Review article/Pregledni znanstveni članek

The influence of the endotracheal tube cuff on the occurrence of ventilator-associated pneumonia

Vpliv mešička tubusa na pojav ventilatorske pljučnice

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Key words: ventilator-associated pneumonia prevention; cuff pressure; cuff shape; cuff material; nursing

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ABSTRACT

Introduction: An endotracheal tube enables patient ventilation, but also presents a risk of complications. The accumulation of subglottic secretions above the cuff may cause ventilator-associated pneumonia. The purpose of the article is to establish the effect of the endotracheal tube cuff (shape and material, method of inflation, verifying and maintaining pressure) on the incidence of ventilator-associated pneumonia.
Methods: A descriptive method with a systematic review of domestic and foreign literature was used. The literature was retrieved from electronic databases and the cooperative bibliographic/ catalogue database. According to eligibility criteria, sixteen original scientific articles published in the last ten years were finally used. Data were processed with qualitative content analysis.
Results: Cuff inflation control with a manometer and continuous measuring and adjustment of cuff pressure with modern equipment were found to be the safest methods. According to the articles on shape and material, conical polyurethane cuffs provide the best sealing.
Discussion and conclusion: Ventilator-associated pneumonia is a serious complication in mechanically ventilated patients. Maintaining appropriate cuff pressure proved to be a very effective preventive measure. The research presented here is limited by the small number of available articles. Further research is needed before practical applications are attempted.

IZVLEČEK

Uvod: Endotrahealni tubus omogoča predihavanje pacienta, a hkrati pomeni tveganje za razvoj zapletov. Nad mešičkom tubusa se nabira sekret, ki lahko povzroči ventilatorsko pljučnico. Namen članka je ugotoviti, ali mešiček tubusa (oblika in material ter način napihovanja, preverjanja in vzdrževanja tlaka) vpliva na incidenco ventilatorske pljučnice.
Metode: Uporabljena je bila deskriptivna metoda dela s sistematičnim pregledom domače in tuje literature. Članki so bili najdeni s pomočjo elektronskih podatkovnih baz in vzajemne bibliografsko-kataloške baze podatkov. Za iskanje odgovorov na raziskovalna vprašanja smo glede na vključitvene in izključitvene kriterije uporabili 16 izvirnih znanstvenih člankov iz obdobja zadnjih 10 let. Podatki so bili po izboru obdelani s kvalitativno vsebinsko analizo.
Rezultati: Ugotovljeno je bilo, da je najbolj varno napihovanje mešička z manometrom ter kontinuirano merjenje in sprotno prilagajanje tlaka v mešičku s pomočjo sodobnih pripomočkov. Najboljšo funkcijo tesnjenja je nudil poliuretanski koničasti mešiček, kar potrjujejo vsi članki o materialu in obliki.
Diskusija in zaključek: Ventilatorska pljučnica je resen zaplet mehanske ventilacije. Vzdrževanje primernega tlaka v mešičku je učinkovit preventivni ukrep, vendar je uspeh možen samo ob sočasnem izvajanju ostalih potrebnih ukrepov. Predstavljena raziskava je omejena z majhnim številom člankov, zato bodo pred uvajanjem sprememb v prakso potrebne nove raziskave.

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Introduction

An artificial airway with an inserted endotracheal tube (ETT) or tracheal cannula allows mechanical ventilation of the patient when it is not possible to provide appropriate ventilation with non-invasive methods or in the case of severe airway obstruction. It provides effective protection against the possible aspiration of stomach contents or oral and nasal secretions and also allows easier removal of secretions from the lower respiratory tract. At the same time, the artificial airway enables the rapid transition of pathogenic microorganisms into the lower respiratory tract due to a reduced defense mechanism and disabled cough reflex. This increases the risk of ventilator-associated pneumonia (VAP) (Rosenblatt, 2006; St. John, 2006).

