Ventilator-Associated Pneumonia and Role of Nurses in Its Prevention

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ABSTRACT

Ventilator-associated pneumonia (VAP) is one of the most frequent nosocomial infections among ventilated patients in ICUs, associated with an increase in days of ICU stay, morbidity, and mortality. Its prevention is a significant concern in every hospital. Most of the interventions and prevention strategies are part of routine nursing care. Nurses have different vital roles such as care provider, manager, educator, coordinator, and evaluator in preventing VAP. Lack of knowledge of infection prevention and proper nursing care among nurses may become a barrier in adhering to evidence-based guidelines for preventing ventilator-associated pneumonia. This study will help nurses to know about VAP and its prevention in detail so that they can apply the knowledge in clinical practice. Understanding pathophysiology of VAP, its risk factors, and care bundle is vital for the proper prevention and treatment of VAP. There must be specific protocols, strategies and active surveillance in every ICU regarding the care bundle.

Keywords: *Mechanical ventilation; Nosocomial infections; Nurses role; Ventilator-associated pneumonia; VAP Prevention.*

INTRODUCTION

Ventilator-associated pneumonia (VAP), a subset of nosocomial pneumonia, is the common infectious complication among intensive care units (ICUs) patients who have been treated with mechanical ventilation for 48 hours or longer, with no prior signs or symptoms of lower respiratory infection before being intubated and treated with mechanical ventilation. Thus, resulting in the substantial increase in hospital costs and length of stay (LOS) for the patients.[1-4] Furthermore, VAP is also associated with delayed extubation, prolonged stay in the ICU and hospital, increased mortality and morbidity, and increased use of healthcare resources.[5]

Prevention of VAP is much more cost-effective than treatment which is an essential objective of health care delivery within ICUs.[6] Care bundle protocols are different and controversial in different hospitals, which will be discussed further in detail in this paper. In the rest of this paper, the background of VAP will be discussed followed by diagnosis, pathophysiology, risk factors, preventive measures and nurses' role in VAP prevention. This study will help nurses to know about VAP in detail so that they can apply the knowledge in clinical practice for the prevention of VAP.

SEARCH STRATEGIES

This review article "Ventilator-Associated Pneumonia And Role Of Nurses In Its Prevention" is based on a summary of the evidence from the literature and the guidelines of the Centers for Disease Control and Prevention (CDCP), American Association of Critical-Care Nurses as well as original researches and review articles published in different medical journals. Publications in English from 2000 to 2017 were searched in PubMed, Google Scholar, Science Direct, Medline, Wiley Online Library and Bing on the following

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major headings: ''ventilator-associated pneumonia'', "VAP Prevention", "nurses role in VAP Prevention", "Nosocomial infection" and "Mechanical ventilation". References were selected on the basis of the content regarding nurses' role in the prevention of VAP.

BACKGROUND

VAP is responsible for 25–42% of all infections that occur within ICUs and is the second most common healthcare-associated infections.[7] Intubated patients are at risk of developing VAP and the incidence increases with the duration of ventilator support.[8] The incidence of VAP is 22.8% in patients receiving mechanical ventilation. This is widespread in nosocomial pneumonia as 86% patients receive ventilatory support.[4] Nevertheless, variation is found depending on criteria used for diagnosis, the type of ICU, hospital resources or study population.[8] The estimated rate of VAP is 1.4 to 5.8 events per 1000 intubated patients, with a downward trend since 2000.[9,10] Downward trend is more prominent in the United States, probably due to the implementation of ventilator bundles.[11] It has been reported that the VAP mortality rate is between "10%" to "40%".[12] LOS in the intensive care unit is increased by 5 to 7 days and hospital length of stay 2-to to 3-fold in patients with VAP. Hospital costs associated with VAP were estimated 40,000$ for each case of VAP.[2,13] Development of VAP also increases ventilator days.[14-16] VAP is a significant concern for ventilated patients in the intensive care units (ICUs), so a priority must be given while caring critically ill patients.[7,15,17,18]

PATHOPHYSIOLOGY

To understand and follow VAP prevention strategies, nurses should be aware of the pathophysiology of VAP. The VAP can be divided into two types according to the time elapsed from the beginning of the mechanical ventilation (MV) to the onset of pneumonia: early onset and late onset.[19] Early- onset occurs 48 to 96 hours subsequent to intubation and is associated with antibiotic-susceptible organisms such as Staphylococcus aureus, Streptococcus pneumonia, Hemophilus influenza, Proteus species, Serratia marcescens, Klebsiella pneumonia and Escherichia coli. Late-onset usually occurs after 96 hours of intubation and is associated with antibiotic-resistant organisms such as Pseudomonas aeruginosin, Methicillin-resistant Staphylococcus aureus, Acinetobacter species and Enterobacter species.[2]

