Preventive Strategies of Ventilator Associated Pneumonia

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Purpose: Despite numerous evidence based preventive strategies of ventilator associated pneumonia (VAP) have been introduced, the incidence rate of VAP continues in an unacceptable range. The purposes of this review were to identify risk factors and diagnosis of VAP and to introduce current evidence based preventive strategies of VAP. **Methods:** A comprehensive literature search using keywords, including ventilator associated pneumonia were entered into a search engine. A number of highly pertinent papers relevant to the purpose of the review were identified. The papers that discussed specific preventive strategies of VAP were selected for analysis and inclusion in this review. **Results:** A number of evidence based preventive strategies that nurses can implement in their clinical practice to prevent VAP were identified. Such strategies include hand washing, use of protective gloves and gowns, oral care, stress ulcer prophylaxis, avoidance of unnecessary intubation, weaning protocol, sedation vacation, use of non-invasive ventilation, semi-recumbent position, continuous aspiration of subglottic secretions, and maintenance of proper endotracheal tube cuff pressure. Staff education is essential in preventing VAP. **Conclusion:** Preventive strategies of VAP should be applied to daily nursing care and each critical nurse should play a functional role in preventing VAP.

Keywords: Ventilator associated pneumonia, Risk factors, Diagnosis, Prevention

I. Introduction

Ventilator associated pneumonia (VAP) is the most frequent nosocomial infection in intensive care unit (ICU) patients (Shorr & Kollef, 2005). According to the Center for Disease Control and Prevention (CDC), pneumonia is the second most common nosocomial infection, accounting for approximately 15% of all hospital acquired infections and 27% and 24% of all infections acquired in the medical intensive-care unit (ICU) and coronary care unit in the United States, respectively. It is also the leading cause of death from nosocomial infection (CDC, 2005).

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Mechanical ventilation has been identified as one of the single most important risk factors for the development of nosocomial pneumonia (CDC, 2005). Patients receiving mechanical ventilation have 6 to 21 times the risk for acquiring nosocomial pneumonia compared with patients not receiving mechanical ventilation (Genuit, Bochicchio, Napolitano, McCarter, & Roghman, 2001). The average occurrence rate of VAP ranges from 9% to 78% in mechanically ventilated ICU patients (Grap, Munro, Ashtiani, & Bryant, 2003). According to the National Nosocomial Infection Surveillance (NNIS) system (2005), the data summary from 1998 to 2003 revealed that VAP occurs at a rate of 5.9 per 1000 ventilator days in ICU patients.

VAP has been associated with increased morbidity, prolonged length of ICU or hospital stay, attributable mortality, increased duration of mechanical ventilation, and higher costs for medical care. Studies show that VAP increases length of ICU stay by 6.1 days and length of hospital stay by 10.5 days (Schleder, 2003). In patients with VAP, crude mortality rates of 20% to 30% and attributable mortality rates of up to 30% have been documented (Bercault & Boulain, 2001). Financially, several estimates suggest that VAP increases costs by almost $12,000 per case (Shorr & Kollef, 2005).

VAP is preventable and disease prevention employed by health care providers is the most effective strategy to decrease morbidity and control medical care costs. Prevention strategies are most efficacious when the prevalence of disease is high and the factors associated with the disease can be identified and modified. VAP fulfills both of these requirements and has been previously identified by the CDC.

The first CDC Guidelines for prevention of nosocomial pneumonia were published in 1981. At that time, the CDC Guidelines were focused on the main infection control problems related to hospital acquired pneumonia. In 1994, the Healthcare Infection Control Practices Advisory Committee (HICPAC) addressed concerns related to prevention of VAP (CDC, 2005). Strategies for prevention of VAP have become a higher priority since the Intensive Care Advisory Panel of the Joint Commission proposed prevention of VAP as a core ICU performance measure in September 2002 (Joint Commission on Accreditation of Health Organization, 2003).

