁸⁾ and through microchannels formed by the cuff material collapsing upon itself.⁽⁹⁻¹¹⁾ These events lead to sustained bronchoaspiration of accumulated peri-cuff materials,⁽⁶⁻⁸⁾ which is a process called microaspiration. Microaspiration, combined with bacterial colonization of the aerodigestive tract, is the main cause of ventilator-associated pneumonia (VAP).^(12,13)

VAP is defined as inflammation of the lung parenchyma that is caused by infectious agents 48 to 72 hours after orotracheal intubation and the onset of mechanical ventilation.⁽¹⁴⁾ VAP is typically the most frequent infection in patients admitted to the intensive care unit (ICU),⁽¹⁵⁾ representing approximately 60% of nosocomial infections⁽¹⁶⁾ and increasing the duration of hospitalization, thereby increasing hospital costs.⁽¹⁴⁾ Indeed, VAP is the leading cause of morbidity and mortality among critically ill patients.⁽¹⁷⁾

Although the classification of VAP has been recently questioned, the disease is categorized as two types: early-onset (developing up to four days after the initiation of mechanical ventilation) and late-onset (developing after the fifth day of mechanical ventilation).^(16,18) Early-onset VAP is usually caused by microaspiration of bacteria colonizing the oropharynx (Gram-positive cocci and *Haemophilus influenza*)⁽¹⁴⁾ and usually yields a better prognosis because the disease-causing microorganisms are sensitive to antibiotics.⁽¹⁸⁾ Late-onset VAP is usually caused by nosocomial organisms, including *Pseudomonas aeruginosa*, *Stenotrophomonas maltophilia*, and methicillin-resistant *Acinetobacter* and *Staphylococcus aureus* species⁽¹⁴⁾ (multi-resistant microorganisms), which are associated with increased morbimortality.⁽¹⁸⁾

The concept of preventing bronchoaspiration (and thereby, VAP) is based on reducing the amount of the aspirate, among other factors.⁽⁶⁾ A possibly preventive

method is the suction of pulmonary secretions,⁽¹⁹⁾ which is usually performed via an open or closed suction system.⁽²⁰⁾ In the literature, both tracheal suction systems have similar effects on the development of VAP, but these systems fail to achieve suction of secretions that accumulate in the subglottic space proximal to the cuff.⁽²⁰⁾ New endotracheal tubes and tracheostomy cannulae have been developed, which have a dorsal lumen that facilitates continuous or intermittent suction of the subglottic space, thus targeting the leakage of peri-cuff secretions.⁽¹⁵⁾

Several studies have demonstrated that aspiration of subglottic secretions (ASS) using a device with a dorsal suction lumen above the cuff of the endotracheal tube delays the onset and reduces the incidence of VAP.^(15,21-25)

METHODS

The literature review was conducted using the following electronic databases: MEDLINE (Medical Literature Analysis and Retrieval System Online), PubMed (Public MEDLINE), Cochrane, SciELO (Scientific Electronic Library Online), and LILACS (Latin-American and Caribbean Health Sciences Literature Database) for the period from 1986 to 2011. The keywords used were “subglottic secretions drainage,” “subglottic aspiration,” and “ventilator-associated pneumonia”.

RESULTS

The seven relevant studies that were found are listed in table 1.

Vallés et al.⁽²¹⁾ demonstrated that using ASS in intubated patients reduces the VAP incidence by 43.4%. However, there was no significant difference in VAP incidence between the groups given continuous ASS versus conventional aspiration, after the first week of mechanical ventilation. According to the authors, these results were possibly due to the putative decrease in the volume of oropharyngeal secretions aspirated from the interior of the bronchial tract by ASS and to the putative decrease in inoculum size. Thus, the minimum inoculum required to induce early-onset pneumonia is larger than the inoculum required to induce late-onset pneumonia. Consequently, reduction of the inoculum size might explain the delayed progression of late-onset pneumonia and reduced early-onset pneumonia in patients undergoing ASS. Finally, the authors concluded that the incidence of nosocomial pneumonia in mechanically ventilated patients can be significantly reduced using this simple method, which reduces chronic microaspiration through the cuff of endotracheal tubes.