According to the CDCP, a patient with VAP may have increased body temperature, leukopenia, new onset of purulent sputum, apnea, tachypnea, nasal flaring with retraction of the chest wall or grunting, wheezing, rales, rhonchi, and cough.[9] The pathophysiology of VAP involves colonization of the respiratory and digestive tracts and microaspiration of secretions from the upper and lower parts of the airway. VAP develops when bacteria colonize the pulmonary parenchyma or lower respiratory tract of a patient receiving mechanical ventilation. Due to aspiration of secretions or the use of contaminated equipment, organisms may spread through the oropharynx, sinus cavities, nares, dental plaque, gastrointestinal tract, patient-to-patient contact and ventilator circuit leading to bacterial colonization of the lungs.[2,20,21] Inhaling of colonized bacteria from the sources described above can result in an active host response, resulting VAP in the patient.

The presence of an endotracheal tube provides a direct route for colonized bacteria to enter the lower respiratory tract. Upper airway and oral secretions pool above the cuff of the tube. The pool lines along the tube forming a biofilm and contains a large amount of bacteria that can spread to the lungs by ventilator-induced breaths, which may be dislodged by instilling of saline into the tube, suctioning, coughing, or repositioning of the tube.[21,22] Endotracheal tubes cause an unusual interruption between the upper airway and the trachea, providing bacteria a direct route into the lower airway, bypassing the upper airway.[21] Due to the presence of bacteria in lower airway, the body's ability to filter and humidify air will decrease.[22] Because of the presence of such tube, the cough reflex is frequently decreased or eliminated and mucociliary clearance can be impaired. Furthermore, an endotracheal tube provides a place for bacteria to bind in the trachea leading increment in the production and secretion of mucus.[23] This leads to impairment of natural host defense mechanisms increasing the likelihood of bacterial colonization and subsequent aspiration of the colonized organisms. Micro or macro aspirations of oropharyngeal or gastric fluids are an essential step in the development of VAP.[14]

As stomach may serve as a reservoir for bacteria,aspiration of gastric contents can be another potential cause of VAP. Patients receiving mechanical ventilation mostly have a nasogastric or an orogastric tube for enteral feedings, administration of medications or gastric decompression. The presence of a nasogastric or an orogastric tube interrupts the gastro-esophageal sphincter leading to increased gastrointestinal reflux, provides a route for bacteria to translocate to the oropharynx and colonizes the upper airway. Enteral feedings increase both gastric pH and gastric volume, increasing the risk of both bacterial colonization and aspiration, and subsequently may cause infection.[24]

DIAGNOSIS

Accurate diagnosis and treatment of VAP are challenging as well as controversial since every intubated patient who is receiving ventilatory support is at risk.[25] The

diagnosis is done on the basis of radiographic findings, clinical findings, and results of microbiological tests of sputum such as culture and sensitivity, or invasive testing such as bronchoscopy.[26] Findings on chest radiographs are not reproducible and should not be used alone for the diagnosis of VAP, as pulmonary infiltrates visualized on chest radiographs of patients receiving mechanical ventilation may be because of atelectasis, aspiration, pulmonary embolism, pulmonary edema, alveolar hemorrhage, pulmonary infarction, and acute respiratory distress syndrome.[2] Five of the predominant signs of VAP are significant heavy growth reported in the culture of tracheal aspirates, body temperature more than 38^0 C or less than 35^0 C, development of progressive new infiltrate on X-ray, leukocytosis WBC more than 10x 109/L or leucopenia WBC less than 3x109 /L and ten leucocytes per HPF in gram stain of tracheal aspirates. The presence of any two of the above signs can be considered as diagnostic of VAP.

RISK FACTORS

Every intubated patient receiving ventilatory support is at risk for VAP. There are different types of risk factors, which can be divided into three categories: host related, device related, and personnel related.