Several evidence based interventions are known to reduce the incidence of VAP and these have been incorporated into guidelines by a number of health care organizations in many countries. However, translating into consistent delivered care at the bedside remains a challenge (Hawe, Ellis, Cairns, & Longmate, 2009).

The successful implementation of guidelines is dependent upon many factors. Especially, knowledge of strategies for behavior change including staff education is essential for successfully implementing evidence based guidelines. Educational interventions for staff have been shown to effectively reduce the incidence of VAP in many studies. Nurses need to understand the risk factors for VAP, diagnostic methods, and preventive strategies that may prevent VAP. This review summarizes the current literature on VAP considered clinically most relevant.

II. Preventive strategies of ventilator associated pneumonia

1. Pathogenesis

VAP refers specifically to nosocomial bacteria pneumonia that has developed in patients receiving mechanical ventilation. VAP is typically categorized as either early-onset VAP or late-onset VAP. Early onset VAP, occurring within 48 to 72 hours after tracheal intubation, is associated with antibiotic sensitive pathogens such as Staphylococcus aureus, Haemophilus influenzae, and Streptococcus pneumonia and often results from aspiration which complicates the intubation process. Late onset VAP occurs more than 96 hours after tracheal intubation and is more often caused by antibiotic resistant pathogens such as Enterobacteriaceae, Pseudomonas aeruginosa, and Staphylococcus aureus (Paul et al., 2003).

Bacterial colonization of the respiratory and digestive tracts and microaspiration of contaminated secretions of the upper and lower parts of the airways are critical pathogenesis of VAP and major targets for prevention (Craven, 2006). Oropharyngeal colonization with gram-negative bacilli occurs within a few days of ICU admission in about 80% of mechanically ventilated patients and increases the subsequent risk of VAP. The sources of these bacteria are endogenous and exogenous. The endogenous sources include the gastrointestinal tract and the upper respiratory tract including oropharynx, sinus cavities, the nares, and dental plaque. The exogenous sources include patient to patient contact and ventilator circuit (Kunis & Puntillo, 2003).

Dental plaque is an important site for growth of potential pathogens providing a nidus of infection for microorganisms that are responsible for the development of VAP (Schleder, 2003). The presence of an endotracheal tube provides a pathway for direct entry of colonized bacteria from the oropharynx through an open glottis to the lower respiratory tract and decreases the body's ability to filter and humidify air. It also promotes colonization by interfering with the cough reflex and the function of the mucociliary escalator and by stimulating excessive mucous secretion (Grap, Munro, Elswick, Sessler, & Ward, 2004).

Within 24 hours after oral intubation, potential pathogens for VAP appear in oral secretions in 67% of mechanically ventilated patients. After 24 hours, most suction equipment is colonized with many of the same pathogens cultured from oral secretions. Oral secretions may become subglottic secretions that pool above the endotracheal tube cuff leading to aspiration into the lower respiratory tract and line the tube, forming a biofilm. The endotracheal tube cuff does not prevent the leakage of infected oral secretions from the subglottis to the trachea (Schleder, 2003). The biofilm containing large amounts of bacteria can be disseminated into the lungs by ventilator induced breaths, instillation of saline into the endotracheal tube, suctioning, coughing, or repositioning of the endotracheal tube (Olson, Harmon, & Kollef, 2002).

2. Risk Factors

Many risk factors for the development of VAP have been identified. These risk factors can be divided into modifiable and non-modifiable and patient-related and treatment related. Non-modifiable patient-related risk factors include preexisting medical conditions such as immunosuppression, chronic obstructive pulmonary disease, adult respiratory distress syndrome, and multiple organ system failure. Other non-modifiable patient-related risk factors are age > 70, male sex, coma status, and APACHE II score ≥18 (Augustyn, 2007; Bonten, Kollef, & Hall, 2004; Segers & de Mol, 2009).