Table 1 - Summary of results

Author	Sample number (N)	Study design	Type of ICU	Time of MV for the beginning of the evaluation of VAP	Ventilatory prosthesis	Control of cuff pressure	ASS method	Use of prophylactic antibiotic treatment	Results
Vallés et al. ⁽²¹⁾	153	Double-blind, randomized, controlled study	Medical-surgical	> 72 hours	OTI with supra-cuff device (open versus closed dorsal suction port)	> 20 mmHg, measured every four hours	Continuous	No	Reduces early-onset VAP incidence by 43.3%
Kollef et al. ⁽²⁶⁾	343	Prospective clinical trial	Cardiothoracic	Shortly after heart surgery	OTI with supra-cuff device (open versus closed dorsal suction port dorsal)	Not performed	Intermittent	Yes	Delayed VAP progression in the ASS group
Smulders et al. ⁽²²⁾	150	Randomized clinical trial	General	> 72 hours	OTI with supra-cuff device versus conventional OTI	Cuff inflated in an empirical manner; pressure measured every four hours	Intermittent	No	10% of patients who developed VAP: 4% from the ASS group and 16% from the control group
Bouza et al. ⁽¹⁵⁾	690	Prospective randomized clinical trial	Cardiothoracic	> 48 hours	OTI with supra-cuff device versus conventional OTI TQT maintains standard used in OTI	20 to 30 mmHg, measured at every shift	Continuous	Yes	Reduces VAP incidence and the length of MV and ICU stay, in addition to reducing hospital costs
Lacherade et al. ⁽²⁵⁾	333	Multicenter randomized and controlled clinical trial	Medical-surgical	> 48 hours	OTI with supra-cuff device versus conventional OTI	20 to 30 cmH ₂ O, measured every three hours	Intermittent (manual with syringe)	Yes	Reduces early- and late-onset VAP incidence
Dezfulian et al. ⁽²³⁾	896	Systematic meta-analysis							Reduces the risk of early-onset VAP by 50%. Reduces the days of MV and ICU stay
Coffman et al. ⁽²⁴⁾		Prospective study			Anatomical model: TQT with supra-cuff device versus conventional TQT		Absent Continuous Intermittent		Reduces saliva suction. Continuous ASS appears more effective

ICU – intensive care unit; MV – mechanical ventilation; VAP – ventilator-associated pneumonia; ASS – aspiration of subglottic secretions; OTI – orotracheal intubation; TQT – tracheotomy.

According to Kollef et al.,⁽²⁶⁾ VAP progression is delayed in patients subjected to ASS. However, no difference was found in the overall rate of VAP between patients submitted to intermittent ASS and those who were not. The explanation of the authors for the discrepancy between their results and other studies was the small sample, the investigation of only one ICU, and the randomization method, which was based on the participants' birthdays. However, these arguments are flawed because the study utilized a larger sample than did other studies,^(21,22,25) several of which were also conducted at only one institution,^(15,21,22) and the randomization efficiently generated groups of patients without significant differences. However, Kollef et al.⁽²⁶⁾ failed to mention having performed measurements of the cuff pressure, which could indeed explain the lack of significant differences regarding the use of ASS. Therefore, the authors conclude that ASS can be safely administered in patients undergoing heart surgery and

that the occurrence of VAP can be significantly delayed in these patients via an easily applied technique.

Smulders et al.⁽²²⁾ determined that VAP can be prevented by ASS in mechanically ventilated patients for more than three days and recommended incorporation of the technique into the routine care of such patients.

Dezfulian et al.⁽²³⁾ found that based on the bacteriological etiology, ASS reduces the risk of VAP by approximately 50% and delays progression of VAP (compared with the control group) in addition to reducing the risk of early-onset pneumonia. Furthermore, patients submitted to ASS remain fewer days on mechanical ventilation and spend less time in the ICU. However, the length of hospital stay and mortality does not significantly differ between the groups. Thus, the authors found that ASS primarily reduces early-onset VAP and argued that it is unclear why this result did not hold for late-onset pneumonia.