Host-related risk factors include preexisting conditions such as immunosuppression, chronic obstructive lung disease, and acute respiratory distress syndrome. Other host-related factors include patients' body positioning, advanced age, the level of consciousness, the number of intubations, blood transfusion and medications including sedative agents and antibiotics.[2,27] Decreased in the level of consciousness results in the loss of a cough and gag reflexes and increased the risk of aspiration and VAP.[28]

Device-related risk factors include the endotracheal tube, the ventilator circuit, and the presence of a nasogastric or an orogastric tube. When a patient is in the supine position, pulmonary aspiration increases and secretions pool above the cuff of an endotracheal tube. In low cuff pressure, such pools may lead to microaspiration or leakage of bacteria around the cuff into the trachea. In addition, nasogastric and orogastric tubes also disrupt the gastro-esophageal sphincter leading to reflux and an increased risk for VAP.[2,29]

Personnel-related risk factors include improper hand washing , failure to change gloves between contacts with patients and not wearing personal protective equipment when antibiotic-resistant bacteria have been identified. If healthcare staffs do not use proper hand-washing techniques during interventions such as suctioning or manipulation of the ventilator circuit of an intubated patient, the likelihood of cross-contamination between patients will increase the risk of VAP. Failure to wash hands and change gloves between contaminated patients has also been associated with an increased incidence of VAP.[30] Not only this but also failure to wear proper personal protective equipment when antibiotic-resistant organisms have been identified increased the risk of cross-contamination between patients.[25]

MANAGEMENT

The management of VAP is important as well as challenging job for healthcare team in the ICU. It depends on the interaction between the infective agent, the host response, and the antimicrobial drug used. The pulmonary infection may occur when the pathogen spreads to the lungs. However, the vigorous approach has evolved in VAP management, updating local epidemiology, evaluating VAP, diagnostic tools every day, and assessing host response using clinical and biochemical parameters. The two important steps recommended for the treatment of a patient with VAP are etiologic diagnostic testing and the immediate initiation of antibiotics.[31] Antibiotic Management: As the initial management of VAP, appropriate antibiotics should be selected for each patient based on the individual risk factors for multidrug-resistant pathogens and time of onset of disease. Furthermore, antimicrobial spectrum of activity, effective doses of antibiotics, pharmacokinetic profiles and adverse effects of individual antimicrobials should be carefully reviewed.[32] For the patients with early-onset VAP and no risk factors for multidrug-resistant (MDR) pathogens, currently recommended initial empiric antibiotics include one of the following options: Ceftriaxone, Fluoroquinolones, Ampicillin-sulbactam and Ertapenem. For patients with VAP and risk factors for MDR pathogens or for patients with late-onset VAP, initial antibiotic therapy may consist of one of the following options: Antipseudomonal cephalosporins (eg, cefepime, ceftazidime), Antipseudomonal carbapenems (imipenem or meropenem), Beta-lactam/beta-lactamase inhibitors (piperacillin-tazobactam) with an antipseudomonal fluoroquinolone (ciprofloxacin) or aminoglycoside plus linezolid or vancomycin (if risk factors for methicillin-resistant Staphylococcus aureus are present) and Telavancin is indicated for HABP/VAP caused by susceptible isolates of Staphylococcus aureus, including methicillin-susceptible and resistant isolates, when alternative treatments are not suitable.[33]

PREVENTION

A care bundle is a set of key interventions derived from evidence-based guidelines that are expected to improve patients' health outcomes by facilitating, promoting changes in patient care and encouraging guideline compliance.[34-36] It is based on pathophysiology and

etiology of pneumonia, mode of mechanical ventilation and duration of ventilation, which offers prompt and consistent preventive strategies.[4] Implementing care bundles in clinical practice for mechanically ventilated patients admitted to ICUs [34] and active surveillance [28] are associated with a reduced risk of VAP.

For prevention and reduction of VAP, appropriate multidisciplinary approaches and interventions should be applied in ICUs which should begin at the time of intubation, or if possible prior to intubation and should be continued until extubation.[2,37] It should focus on avoiding microaspiration of subglottic secretions, preventing oropharyngeal colonization, and preventing contamination of ventilator equipment.[38] Many strategies and guidelines have been developed and proposed. However, in clinical practice, the implementations of evidence-based guidelines for VAP are variable and are adversely affected by the lack of training, lack of an adequate infection control program, and lack of knowledge among healthcare providers of such guidelines.