Increased age is a risk factor for the development of VAP with a cut off age of 70 years. Physiologically, pulmonary function decreases with increased age. Changes that occur due to the aging process include decreased elastance of lung tissue, increased elastance of the chest wall, and decreased maximal airflow rates. With advancing age, the functional residual capacity decreases and closing volume may exceed functional residual capacity leading to closure (Brooks, 2001). VAP also occurs more often in patients with acute respiratory distress syndrome and co-morbidity conditions such as renal disease, diabetes, liver disease, and cancer.

Non-modifiable treatment-related risk factors include reintubation, blood transfusion, the necessity of neurosurgery, monitoring of intracranial pressure, cardiopulmonary bypass time, emergent surgery, intraoperative inotropic support, and transportation out of ICU (Augustyn, 2007; Bonten et al, 2004; Segers & de Mol, 2009). The intubation process itself contributes to the risk of VAP and several studies have identified the duration of mechanical ventilation as an important determinant for the development of VAP. In a large cohort study, the risk for the development of VAP was estimated to be 3% per day in the first week, 2% per day in the second week, and 1% per day in the third week and beyond (Boten et al, 2004).

Modifiable risk factors include use of H2 receptor antagonist, use of antacids, ventilator circuit, use of antibiotics, supine position, receipt of enteral nutrition, failed subglottic aspiration, endotracheal tube cuff pressure of < $20cmH_2O$, tracheostomy, and aerosol treatment (Augustyn, 2007; Bonten et al, 2004; Segers & de Mol, 2009). Patients taking antacids and H2 receptor antagonists may have bacterial overgrowth and develop pneumonia (Schleder, 2003).

Oral secretions pool above the endotracheal tube cuff and low cuff pressure can lead to microaspiration or leakage of bacteria around the cuff into the trachea (Ferrer & Artigas, 2001). Failure of continuous aspiration of subglottic secretions has been associated with significant increase in the incidence of VAP (Smulders, van der, Weers-Pothoff, & Vandenbroucke-Grauls, 2002). Supine position may facilitate aspiration and increase the risk of development of VAP (Bonten et al, 2004).

A nasogastric or an orogastric tube is placed in many patients receiving mechanical ventilation for enteral feeding and administration of medication or for gastric decompression. The stomach serves as a reservoir for bacteria. The presence of a nasogastric or an orogastric tube interrupts the gastroesophageal sphincter and increases the risk of gastrointestinal aspiration or reflux, leading to providing a route for bacteria to translocate to the oropharynx and colonize the upper airway. Enteral tube feeding is also a risk factor for the development of VAP, mainly because of an increased risk of bacterial colonization and aspiration due to increased gastric pH and gastric volume (Ferrer & Artigas, 2001).

Failure to perform proper hand washing and change gloves between contaminated patients has been associated with an increased incidence of VAP due to cross contamination between patients (Kollef, 2004). In addition, failure to wear personal protective devices when antibiotic resistant bacteria have been identified increases the risk of cross-contamination between patients (Tablan, Anderson, Besser, Bridges & Hajjeh, 2003).

3. Diagnostic Methods

There is no gold standard for the diagnosis of VAP. The current diagnostic methods of VAP include clinical diagnostic criteria, chest radiography, clinical pulmonary infection score, quantitative cultures of endotracheal aspirates (EA), and quantitative cultures with bronchoscopy with protected specimen brush (Br-PSB) or with bronchoalveolar lavage (Br-BAL) (De Rosa & Craven, 2003).

Clinical diagnostic criteria of VAP are based on symptoms including fever, leukocytosis, cough, and purulent tracheal secretion. Moreover, a positive microbiological culture result of tracheal secretions and the appearance of new or persistent chest radiographic infiltrate are suggestive for VAP. These methods are commonly used for diagnosis of VAP. It can be diagnosed with high sensitivity, but these methods lack specificity. Therefore, use of these methods may lead to over diagnosis of VAP and unnecessary antibiotic treatment

(De Rosa & Craven, 2003).