Dezfulian et al.⁽²³⁾ also mentioned the existence of few ASS-related complications and the occurrence of dorsal lumen obstruction in the tube with a supra-cuff device due to aspirated secretions, which caused the device to stop functioning; however, there were no adverse effects in the patient because the orotracheal tube later merely became similar to a conventional endotracheal tube. Thus, ASS appears to be effective in preventing early-onset VAP among patients who are ventilated for more than 72 hours.

Bouza et al.⁽¹⁵⁾ observed a significant reduction in VAP incidence in the continuous ASS group and a reduction in the density of VAP incidence. The length of stay in the ICU and the duration of mechanical ventilation are also lower in patients with continuous ASS, and there is a significant reduction in the daily dose of antibiotics in this group. Thus, continuous aspiration should be included in the protocol used to reduce the incidence and outcomes of VAP, at least in populations of patients undergoing heart surgery.

Lacherade et al.,⁽²⁵⁾ in their multicenter randomized study, demonstrated that intermittent ASS reduces the incidence of VAP, including late-onset VAP without any adverse effects. The authors suggest that the reduction in the late-onset VAP incidence may have been revealed due to the large sample size, the use of prolonged mechanical ventilation (more than five days), and the low early-onset VAP incidence (use of prophylactic antibiotic treatment), as more patients could be evaluated for an extended period.

Few studies assess the effectiveness of tracheotomy cannulae combined with a supra-cuff device. Of the studies found, only Coffman et al.⁽²⁴⁾ observed that aspiration of saliva is reduced by using a subglottic suction port, and continuous aspiration appears to be more effective than intermittent aspiration. These results suggest a potential decrease in the risk of aspiration in chronically ventilated patients when a tracheotomy tube with suction is used. However, the performance is expected to be similar to that of an orotracheal tube with the same device.

Several studies mention the cost of using orotracheal tubes with a supra-cuff suction device. However, Bouza et al.⁽¹⁵⁾ reported that ASS ensures a considerable reduction in hospital costs because the savings from purchasing antibiotics is much higher than the costs associated with an orotracheal tube with the supra-cuff device. Shorr and O'Malley⁽¹⁷⁾ demonstrated that tubes with the supra-cuff device may lead to significant savings if regularly used in all emergency orotracheal intubations. Although these

devices are more expensive than traditional orotracheal tubes, this difference is offset by the high costs associated with VAP.

Suction of subglottic secretions provides significant clinical value. However, using bronchoscopy, Dragoumanis et al.⁽²⁷⁾ observed a suction-lumen malfunction in 19 out of 40 patients (48%); 17 cases (43%) were attributed to blockage of the subglottic suction port (due to suction of the tracheal mucosa), one case of obstruction was caused by thick secretions, and one case was indeterminate. Thus, the authors argued that a negative pressure of less than 20 mmHg favors the prolapse of tracheal mucosa into the subglottic suction port, triggering local ischemia in the tracheal mucosa and exposing the patient to an elevated risk of tracheal injury.

According to Bouza et al.,⁽¹⁵⁾ the cuff pressure should be assessed, and the suction lumen should be maintained permeable. The authors recommend instilling 10 mL of sterile water into the subglottic lumen to keep it patent. If an obstruction exists, then permeability should be restored with an air bolus through the subglottic lumen. Consequently, no continuous ASS-related complications were observed in this study. Moreover, there were no cases of lumen obstruction, as the aforementioned protocol was maintained.

In 2005, a design change in the orotracheal tube with the supra-cuff device was introduced to solve issues regarding tracheal injury and suction-lumen obstruction by thick secretions. To this end, the subglottic suction port was moved nearest the cuff, preventing suction of the tracheal mucosa, and the suction port and the lumen were extended to prevent obstruction by thick secretions. Consequently, the device had a greater external diameter than did the conventional orotracheal tube and was most likely stiffer. However, the effects of the new design on the failure rate of subglottic suction or on the occurrence of laryngeal/tracheal injuries have not yet been assessed.⁽¹¹⁾

Another issue is the mode of suction of subglottic secretions. Smulders et al.⁽²²⁾ restricted the use of intermittent ASS because continuous suction with 100 mmHg can damage the tracheal wall.