Protocols for non-invasive mechanical ventilation (NIMV) in acute exacerbations of chronic obstructive pulmonary disease (COPD), weaning and sedation promoting lower infusion doses or its daily interruption should be available in every ICU.[19,39,40] Strategies should be developed to incorporate evidence-based practices into the daily care provided to patients receiving mechanical ventilation.[41] Daily assessments of readiness to wean and use of weaning protocols are very essential because the risk of VAP development increases with duration of mechanical ventilation.[40,42,43] Proper implementation of the VAP bundle will decrease the ventilator days, LOS, and ultimately the VAP rates.[15]

Nurses are the first line of defense in preventing bacterial colonization of the oropharynx and the gastrointestinal tract. However, multidisciplinary persons like nurses, physicians, respiratory therapists and clinical pharmacists should be a part of VAP practices for high effectiveness. Critical care unit should ensure the availability of practice documents such as a policy, procedure or standards of care.[2,14] Hand washing is the cost-effective measures to minimize nosocomial infection like VAP, so, the hand should be washed properly for 10 seconds prior and subsequent to all contact with patients.[25,44] Similarly, wearing gloves is also an important action in the prevention of VAP.[41] Bacterial colonization of the oropharynx and the gastrointestinal tract can be prevented by following the certain strategies such as proper hand washing, using oral decontamination , using stress ulcer prophylaxis, avoiding saline lavage with suctioning, turning patients at least every 2 hours and changing ventilator circuit when it is contaminated. Aspiration of oropharyngeal secretions and gastric contents containing bacteria are considered an essential step in the pathogenesis of VAP.[26] Aspiration can be prevented by positioning the head of the bed at an angle of 30° to 45° unless medically contraindicated, minimizing the use of narcotic and sedative agents , thoroughly suctioning the oropharynx, using endotracheal tubes that comprise continuous subglottic suction ports, monitoring gastric residual volumes for overdistention and maintaining adequate endotracheal tube.[2,14,44] Head elevation prevents reflux and aspiration of bacteria from the stomach into the airways.[15,37,40,45,46,47] Routine turning of patients at least every two hours can also increase pulmonary drainage and decrease the risk of VAP.[48]

Use of noninvasive ventilation whenever possible and the minimization of the duration of ventilation can also aid in preventing VAP.[40,42] Re-intubation has also been considered a risk of VAP due to an increased risk of aspiration of pathogens from the oropharynx of patients with subglottic dysfunction subsequent to several days of endotracheal intubation. Re-intubation should be avoided as far as possible and planned extubations should be improved with the design of protocols to enhance the quality of weaning, and planned tracheostomy for long-term ventilation.[49] Preferable use of orotracheal instead of nasotracheal intubation [42] and prevention of airway contamination and maintenance of aseptic technique subsequent to intubation is essential while performing endotracheal suctioning. Proper oral hygiene decreases the risk of translocation and colonization of bacteria.[47] Oral decontamination by both mechanical and pharmacological interventions decreases the likelihood of colonization of the oropharynx. Mechanical interventions such as tooth brushing and rinsing of the oral cavity or thoroughly suctioning secretions from the mouth to remove dental plaque and pharmacological interventions such as the use of chlorhexidine mouthwash, gentamicin, colistin, and vancomycin decrease the incidence of VAP by decreasing colonization.[2,37,46,50] Appropriate antibiotic should be used for treating the patient in ICUs because extensive use of antibiotics has resulted in the emergence and rapid dissemination of Multidrug-resistant (MDR), Methicillin-Resistant Staphylococcus aureus (MRSA), Extended-Spectrum □-Lactamase (ESBL) and Metallo-□-Lactamase (MBL) bacteria. Thus, their detection is crucial for the optimal treatment of patients and to control the spread of resistance.[51] Saline lavage has long been considered a means to liquefy secretions and prevent plugs of mucus in endotracheal tubes. However, saline installation does not thin secretions, it reduces the amount of oxygen that reaches the lungs and increases blood pressure, heart rate, intracranial pressure and dislodges bacteria from the endotracheal tube into the lower airways increasing

the risk of VAP. Maintaining adequate hydration, ensuring proper humidification of the ventilator circuit and using the nebulizer or mucolytic agents can help decrease the viscosity of secretions and eliminate the need for saline lavage.[2] The CDCP does not recommend changing the ventilator circuit more than once every 48 hours but only when visibly soiled.[25] As the prolonged endotracheal intubation and subsequent aspiration of secretions around the endotracheal tube cuff are the major but not easily preventable determinants of VAP development,[52] daily interruptions of sedation and daily assessment of readiness for extubation are other integral components of the ventilator bundle, which helps in reducing duration of mechanical ventilation and LOS in the intensive care unit.[11]