VAP is an infection of the respiratory tract in a patient on an invasive mechanical ventilation (MV) that occurs at least 48 hours after the insertion of ETT. Most commonly, it is caused by the aspiration of secretion from the upper respiratory tract or of stomach contents. VAP is the most common nosocomial infection in patients in intensive care units. The infection increases morbidity, mortality and treatment costs (Videčnik Zorman, 2007; Muzlovič, 2009; Craven & Hjalmarson, 2010; Vincent, et al., 2010). Díaz and colleagues (2010) enumerate the factors that increase the risk of VAP in patients on MV: prone position, gastric distension, contamination of tubes or other parts of mechanical ventilator, frequent movement of patients and low cuff pressure.

There are many preventive measures against VAP. Jaklič (2011) and Díaz and colleagues (2010) state the activities and conditions that significantly reduce the incidence of VAP: performing subglottic aspiration, checking pressure in the cuff, putting the patient in a semi-seated position, performing oral care with a chlorhexidine solution, regular and correct tracheal aspiration, proper handling of MV equipment, avoiding unnecessary movement of patients, early disconnection from MV, use of non-invasive MV, use of orogastric instead of nasogastric tubes and enteral nutrition to maintain gastrointestinal functions and a smaller increase in pathogenic microorganisms that could cause VAP. Jaklič (2011) and Muzlovič (2007) point out that nursing care activities reduce the incidence of VAP.

The cuff is crucial in preventing fluid leakage from the subglottic area to the lower respiratory tract. Conical and cylindrical cuffs are currently the most common ones. The most common cuffs are made of polyvinyl chloride (PVC) and polyurethane (PU). The purpose of the cuff is to ensure sufficient sealing and thus prevent the flow of air, fluid or other substances into the lower airway. Besides the sealing function, a properly inflated cuff also provides fixation, reducing the probability of unwanted extubation. An inflated cuff holds the ETT at the centre of the trachea, reducing the incidence of injuries arising from the tube tip rubbing against the trachea wall. Cuff pressure is the main factor influencing the effectiveness of the cuff. An ideal pressure prevents microaspiration and at the same time does not reduce the affected tracheal wall perfusion. Even a relatively high pressure, for example 60 cm H_2O, would not completely prevent microaspiration, but would certainly cause various tissue damage: tracheal rupture, necrosis, tracheoesophageal fistula, tracheal stenosis, or paralysis of the laryngeal nerve with the danger of stridor or sore throat after extubation (Vyas, et al., 2002; Rose & Redl, 2008; Díaz, et al., 2010). With the occurrence of high volume, low pressure cuffs with lower and more equally distributed pressure on the trachea wall, the incidence of these complications has decreased (Papla, et al., 2003; De & De, 2008; Zias, et al., 2008). The valid recommended pressure in a cuff that is supposed to provide sufficient sealing while causing minimal complications is between 20 and 30 cm H_2O, which equals 15 to 22 mm Hg (Spiegel, 2010; Sole, et al., 2011; Madjdpour, et al., 2012).

There are many ways to inflate and control cuff pressure; they often depend on the experience of staff and common practice in the institution. The most reliable methods are to inflate and control the pressure with a manometer and the use of a "cuff controller". The other two methods are manual palpation of the exterior cuff on the ETT and palpation of vibration or listening to a murmur around the thyroid cartilage with a stethoscope (sealing technique). Both methods are reliable enough to inflate the cuff to provide a satisfactory seal. The danger lies in inflating the cuff to above 30 cm H_2O. The cuff pressure has to be checked regularly in all cases, either intermittently or continuously. Continuous checking provides easier control, as the cuff pressure is constantly shown on the display (Černivec, et al., 2002; Prestor, 2006; Kodila, 2008; Sole, et al., 2009; Mažič, 2011).

Purpose and goal

The purpose of the article is to establish on the basis of recent studies, the effect and extent of the cuff on the incidence of VAP, especially in long-term treatments of intubated life-threatened patients in intensive care units.