Using the Clinical Pulmonary Infection Score (CPIS) can improve the reliability of a clinical diagnosis of VAP. The CPIS may assist health care providers to identify patients with a low likelihood of VAP or may serve as a tool for following clinical response to antibiotic therapy. The CPIS varies from 0 to 12 points. Scores higher than six correlate well with results from bronchoscopic diagnostic measures for VAP such as Br-PSB or Br-BAL and scores of six or lower suggest a low probability of pneumonia(De Rosa & Craven, 2003).

Quantitative cultures of EA for the diagnosis of VAP are easy to perform and results have compared well with quantitative cultures of Br-PSB or with Br-BAL. There are no significant differences reported in number of hospital days, duration of mechanical ventilation, morbidity, or mortality using quantitative cultures of EA as the diagnostic method compared with use of quantitative cultures of Br-PSB or Br-BAL (De Rosa & Craven, 2003).

VAP can be highly suspected when the count of microorganisms in uncontaminated distal bronchial secretion exceeds a certain threshold value. The Br-BAL performed in a distal bronchus in wedge-position is a suitable technique to diagnose VAP and a count of at least 104 CFU/ml is considered as significant. The use of Br-PSB also provides reliable sampling. Using a catheter closed by a soluble plug, the brush is preserved from contamination with secretions of upper airway. After bronchoscopic insertion of the device, the soluble plug is expelled and the sampling catheter is advanced into airway. A growth of at least 103 CFU/ml is indicative of VAP. The threshold values for diagnosing VAP by means of Br-BAL and Br-PSB reflect a bacterial concentration of 105 to 106 microorganisms per 1 ml bronchial secretion. In a meta-analysis, the sensitivity of Br-BAL and Br-PSB was 86% to100% and up to 91% respectively and the specificity of Br-BAL and Br-PSB was 100% and 95% respectively (Unertl & Heininger, 2004).

Mayhall (2001) stated that the diagnostic methods of choice for VAP are quantitative cultures and microscopic examination of lower respiratory tract secretions. These methods provide the most accurate diagnosis of VAP and identification of the causative microorganisms, can predict the onset of VAP, and provide the identity and susceptibility of the causative microorganisms at the time clinical manifestations of VAP appear.

According to the recommendations by the American College of Chest Physicians (2000), VAP should be suspected in mechanically ventilated patients if two or more of the following clinical features are present: temperature higher than 38 ˚C or lower than 36 ˚C; leukopenia or leukocytosis; purulent tracheal secretions; and decreased partial pressure of oxygen in arterial blood. In the absence of these clinical features, no further investigations are required and observation will be sufficient. If two or more of the clinical features are abnormal, a chest radiograph should be evaluated. If the radiograph shows alveolar infiltrates or an air bronchogram sign or the findings have worsened, the panel experts recommend two options: (1) involving quantitative testing or (2) empirical treatment and non-quantitative testing.

4. Preventive Strategies

1) Preventive strategies of bacterial colonization

Effective hand washing and the use of protective gloves and gowns

Hand washing is widely recognized as an important measure to prevent nosocomial infections. Strict hand washing for 10 seconds should be performed before and after all contact with patient. In addition, gloves should be used when contact with oral or endotracheal secretions is possible. Proper hand washing and use of gloves are easy and cost effective measures that can minimize cross contamination of bacteria between patients. Although the use of protective gown is not recommended for the routine prevention of VAP, its use appears to be most effective when specific antibiotic resistant pathogens have been isolated and identified (Tablan et al, 2003).

Oral care

Oral care has been shown to be an important preventive measure against VAP by reducing dental plaque accumulation and oropharyngeal colonization and not merely a comfort measure in ICU patients. An abundance of research studies support the evidence that the most easy and effective preventative nursing strategies to reduce oropharyngeal colonization and dental plaque accumulation are tooth brushing and application of the 0.12% chlorhexidine oral rinse.