The decrease in the use of narcotic and sedative agents prevents aspiration of gastric contents. Monitoring gastric residual volumes and administering agents to increase gastric motility have also been suggested to prevent gastric over distention.[15] Prophylaxis to reduce deep-vein thrombosis (DVT) and peptic ulcer disease (PUD) are the important aspects of the VAP bundle. Patients treated with mechanical ventilation are sedated. So, DVT prophylaxis with administration of antithrombotic medications and antiembolism stockings are used. PUD prophylaxis such as histamine2 blockers increases the pH of gastric contents and protects the airway against acidic contents.[46]

The oropharynx should be suctioned thoroughly to prevent aspiration of the pooled secretions prior to replacing an endotracheal tube.[46] Continuous low suction drainage of oral secretion from above the cuff decreases the chance to seep secretions into the lungs.[41] The pressure within the cuff should be measured and maintained between 20 and 30 cm H2O to prevent aspiration of the secretions.[37] Prevention of aspiration leads to prevention of colonization which decreases the risk of VAP.

Patients should be assessed daily for potential weaning and extubation from mechanical ventilation to decreases the risk of VAP by using methods like T-piece trials, weaning intermittent mandatory ventilation, and pressure-support ventilation as the presence of an endotracheal tube predisposes patients to VAP.[15, 53] Daily assessment of the patient with an interruption in sedation and a spontaneous breathing trial for patient's readiness to be weaned from mechanical ventilation can reduce its duration, preventing VAP.[47] The important VAP prevention bundle components discussed above are summarized in Table 1.

Table 1. Important bundle components for prevention of VAP.

1.	Active surveillance for VAP.[2,14,34,42]
2.	Ventilator weaning protocols.[41,42,43,40]
3.	Proper hand hygiene.[25,44]
4.	Wearing gloves.[38,41]
5.	Use oral decontamination such as Chlorhexidine gluconate antiseptic rinse.[2,37,46, 47,50,]
6.	Appropriate antibiotic use.[51]
7.	Use of stress ulcer prophylaxis.[15,26,41]
8.	Use of deep vein thrombosis prophylaxis.[41]
9.	Sedation interruption and spontaneous breathing trials of a patient's readiness to be weaned from mechanical ventilation.[11,17,47]
10.	Minimized duration of mechanical ventilation.[40,42]
11.	Avoided intubation and re-intubation if possible (Use of noninvasive, BiPAP or other strategies) and improving planned extubations with the design of protocols to improve quality of weaning. [15,19,39,40,42,48,53]
12.	Avoid saline lavage with suctioning.[2]
13.	Thoroughly suction the oropharynx.[46]
14.	Subglottic suctioning prior to deflating the cuff of an endotracheal tube or moving the tube.[26]
15.	Maintenance of endotracheal and tracheostomy cuff pressures between 20 and 30 cmH2O.[37]
16.	Planned tracheostomy for long-term ventilation.[49]
17.	Education of healthcare workers regarding nosocomial infection prevention.[2,14,19]
18.	Turn patients at least every 2 hours. [2,14, 44,48]
19.	Elevation of the head of bed 30°-45°, if not contraindicated.[2,14,15,37,40,44, 45, 46, 47]
20.	Monitor gastric residual volumes for over distention.[15,26]
21.	Change the ventilator circuit when visibly soiled.[25]

Nurse's Role in Prevention of VAP

Preventing infections is the daily work of nurses in every hospital. This applies to the critical unit as well where nurses are the forefront of infection prevention either VAP or other. They create and provide the safe environment, take responsibility for nursing care and play a pivotal role in preventing nosocomial infections.

Nurses lead health care members in practicing prevention strategies to protect the patient from infection. So, lack of knowledge of infection prevention and proper nursing care may become a barrier in adhering to evidence-based guidelines for preventing