Thus, only in the study by Kollef et al.⁽²⁶⁾ there were no significant difference in VAP incidence between the groups subjected to ASS and the group undergoing conventional care. The remaining studies demonstrated a reduced VAP incidence with the use of ASS combined with cuff pressure control.^(15,21-23,25)

Additionally, although ASS yields few instances

of decreased duration of mechanical ventilation and ICU/hospital stay^(15,23) and is ineffective in decreasing mortality,^(15,21-23,25,26) the technique efficiently reduces early-onset VAP incidence,^(15,21-23,25) with few adverse effects being reported.^(15,23,27) Furthermore, ASS effectively reduces VAP-related hospital costs^(15,17) and is thus supported by the guidelines of three of four agencies: the Centers for Disease Control and Prevention (2004), the Canadian Critical Care Society (2004), the American Thoracic Society, and the Infectious Disease Society (2005).⁽²⁸⁾ Nevertheless, cannulae combined with supra-cuff suction devices are only occasionally used, despite recommendation by these agencies' guidelines. Gentile and Siobal⁽¹¹⁾ have stated that among other aspects, the inconsistent methodologies leading to heterogeneous patient populations among studies and the lack of standard VAP diagnosis criteria could affect study results, sustaining disagreement on the strength of evidence regarding the method's effectiveness. Another factor that should be addressed is the method of using supra-cuff devices; though intermittent suction is less harmful to the tracheal mucosa, further studies are needed to define how it should be used (i.e., the negative pressure value, suction time, and intervals). Future studies on the impact of using the supra-cuff device in tracheostomized patients are still necessary in addition to investigations assessing the effectiveness of the new design of the orotracheal tube with a supra-cuff device.

CLOSING REMARKS

Cannulae combined with supra-cuff suction devices enable the suction of subglottic secretions, which is beneficial to critically ill patients because these devices reduce VAP incidence and, consequently, hospital costs—with no large-scale adverse effects. However, other forms of VAP prevention must be combined with

use of the orotracheal tube with a supra-cuff device, as the device alone has not proven effective in reducing the duration of mechanical ventilation, ICU/hospital stays, and mortality rates.

RESUMO

O paciente crítico encontra-se intubado ou traqueostomizado por necessitar, na maioria dos casos, de ventilação mecânica invasiva. As cânulas utilizadas possuem o *cuff*, que pode atuar como um reservatório de secreções da orofaringe, predispondo à pneumonia associada à ventilação mecânica. Estudos têm demonstrado que a aspiração das secreções subglóticas por lúmen dorsal de sucção acima do *cuff* do tubo orotraqueal retarda e reduz a incidência de pneumonia associada à ventilação mecânica. O objetivo desta revisão foi verificar, na literatura, a importância da utilização da aspiração com dispositivo supra-*cuff* em pacientes críticos submetidos à intubação orotraqueal ou traqueostomia na prevenção de pneumonia associada à ventilação mecânica. Para tanto, foi realizada revisão bibliográfica entre os anos de 1986 a 2011, por meio de portais de bases de dados nacionais e internacionais. Verificou-se que a aspiração das secreções subglóticas apresenta poucos resultados em relação à diminuição dos dias de ventilação mecânica e de permanência na unidade de terapia intensiva, além de não ser efetiva na diminuição da mortalidade, porém, mostra-se eficaz na redução da incidência da pneumonia associada à ventilação mecânica de início precoce e na redução de seus custos hospitalares. A forma de aspiração das secreções subglóticas contínua mostra-se mais eficiente na remoção de secreções; contudo, a forma intermitente parece ser a menos lesiva. Conclui-se que as cânulas com dispositivo de aspiração supra-*cuff* permitem a aspiração das secreções subglóticas, proporcionando benefícios aos pacientes críticos, uma vez que reduzem-se a incidência de pneumonia associada à ventilação mecânica e, conseqüentemente, os custos hospitalares, além de não haver relação com efeitos adversos em larga escala.

Descritores: Aspiração subglótica; Sucção; Pneumonia associada à ventilação mecânica; Terapia intensiva

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