According to Grap and colleagues (2003), a toothbrush is the best tool for oral care thus oral care with toothbrushes may cause better outcomes than that with other tools such as foam swabs or toothettes in the ability to remove dental plaque. To achieve ideal oral health, tooth brushing for at least two minutes twice daily is recommended by the American Dental Association (2008). Tooth brushing with a child-size brush is superior to form swabs in removing dental plaque and bacteria in nurse administered oral care (Pearson & Hutton, 2002). An interventional study by Mori et al (2006) showed that oral care administered by nursing staff via a defined oral care protocol with a toothbrush and non-prescriptive toothpaste enhanced more ability to remove dental plaque and reduced the incidence of VAP significantly in ICU patients compared with non oral care group.

Several investigators have reported significant reduced dental plaque accumulation and oropharyngeal colonization with 15 ml of 0.12% chlorhexidine oral rinse twice daily for 30 seconds. A study by Grap et al (2004) explained that single application of 0.12% chlorhexidine is an easy and relatively inexpensive preventative strategy with minimal side effects for prevention of VAP by reducing oropharyngeal colonization and dental plaque accumulation. The researchers also suggested that use of 0.12% chlorhexidine oral rinse in the early post-intubation period might delay or reduce the development of VAP. In this study, 15ml of 0.12% chlorhexidine was administered twice daily.

Stress ulcer prophylaxis

Patients receiving mechanical ventilation are at high risk for upper gastrointestinal bleeding from stress ulcers and thus they are given stress ulcer prophylaxis such as H_2 antagonist and antacids. By decreasing gastric pH and increasing gastric volume, bacterial colonization of the stomach and aspiration can be enhanced, favoring the development of VAP.

The administration of sucralfate has been found to prevent bleeding from stress ulcer without lowering gastric pH or increasing gastric volume. However, double-blind, randomized trials have failed to confirm the effects of using sucralfate for prevention of VAP (Bonten et al, 2004). In the study conducted in pediatric intensive care units, incidence rates of VAP did not differ between the patients receiving ranitidine, omeprazole, or sucralfate for stress ulcer prophylaxis (Yildizdas, Yapicioglu, & Yilmaz, 2002).

The summarized results of eight trials comparing sucralfate with ranitidine for stress ulcer prophylaxis showed a relative risk reduction for VAP of 0.21(95% CI, 0.05-0.38). Thus, although the use of sucralfate may offer some benefits of reducing the risk of VAP, these benefits may be more than offset by increased risk of gastrointestinal bleeding (Bonten et al, 2004).

Routine maintenance of ventilator circuits

Colonization of the ventilator circuit can play a role in the development of VAP. However, several clinical studies found that no benefit from routinely changing ventilator circuit. The center for Disease Control and Prevention does not recommend changing the ventilator circuit more than once every 48hours (CDC, 2005). Nevertheless, ventilator circuit occasionally requires replacement when visibly soiled or mechanical malfunction (Tablan et al, 2004). Ventilator circuit should also be monitored regularly so that accumulated condensate in the tubing can be removed. Condensate collecting in the ventilator circuit can become contaminated from patient secretions or by opening the circuit. Vigilance is needed to prevent inadvertently flushing the condensate into the lower airway during patient transport (Branson, 2005).

There is insufficient evidence to conclude that the incidence rate of VAP differs in patients ventilated with heated humidifiers compared to heat and moisture exchangers. In a prospective, randomized trial of 369 patients in two French university hospitals requiring mechanical ventilation for more than 48hours, no differences in the incidence of VAP or duration of mechanical ventilation were found between patients with heated humidifier and patients with heat and moisture exchangers (Lacherade et al, 2005). Use of passive humidifier with or without filtering capacity has been found to decrease bacterial colonization of the ventilator circuit, but it has not been found to reduce the development of VAP. Thus, there is no benefit to changing passive humidifiers more frequently than every 48 hours (Hess et al, 2003).