ventilator-associated pneumonia. The occurrence of VAP is directly related to the inadequacy of experienced nurses, insufficient knowledge and understanding about the pathophysiology and risk factor regarding development and prevention strategies of VAP.[2,54] This is because ICUs nurses are in constant contact with the patient providing nursing care, performing most of the procedures related to mechanical ventilation and guiding others who are in contact with the patient such as students, health workers, and visitors. Furthermore, they should correlate the knowledge, skill, and responsibility at the time of delivering nursing care to the patient. From the time of patient's admission, nurses should follow the nursing process systematically, which are assessment, planning, implementation, and evaluation. Nurses identify patients who are at a high-risk of infection and also prompt the physician by reporting patients' response and improvement. Nurses should protect patients as well as themselves focusing on infection control by following the universal precautions such as environmental hygiene , hand hygiene, use of personal protective equipment, safe use and disposal of sharps instruments. They should be alert while providing care to the patient with invasive devices such as an endotracheal tube, tracheostomy tube and nasogastric tube to prevent VAP. Breaking the chain of infection prevention anywhere may lead to nosocomial infection in patients. This can be prevented through proper hand washingafter direct or indirect contact with patients, proper disinfection and sterilization techniques, isolation of infected patients, recognition of susceptible host and protection of high-risk patients.

Nurses perform most procedures related to mechanical ventilation, so they should have appropriate knowledge regarding non-invasive positive pressure ventilation, daily weaning trials, sedation holidays, aspiration prevention, subglottic suctioning of endotracheal tubes, ET tube cuff pressure and head of the bed elevation. This knowledge should be applied correctly in practice to reduce the risk of VAP.[43,55] Nurses should keep the records and reports accurately, manage in-service education to the nursing staff regarding infection prevention and proper health education counseling to the visitors.

As a whole, nurses are responsible for the overall care of the patient from admission till discharge. They are one of the members of the health team who spend most of the time caring patient and thus, have a vital role in the prevention of VAP. However, only having the knowledge is not sufficient but also applying it in the right place at the right time by providing overall nursing care as per the need of patient is essential. That is why critical care nurses play the most important role in the prevention of VAP.

WAY FORWARD

VAP is the common infectious complication among ICUs patients who have been treated with mechanical ventilation for 48 hours or longer, contributing to the substantial increase in morbidity, mortality, hospital costs and LOS. Healthcare systems play an important role in preventing VAP by developing strategies and guidelines and implementing it strictly. For the prevention and reduction of VAP rate, the successful multidisciplinary approaches should be applied in ICUs and education should be provided for all healthcare providers focusing on the risk factors and preventive measures of VAP. Most of the interventions and prevention strategies are part of routine nursing care, which they provide by playing different roles such as care provider, manager, educator, coordinator, and evaluator.

Conflict of Interest : None.

REFERENCES:

1. YAZDANI M, SABETIAN G, RA'OFI SH, ROUDGARI A, FEIZI M. A comparative study of teaching clinical guideline for prevention of ventilator-associated pneumonia in two ways: face-to-face and workshop training on the knowledge and practice of nurses in the Intensive Care Unit. J ADV MED EDUC PROF. 2015 Apr;3(2):68. [PubMed]
2. Augustyn B. Ventilator-associated pneumonia risk factors and prevention. Crit Care Nurse. 2007 Aug 1;27(4):32-9. [PubMed | Full text]
3. Wałaszek M, Kosiarska A, Gniadek A, Kołpa M, Wolak Z, Dobroś W, Siadek J. The risk factors for hospital-acquired pneumonia in the Intensive Care Unit. Przegl Epidemiol. 2016;70(1):107. [Full text]
4. Cooper VB, Haut C. Preventing ventilator-associated pneumonia in children: an evidence-based protocol. Critic Care nurse. 2013 Jun 1;33(3):21-9. [PubMed | Full text]
5. El-Khatib MF, Zeineldine S, Ayoub C, Husari A, Bou-Khalil PK. Critical care clinicians' knowledge of evidence-based guidelines for preventing ventilator-associated pneumonia. Am J Crit Care. 2010 May 1;19(3):272-6. [PubMed]
6. Pérez-Granda MJ, Muñoz P, Heras C, Sánchez G, Rello J, Bouza E. Prevention of ventilator-associated pneumonia: can knowledge and clinical practice be simply assessed in a large institution?. Respir Care. 2013 Jul :58(7):1213-9. [PubMed]