The goal is to answer the following research question: can the cuff inflation method, method of checking and maintaining cuff pressure, and the shape and material of the cuff influence the incidence of VAP?

Methods

A systematic literature review was conducted to determine the influence of the cuff shape and inflation/pressure control methods on the occurrence of VAP. The aim of this descriptive method is to assess all the available studies on a particular topic (Moule & Goodman, 2009).

Review methods

Professional, original scientific and review articles were found with the help of electronic databases (Medline, Cochrane, CINAHL) and the Digital Library of the University of Ljubljana (DiKUL). Postings from publications, handbooks and books found via the Slovenian cooperative bibliographic/catalogue database (COBIB.SI) were also used. The key words used on the internet databases for the research were: nursing, invasive mechanical ventilation, ventilator-associated pneumonia, endotracheal tube, and cuff. Different combinations of key words were used, and the Boolean operator "AND". The Slovene key words used in the COBIB.SI search were: mechanical ventilation, artificial ventilation, and artificial airway. We searched for full peer-reviewed articles in Slovenian or English published between January 2008 and June 2014. We excluded short reports and editorials. We additionally excluded studies from the results that included children in the study group, short-term mechanical ventilation, and non-cuff-related topics.

Results of the review

We found 373 articles in foreign databases. After a critical reading of titles and abstracts, 41 articles passed the screening process; 16 articles were included in the qualitative text synthesis. Only 35 Slovene hits in total were published in 2008 or later. We found no Slovene studies that met the inclusion criteria for the analysis and synthesis.

The quality assessment of the review and the description of data processing

With the approach described above, we found articles of different levels evidence of research. The inclusion criteria were based on scientific facts, contextual relevance and full-text availability. According to the hierarchy of evidence in scientific research work as described by Skela-Savič (2009), there were 6 randomised clinical trials – level 2a (Al-Metwalli, et al., 2011; Sole, et al., 2011; Alijanpour, et al., 2013; Jaillette, et al., 2013; Poelaert, et al., 2008; Bulpa, et al., 2013); 1 non-randomised clinical trial – level 2b; 6 observational clinical studies – levels 4 and 3, observational in-vitro studies – level 4. Relevant articles were analysed with a qualitative method of data analysis, compilation and text synthesis. An accurate review and content analysis is presented in Tables 1, 2 and 3.

Results

Several researchers have investigated cuff inflation methods (Table 1). Al-Metwalli and colleagues (2011) published the results of a prospective, randomised in-vivo study in which the reliability of cuff inflations with the aid of a manometer, sealing technique and exterior cuff palpation were compared. In all three cases, the cuff pressure was measured with a manometer. Significant deviations in cuff pressure were noted. Cuff pressure measured in the sealing technique group was significantly lower, while in the palpation group it was significantly higher. Similar results were published in two more published in vivo studies. Stewart and colleagues (2003) performed a study among anaesthesia providers who inflated the cuff with their usual inflation method. The palpation method was used in 88 % of cases, and cuff pressure was above normal values in 65 % of all cases. Sengupta and colleagues (2004) also report unduly high cuff pressures in 50 % of measurements after inflation with the palpation method.

Cuff pressure can change with some activities and changes in the patient's state and so it must be constantly checked. Researchers have investigated

Table 1: *Articles on cuff inflation*
Tabela 1: *Članki o napihovanju mešička tubusa*