Type of suction catheter

There are two types of suction catheter systems available: the open, single-use system and the closed, multiuse system. No difference has been reported in the incidence of VAP with open versus closed suction systems. However, the main advantages attributed to the closed, multiuse system are lower costs and decreased environmental cross contamination. Daily changes of in-line suction catheters are not necessary, which is another advantage of using closed, multiuse system, especially for patients but the suction catheter should be rinsed free of secretions away from the patient (Zeitoun, De Barros, & Diccini, 2003).

A recent study by Jung et al (2008) demonstrated that the closed, multiuse system had the similar incidence of MRSA colonization and VAP compared with open, single use system when the suction catheter was changed every 48hours. The costs per patient per day for suctioning were $28.27 for the open, single use system and $ 23.76 for the closed, multiuse system.

Prophylactic systemic antibiotic therapy

The role of prophylactic systemic antibiotic therapy in the development of VAP is unclear. Because of its lack of efficacy and the subsequent emergence of antibiotic-resistant infections, the routine use of systemic antibiotics for the prevention of VAP is not recommended.

Postural changes

Patients who are confined to bed have an increased frequency of pulmonary and non-pulmonary complications. Routine turning of patients a minimum of every two hours can increase pulmonary drainage and decrease the risk for the development of VAP. Use of beds capable of continuous lateral rotation can reduce the incidence of VAP but do not decrease mortality and duration of mechanical ventilation (Kirschenbaum, Azzi, Sfier, Tietjen, & Astiz, 2002). Because of the added expense and lack of demonstrated effectiveness, these special beds are not recommended for routine use in the prevention of VAP. However, the use of specialty beds may be cost effective and therapeutic for patients with poor oxygenation or impaired wound healing (Augustyn, 2007).

Saline lavage of endotracheal tube

Saline lavage of endotracheal tube before suctioning can cause dislodge bacteria from the endotracheal tube into the lower airway, increasing the risk for the development of VAP (Moore, 2003). Saline lavage has been used as a means to liquefy secretions and prevent plugs of mucus in endotracheal tube. However, the study showed that saline instillation did not help to thin secretions; rather ;t reduced the amount of oxygen that reached the lungs and increased blood pressure, heart rate, intracranial pressure, and the risk for the development of VAP (Akgul & Akyolu, 2002). Maintaining adequate hydration, ensuring proper humidification of the ventilator circuit, and using nebulizer or mucolytic agents can decrease the viscosity of secretions and eliminate the need for saline lavage (Akgul & Akyolu, 2002; Moore, 2003).

2) Preventive nursing strategies of aspiration of contaminated secretions

Intubation

The best and most obvious way to prevent VAP in ICU patients is to avoid unnecessary intubation and implement non-invasive ventilation whenever possible. Non-invasive positive pressure ventilation (NPPV) provides ventilator support without the need for intubation and for earlier removal of endotracheal tube to reduce complications related to prolonged intubation. A recent Cochrane review reported significant benefits of using NPPV including decreased mortality, lower incidence rates of VAP, decreased length of ICU and hospital stays, and decreased duration of ventilator support (Burns, 2006). The impact of NPPV is greater in patients with chronic obstructive pulmonary disease exacerbations or congestive heart failure than for patient with VAP. In addition, recent data indicate that NPPV may not be a good strategy to avoid reintubation after initial extubation (Esteban et al, 2004).

Prolonged nasotracheal intubation (for more than 48 hours) should be avoided because it clearly is a risk of nosocomial sinusitis, leading to the development of VAP. Nosocomial sinusitis may predispose the patient to pneumonia through aspiration of infected secretions from the nasal sinuses. Therefore, the preferred route of intubation is the oropharynx (Kollef, 2004).