Articles/ Članki	***Goals/ Cilji***	***Sample/ Vzorec***	***Variables/ Spremenljivke***	***Findings/ Ugotovitve***
Al-Metwalli, et al., 2011	To determine the most reliable cuff inflation method	75 patients	- inflation with a manometer - sealing method - palpation method	In the sealing method the deviation of P from standard value was minimal (average 20.52±3.8 cm H_2O). In palpation the deviation was high (average 48.6±14 cm H_2O)
Stewart, et al., 2003	To determine the standard cuff P using estimation methods	40 patients	- ventilation with a predetermined air volume - sealing technique - palpation technique	P was within border values in 30 % of all cases. In 65 % of all cases, it surpassed 40 cm H_2O, in 5 % it was below 25 cm H_2O
Sengupta, et al., 2004	To determine the reliability of cuff inflation with palpation method	93 patients	- cuff inflation with palpation and then control with a manometer	On average, the cuff P was 35.3 cm H_2O. 27 % of cuffs were inflated between 20 and 30 cm H_2O, 50 % over 30 cm H_2O, 23 % below 20 cm H_2O

Legend/Legenda: P – pressure/tlak

which method of pressure checking is more reliable (Table 2) and which situations most often affect changes in pressure. Sole and colleagues (2009) presented an in vivo pilot study comparing intermittent and continuous checking of cuff pressure. From the data gathered on continuous checking it was established that cuff pressure was on average within border values only 54 % of the time; 30 % of the time, cuffs were underinflated, and overinflated 16 % of the time. The data from continuous pressure measurements were analysed together with the data on interventions, procedures, and observations. Changes in pressure were noted in interventions and procedures that on average lasted up to 5 minutes. The highest measured value was 56 cm H_2O. An increase in cuff pressure of 14 to 20 cm H_2O was noted in a tracheal aspiration through ETT. Changes in pressure were also present with a shift in the patient's position. No changes in pressure were noted during oral care or oral cavity aspiration. It has been noted that pressure changes were lower after the application of sedatives.

Cuff pressure was assumed to drop in correlation with the length of MV. In a prospective observational study, Motoyama and colleagues (2014) tried to establish any changes in cuff pressure after a certain time interval. Nurses measured the pressure every 2 hours using a cuff inflator, each time re-adjusting the pressure. Underinflation was recorded in 45% of all measurements.

In a randomised crossover in vivo study Sole and colleagues (2011) compared the reliability of two cuff pressure measurement methods. Cuff pressure was measured continuously and intermittently in all patients; in one intermittent group, the measuring staff had access to the results of the continuous measurements, while in the other they had no such access. It was determined that the time of the pressure outside border values was higher in the group without the option of seeing the results from continuous measurements (51.7 %) compared to the group with this option (11.1 %).

In an in vivo study, Alijanpour and colleagues (2013) determined the connection between various cuff inflation and control methods with the MV complication incidence. A higher complication rate was noted with the palpation technique. Jain and Tripathi

Table 2: *Articles on cuff pressure control methods*
Tabela 2: *Članki o načinu preverjana tlaka v mešičku tubusa*

Articles/ Članki	***Goals/ Cilji***	***Sample/ Vzorec***	***Variables/ Spremenljivke***	***Findings/ Ugotovitve***
Sole, et al., 2009	To determine the reliability of CM of cuff P compared to IM	10 patients	- CM of P with a monitor - IM of P with a manometer	CM with a monitor is better because it provides constant data even when there are no signs of P changes
Sole, et al., 2011	To compare cuff P maintenance at IM and CM	25 patients	- CM of P with a monitor - IM of P with a manometer	CM with a monitor is better because it provides constant data even when there are no signs of P changes
Alijanpour, et al., 2013	To determine if regular P measuring and correction influences the complication incidence due to intubation and MV	1544 patients	- P measuring and correction with a manometer every 6 hrs - controlling P with palpation and correction as needed every 6 hrs	Fewer complications in manometer measuring and correction of P (0.8 %) compared to checking P with palpation (3.74 %)
Jain & Tripathi, 2011	To compare manual cuff P control methods with a device method	100 patients	- manual cuff inflation with an automatic P correction - inflation with an automatic cuff pressure controller	P was constant when the device was used; in manual inflation the P at the beginning was app. 50 cm H_2O, later corrected to 25 cm H_2O
Jaillette, et al., 2013	To determine if CM and P correction enables more constant P in the cuff.	64 patients	- CM and P correction with a pneumatic device - measuring and correction of P with a manometer every 8 hrs	During CM and P correction the P was within border values 95 % of the time; with the use of the manometer it was within border values 44 % of the time. No significant differences were determined regarding microaspiration
Motoyama, et al., 2014	To determine if cuff P changes with time	27 patients	- control and adjustment of P to 24 cm H_2O every 2 hrs	In 45 % of measurements P was below 20 cm H_2O

Legend/Legenda: P – pressure/tlak; CM – continuous measuring/kontinuirano merjenje; IM – intermittent measuring/intermitentno merjenje

(2011) in their in vivo study report similar findings: they established that cuff pressure was significantly higher when the cuff was manually inflated. They also report other complications, such as sore throat, coughing and hoarseness being more frequent in the group where cuff was manually inflated and controlled hourly by a pressure monitor compared to the group where an automatic cuff pressure controller was used and the pressure was maintained at a constant 25 cm H_2O. Jaillette and colleagues (2013) in a prospective, randomised in vivo study wanted to determine the efficiency of a pneumatic device in controlling cuff pressure compared to routine care using a manual manometer. Frequency of microaspirations was also determined.

The effect of the shape and material of the endotracheal tube have also been studied (Table 3). Dave and colleagues (2010) determined the leakage of fluids from six cuffs that differed in shape and material on a model of the trachea. All PU cuffs proved to have better sealing features than PVC cuffs. The best protection was established in a conical PU cuff. Among PVC cuffs, the conical cuff proved to have the best sealing features. The leakage of water in PU cuffs was constant, while in PVC cuffs the starting leakage was higher and gradually decreased.

Zanella and colleagues (2011) studied fluid leakage past the cuff in an in vitro study. Guayule latex cuffs were studied alongside PVC and PU cuffs. Cuff sealing was compared at various positive end-expiratory

Table 3: *Articles on the influence of cuff shape and material*
Tabela 3: *Članki o vplivu oblike in materiala mešička*

Article/ Članki	***Goals/ Cilji***	***Sample/ Vzorec***	***Variables/ Spremenljivke***	***Findings/ Ugotovitve***
Dave, et al., 2010	To determine fluid sealing in cuffs of various shape and material	2 repetitions, each with 144 measurements	- 6 cuff models - 3 trachea model sizes - 8 tubes per cuff and per trachea size	Conical PU cuff has the best sealing capability; PVC cuffs have the lowest sealing capability, especially cylindrical.
Zanella, et al., 2011	To determine the influence of cuff shape and material on fluid leakage past the cuff	7 cuff types	- 3 cylindrical PVC cuffs - 1 cylindrical PU cuff - 1 conical PU cuff - 1 conical PVC cuff - 1 cylindrical Guayule latex cuff - PEEP: 0, 5, 10, 15 cm H_2O	The Guayule latex cuffs showed no leakage at all PEEP levels. Cylindrical and conical PU cuffs showed limited leakage only for PEEP zero. The PVC cuffs showed reduced leakage with increasing PEEP. Among all PVC cuffs, the conical shape had the best sealing properties
Madjdpour, et al., 2012	To determine gas sealing features in various cuff shapes and materials	4 repetitions per each combination	- 3 cuff models - 5 different cuff pressures - two types of measurement - two PIP values	Conical PU cuff has the best sealing properties, cylindrical PVC cuff the worst
Mahmoodpoor, et al., 2013	To determine the influence of cuff shape and material on VAP incidence	96 patients	- 3 cuff types	VAP incidence was lowest with the use of conical PU cuff and the highest with the use of cylindrical PVC cuff
Poelaert, et al., 2008	To determine the influence of cuff material on post-operative pneumonia incidence	134 patients	- PU cuff - PVC cuff	Post-operative pneumonia incidence was lower with PU cuff (23 %) compared to PVC cuff (42 %)
Miller, et al., 2011	To determine if cuff material influences VAP incidence	3207 patients	- PVC cuff - PU cuff	With PU usage VAP incidence was reduced from 5.3 episodes per 1000 days of MV (PVC) to 2.8 episodes per 1000 days of MV
Bulpa, et al., 2013	To determine if cuff material influences microaspiration	29 patients	- PVC cuff - PU cuff	Leakages were observed in 11/29 patients (38 %), with similar rate aspiration in PU (5/16) and PVC (6/13) groups