When an endotracheal tube is necessary, unplanned extubation and reintubation should be avoided because reintubation is significantly associated with the development of VAP. In addition, strategies to reduce the duration of mechanical ventilation should be implemented to decrease the risk for development of VAP. Several studies have identified the duration of mechanical ventilation as an important risk factor for the development of VAP. The most effective sample of such strategies is use of protocols to improve methods of sedation administration and to accelerate weaning process.

Studies have shown that daily assessment and documentation of patient readiness to wean from mechanical ventilation and daily interruption of sedative infusions (sedation vacations) leads to decreased duration of mechanical ventilation and length of ICU stay (Schweickert, Gehlbach, Pohlman, Hall, & Kress, 2004; Dries, McGonigal, Malian, Bor, & Sullivan, 2004). When a sedation vacation with spontaneous breathing trial is attempted, patients should be closely observed throughout this procedure and steps should be taken to prevent self extubation.

Semi-recumbent positioning

Patients receiving mechanical ventilation should be placed in a semi-recumbent position with the head of the bed elevated 30to 45 degree to reduce reflux and aspiration of bacteria from the stomach into the airways and improve spontaneous ventilation. A randomized trial demonstrated a 3-fold reduction in the incidence of VAP in patients who were treated while in a semi-recumbent position, compared with patients who were treated while supine position (Draculovic et al, 1999). The advantage was greatest for patients receiving enteral feeding.

Keeping patients in a semi-recumbent position with the head of the bed elevated 30° to 45° can be difficult to achieve in practice. In a multicenter study, the target semi-recumbent position of 45° was not achieved in 85% of the study time in the intervention group patient and only maximum backrest elevation of 28° was achieved, which was not associated with a decreased incidence of VAP (van Nieuwenhoven et al, 2006). This is similar to findings in other studies, in which the semi-recumbent position was reached for only < 30% of patients receiving mechanical; ventilation, despite a comprehensive program combining education of nurses and physicians and the systematic addition of a standardized order for placing patients in a semi-recumbent position with the head of the bed elevated 45° (Helman, Sherner, & Fitzpatrick, 2003).

William, Chan, and Kelly (2008) introduced a simple, easy to view, and easy to interpret angle indicator whether the head of the bed was properly elevated. Using the new angle indicator, the average of bed angle was 30.9° ± 7.5° ($p< .005$) and compliance with proper head of bed elevation improved from 23% to 72%.

Continuous aspiration of subglottic secretions

The oropharyx is the most important source for microorganism and aspiration of oropharyngeal contents that are contaminated with bacteria colonization plays important role in the pathogenesis of VAP. Studies have shown that continuous aspiration of subglottic secretions is associated with significant reduction in the incidence of VAP.

In a recent meta-analysis, continuous aspiration of subglottic secretions reduced the incidence of VAP by half, shortened the length of ICU stay by three days, and delayed the onset of VAP by six days. In addition, continuous subglottic aspiration was cost effective, saving $4,992/case of VAP prevented or $1,872/patient (Dezfulian et al, 2005). The American Thoracic Society (2005) recommends continuous aspiration of subglottic secretions through the use of a specially designed endotracheal tube and the Centers for Disease Control and Prevention (2005) states that if feasible, use of endotracheal tube with a dorsal lumen to allow drainage (by continuous or frequent intermittent suctioning) of tracheal secretions that accumulate in the patient's subglottic area.

Endotracheal tube cuff pressure

Proper endotracheal tube cuff pressure (at least 20 cmH_2O but no greater than 30 cm H_2O) should be maintained and minimal leak technique is discouraged to prevent oral secretions from migrating into the lungs (Lorente, Blot, & Rello, 2007). In the review article, Ferrer and Artigas (2001) stated that stagnant contaminated oropharyngeal secretions above the endotracheal cuff can easily gain access to the lower airways when endotracheal cuff pressure decreases spontaneously or there is a temporal deflation of the endotracheal cuff. However, the Center for Disease Control and Prevention does not have recommendations for endotracheal cuff pressure in the guidelines (CDC, 2005).