Legend/Legenda: PU – polyurethane/poliuretan; PVC – polyvinyl chloride/polivinil klorid; PIP – peak inspiratory pressure/ maksimalni inspiracijski tlak; VAP – ventilator-associated pneumonia/ventilatorska pljučnica PEEP - positive end-expiratory pressure/pozitivni tlak ob koncu izdiha; MV - mechanical ventilation/mehanska ventilacija

pressures (PEEP). In connection with peak inspiratory pressure (PIP) Madjdpour and colleagues (2012) discovered that the conical PU cuff proved most reliable, while the cylindrical PVC cuff proved least reliable. Higher cuff pressure offered better sealing in all cases.

In vivo studies have been conducted on the influence of various cuffs on VAP incidence. Mahmoodpoor and colleagues (2013) conducted a vast study in Iran and noted VAP occurrence in 11 (34.4 %) patients with cylindrical PVC cuff, 8 (25 %) with cylindrical PU cuff and 7 (21.9 %) with a conical PU cuff. A lower level of reliability of PVC cuffs was also noted by Poelaert and colleagues (2008), who in a prospective, randomised in vivo study, reported VAP incidence with the use of various cuffs. It was determined that the incidence of early post-operative pneumonia was significantly lower in the group where a PU cuff was used compared to a group where a PVC cuff was used (23 % compared to 42 %, $p < 0.03$). Jaillette and colleagues (2013) found no significant difference in the incidence of microaspiration between cylindrical and conical cuffs in the aforementioned study. Miller and colleagues (2011) report a retrospective in vivo study in which they studied VAP incidence before, during and after the replacement of a conventional PVC cuffed endotracheal tube with a PU–cuffed ETT. Lower VAP incidence was noted following the replacement of ETT. Cuff sealing reliability was also studied by Bulpa and colleagues (2013), who compared 16 PU and 13 PVC endotracheal tubes in an in vivo study. To test the sealing capacities of the cuff, 5 ml of 0.9% NaCl with a radiopaque contrast agent was injected via the aspiration channel of the tube. Examination was performed by mobile gamma camera. No substantial differences were discovered.

Discussion

VAP is a dangerous complication of an invasive MV that can seriously endanger a patient's life. Most commonly, it is a result of an aspiration of secretion from nasal or oral cavity which is retained in a subglottic area above the cuff. In practice, minimal, so called "silent" or "microaspiration" cannot be completely prevented; however, it can be greatly reduced with proper nursing care activities and appropriate tools, creating a favourable conditions for a successful treatment outcome.

There are many ETT types from different manufacturers on the market that are distinguished by cuff shape and material. The ETT performs several functions, the most basic being the sealing that enables MV with positive pressure and protection from aspiration of stomach contents or secretions from the upper airway. Recommended cuff pressure after inflation is between 20 and 30 cm H_2O. This is supposed to be the pressure that offers maximum protection with the least damage to trachea tissue in contact with the cuff.

There are more ways to inflate a cuff, but not all ensure that cuff pressure stays within border values. In research conducted by Al-Metwalli and colleagues (2011), cuff inflation with a manometer that directly shows the cuff pressure proved the most reliable. In a sealing technique, the cuff pressure was on average at the lowest level of recommended values. Such pressure provides sufficient sealing for positive pressure MV, but the efficiency of protection against aspiration is questionable. An inflation method that relies on the palpation of the person performing it proved the least reliable (Sengupta, et al., 2004). Two studies show that this method is common in practice (Stewart, et al., 2003; Rose & Redl, 2008). All three studies note that the cuff pressure in this method was too high. The method requires a highly experienced professional. This would probably not cause any serious complications during a short intubation; however, with long-term exposure such high pressure would certainly cause ischemic injuries to the trachea. For this reason, cuff inflation with a manometer is the most recommended, especially in intensive care units where a patient is intubated for a prolonged period. Out of all reviewed literature only three original scientific articles describe cuff inflation methods, making it sensible to further research this field.

Sealing reliability may change with time (Motoyama, et al., 2014) increasing the risk of complications (Alijanpour, et al., 2013). In order to ensure cuff functionality, cuff pressure must be regularly controlled and maintained, either intermittently or continuously. Rose and Redl (2008) report that almost 75 % of respondents control the cuff pressure once per shift. Jordan and colleagues (2012) also report of too infrequent intermittent measurements, as only 52 % of respondents performed cuff pressure measurements every 6-12 hours; 32 % reported performing measurements at 2-4-hour intervals; 15 % assessed cuff pressure when a leak occurred, and 1 % never monitored cuff pressure.

Cuff pressure also changes with different activities. Sole and colleagues (2009; 2011) warn that in most cases, staff do not detect these changes unless they are warned by monitor or other device. Thus continuous cuff pressure measurement with alarms is more appropriate. The pressure must be adjusted every time it exceeds the recommended values. It would be sensible to check and adjust the pressure before and after activities that are known to affect cuff pressure, such as tracheal suctioning and position readjustment.

Some authors recommend the use of devices that continuously adjust cuff pressure automatically (Jain & Tripathi, 2011; Jaillette, et al., 2013). However, in some cases it was established that imminent pressure adjustment is not necessarily positive, such as when the patient attempts to cough, which raises cuff

pressure for only a few seconds. The device reacts by lowering the pressure. After the attempt to cough, the cuff pressure is again reduced, which can lead to aspiration of the secretion gathered above the cuff. In such cases, the use of these devices would be much safer if continuous subglottic suctioning were performed at the same time (Vyas, et al, 2002; Mol, et al., 2004; Cohen, 2006; Young, et al., 2006). The efficiency of an automatic, validated device for continuously regulating cuff pressure in preventing VAP was also researched by Valencia and colleagues (2007, p. 1543); however, it did not result in additional benefits to the semi-recumbent position in preventing VAP. Rouze (2013, p. 440) points out that two main types of devices, electronic and pneumatic, have been developed for continuously controlling cuffs. Both have proved effective, but only the pneumatic device has provided a reduction in microaspiration and VAP incidence.

Several studies have shown that conical cuffs provide better sealing compared to cylindrical cuffs (Dave, et al., 2010; Zanella, et al., 2011; Madjdpour, et al., 2012; Mahmoodpoor, et al., 2013). This beneficial effect is attributed to the fact that the tracheal diameter is not constant, and that a conical cuff might provide a sealing zone regardless of tracheal diameter (Jaillette, et al., 2014, p. 4). It was later shown that the PU cuff was better than the PVC cuff, regardless of shape (Coppadoro, et al., 2011). This material is much thinner than PVC, resulting in less formation of folders between the cuff and tracheal wall (Jaillette, et al., 2014, p. 4). Only the study of Bulpa and colleagues (2013) reports different results; they found no significant difference in the level of microaspiration in either material; however, their sample was small.

An interesting difference was established during the observation of sealing through time: the leaking of liquid in PU cuffs was constant throughout the observation period, while in PVC cuffs the leak rate was higher in the first five minutes, but significantly decreased later (Dave, et al., 2010; Madjdpour, et al., 2012). It would make sense to study both materials during a simultaneous subglottic suctioning during long-term hospitalisation.