Use of enteral tube feeding

Enteral tube feeding is often needed to prevent the development of a catabolic state in patients requiring long tern mechanical ventilation and increases the risk of aspiration and VAP. Preventive steps of VAP include monitoring patients' tolerance for gastric feedings, verifying the correct position of the enteral tube, elevating patients' head for at least 30 degrees during feedings and after feedings for 1 hour to minimize the risk of reflux and pulmonary aspiration. The rate and volume of enteral tube feeding should be also monitored and adjusted to avoid gastric distension (Pruitt & Jacobs, 2006).

3) Staff education

On top of the VAP preventive measures as discussed above, education to health care staff also essential in reducing the incidence of VAP. Studies consistently provide evidence that staff education programs are effective measures to prevent the development of VAP.

A recent study conducted by Babcock and colleagues (2004) found that the incidence rate of VAP in a hospital was significantly reduced after the respiratory care practitioners and intensive care nurses worked together for a staff development program, which VAP was discussed, including its risk factors and prevention. A recent cohort study conducted by Baxter and coworkers (2005) found that introducing prevention protocols and staff education program was effective in reducing the incidence of VAP by 50%. Education is fundamental for the challenging behavioral changes. Together with the knowledge base and motivation, awareness of the preventive measures and nursing practiced could be enhanced.

5. Role of nurses for the prevention of VAP

Although the prevention of VAP is a multidisciplinary issue, the role of nurses in the prevention of VAP should not be underestimated. Also, nurses can contribute a lot in the prevention of VAP. Most of the discussed preventive measures of VAP are largely related to the daily nursing activities at the bedside such as oral care, correct positioning, regular changes of suction equipments, proper hand washing and etc. Neglecting any of these preventive measures could put the patient at risk for the development of VAP and nurseshave the ability to increase their chance of survival merely by carrying out what should be considered as basic nursing care (Ruffell & Adamcova, 2008).

In addition, nurses should be aware of other aspects in the causes of VAP and collaborate with other health care providers so that they can have appropriate input in multidisciplinary team discussions and make a decision on the best treatment plan for patients. When discussing best nursing practice, Kleinpell (2006) stated that if nurses kept abreast of current literature on preventive nursing strategies, they would facilitate optimal delivery of patient care. Although this discussion was based around advances in severe sepsis, it can be adopted to any healthcare environments (Ruffell & Adamcova, 2008).

Unfortunately, according to Babcock and colleagues (2004), a large discrepancy exists in many ICU settings between published guidelines and actual practice. Every one of nurses should be responsible for promoting adherence to guidelines that have been so meticulously researched to provide optimum care for the critically ill patients who depend on our knowledge and expertise.

III. Conclusion

VAP still remains a frequent ICU acquired infection responsible for a significant increase in morbidity, mortality, and health care costs. The prevention of VAP is a key factor in the current critical care nursing practice. Understanding VAP and its risk factors can promote the nurse' s awareness of the problem and help nurses more prepared in active guideline implementation in order to prevent VAP.

There are a lot of preventive measures evaluated lately. Based on the comprehensive reviews of current guidelines and findings from the researches, recommended evidence based nursing practice protocols are as follows;

1) Hand washing
2) Implementation of routine oral care with systematic protocol.
3) Use of semi-recumbent position aiming to have the patient at least 30 to 45 degrees head up if not contraindicated.
4) Use of subglottic secretion drainage in patients likely to be ventilated for more than 48 hours.
5) No scheduled ventilator circuit change, but change if the circuits become soiled.
6) Use of the orotracheal route of intubation when intubation is necessary.
7) Daily assessment of all mechanically ventilated patients for weaning and extubation.
8) Minimization of use of narcotics and sedative agents
9) Staff education

Such preventive measures should be widely applied to daily nursing care to decrease the incidence of VAP. In addition, each critical nurse should play a functional role in reducing and preventing the development of VAP, subsequently improving the patients' outcomes and consequently reducing health care costs.

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