Poelaert and colleagues (2008) and Miller and colleagues (2011) note the reduction in VAP incidence with the use of PU cuffs. Mahmoodpoor and colleagues (2013) complement these data with the detail that the lowest VAP incidence was with the conical PU cuff, while the highest was with the cylindrical PVC cuff. These findings are in line with the sealing characteristics. It would be interesting to determine the effects of cuff type on costs. Differences in the prices of endotracheal tubes with various cuffs and potential additional costs of VAP treatment should be considered.

Some authors report a positive experience with low-volume, low pressure (LVLP) cuff made of silicone (Young, et al., 2006) and research on the use of other materials such as lycra or latex (Zanella, et al, 2011). However, no definitive clinical data on the material of choice to prevent VAP are available (Coppadoro, et al., 2011, p. 4).

In patients expected to be intubated for more than 48 hours, the use of antibacterial coating (most commonly silver-coated ETT) to prevent the formation of a biofilm and bacterial colonisation (Deem & Treggiari, 2010; Coppadoro, et al., 2011; Fernandez, et al., 2012) has been increasingly promoted.

The use of an inflatable silicone rubber inserted into the ETT lumen for the mechanical removal of biofilm has also been proposed. Although no adverse effect related to the mucus shaver, more clinical trials will be needed to evaluate the effectiveness of this device (Fernandez, et al., 2012, p. 236).

Whatever the case, the future of VAP prevention by means of innovative devices probably lies in a combination of characteristics which all comprise VAP prevention potential (Blot, et al. 2011, p. 157). It is important to combine data from in vitro models with data from clinical studies with an emphasis on clinically important outcome measures (Shander, 2011, p. 11).

While the choice of the ETT (with a subglottic suctioning tube and conical PU cuff), correct inflation, maintenance and adjustment of correct cuff pressure proved effective preventive measures, it is important to keep in mind that success is possible only with the simultaneous implementation of other preventive measures. Caries and mouth plaque are perfect media for microorganisms, so in many studies regular oral care with chlorhexidine solution proved to be one of the most important measures in VAP prevention. Special suctioning tubes placed in the oral cavity to continuously remove secretions are in use in some places. This reduces the amount of secretion flowing to the subglottic area (Garcia, et al., 2009; Munro, et al., 2009; Feider, et al., 2010; Chow, et al., 2012). Subglottic suctioning is an effective way of preventing the flow of secretions into the lower airway. It can be performed only on patients with an inserted ETT with embedded lumen for subglottic suctioning (Kodila, 2008; Craven & Hjalmarson, 2010; Díaz, et al., 2010; Dolar & Jaklič, 2010), further confirming the importance of correct ETT choice.

A multidisciplinary approach, constant education of staff, constant alertness and reminding staff about the importance of preventive measures and the use of standardised documentation are all very important (Urden, et al., 2006). Nurses are very important members of medical teams; considering that they undertake nursing care activity, it is crucial they are aware of all the above-stated facts, follow them during the planning, implementation, control and assessment of nursing care and work in accordance with these guidelines for the good of the patient.

Conclusion

VAP is a common and serious complication in MV patients. With the consistent implementation of some activities it can be strongly limited. The choice of ETT, cuff shape and material alone can greatly influence VAP incidence. PU tubes with additional lumen for subglottic aspiration and a conical cuff were the most efficient in the published studies. Taking into consideration the researched facts on the benefits of manometer cuff inflation and continuous checking and maintaining of cuff pressure with simultaneous subglottic aspiration can provide even higher level of protection against VAP. Further studies also assess the financial aspect using these changes. The research reviewed here is limited by the relatively small number of available results on the role of the cuff in VAP prevention. A search in the Slovenian language returned no hits, so new research as well as in vivo research in a clinical environment and good practice are certainly needed.

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