7. Ferreira CR, de Souza DF, Cunha TM, Tavares M, Reis SS, Pedroso RS, de Brito Röder DV. The effectiveness of a bundle in the prevention of ventilator-associated pneumonia. The Brazilian Journal of Infectious Diseases. 2016 Jun 30;20(3):267-71. [Full Text]
8. Ranjit S, Bhattarai B. Incidence and risk factors for ventilator-associated pneumonia in Kathmandu University Hospital. KUMJ. 2012 Jun 7;9(1):28-31. [Full text]
9. Centers for Disease Control and Prevention. Ventilator-associated pneumonia (VAP) event. Device Assoc Events. 2012 Jan 6;1-6:13. [Full text]
10. Klompas M. Is a ventilator-associated pneumonia rate of zero really possible?. Current opinion in infectious diseases. 2012 Apr 1;25(2):176-82. [Full text]
11. Arroliga AC, Pollard CL, Wilde CD, Pellizzari SJ, Chebbo A, Song J, Ordner J, Cormier S, Meyer T. Reduction in the incidence of ventilator-associated pneumonia: a multidisciplinary approach. Respir Care. 2012 May 1;57(5):688-96. [PubMed]
12. Jacobi CA, Schulz C, Malfertheiner P. Treating critically ill patients with probiotics: Beneficial or dangerous?. Gut pathogens. 2011 Feb 27;3(1):2. [Full text]
13. Sachetti A, Rech V, Dias AS, Fontana C, Barbosa GD, Schlichting D. Adherence to the items in a bundle for the prevention of ventilator-associated pneumonia. Revista Brasileira de terapia intensiva. 2014 Dec;26(4):355-9. [PubMed | Full text]
14. Ventilator-Associated Pneumonia. Critic Care Nurse. 2008;28:83-85. [PubMed | Full text]
15. Allagher JA. Implementation of ventilator-associated pneumonia clinical guideline (Bundle). The Journal for Nurse Practitioners. 2012 May 31;8(5):377-82. [Full text]
16. Keeley L. Reducing the risk of ventilator acquired pneumonia through head of bed elevation. Nursing in critical care. 2007 Nov 1;12(6):287-94. [Full Text]
17. Vanhaeren S, Duport C, Magneney M, Dumé L, Dumenil AS, Doucet-Populaire F, Decousser JW. Bacterial contamination of glucose test strips: not to be neglected. American journal of infection control. 2011 Sep 30;39(7):611-3. [Full text]
18. Halpern NA, Hale KE, Sepkowitz KA, Pastores SM. A world without ventilator-associated pneumonia: time to abandon surveillance and deconstruct the bundle. Critical care medicine. 2012 Jan 1;40(1):267-70. [Full text]
19. Oliveira J, Zagalo C, Cavaco-Silva P. Prevention of ventilator-associated pneumonia. Revista portuguesa de pneumologia. 2014 Jun 30;20(3):152-61. [Full text]
20. Coffin SE, Klompas M, Classen D, Arias KM, Podgorny K, Anderson DJ, Burstin H, Calfee DP, Dubberke ER, Fraser V, Gerding DN. Strategies to prevent ventilator-associated pneumonia in acute care hospitals. Infection Control & Hospital Epidemiology. 2008 Oct;29(S1):S31-40. [Full text]
21. Kunis KA, Puntillo KA. Ventilator-Associated Pneumonia in the ICU: Its pathophysiology, risk factors, and prevention. The American Journal of Nursing. 2003 Aug 1;103(8):64AA-GG. [Full text]
22. Morehead RS, Pinto SJ. Ventilator-associated pneumonia. Archives of internal medicine. 2000 Jul 10;160(13):1926-36. [Full text]
23. DE ROSA FG, Craven DE. Ventilator-associated pneumonia: current management strategies. Infections in medicine. 2003;20(5):248-59. [Full text]
24. Ferrer R, Artigas A. Clinical review: non-antibiotic strategies for preventing ventilator-associated pneumonia. Critic Care. 2001 Jan 11;6(1):45. [Full text]
25. Tablan OC, Anderson LJ, Besser R, Bridges C, Hajjeh R. Guidelines for preventing healthcare-associated pneumonia, 2003. MMWR. 2004;53(RR-3):1-36. [Full text]
26. Niël-Weise BS, Gastmeier P, Kola A, Vonberg RP, Wille JC, van den Broek PJ. An evidence-based recommendation on bed head elevation for mechanically ventilated patients. Critic Care. 2011 Apr 11;15(2):R111. [Full text]
27. Cason CL, Tyner T, Saunders S, Broome L. Nurses' implementation of guidelines for ventilator-associated pneumonia from the Centers for Disease Control and Prevention. Am J Crit Care. 2007 Jan 1;16(1):28-37. [PubMed]
28. Salloum Zeitoun S, Botura Leite De Barros AL, Diccini S. A prospective, randomized study of ventilator associated pneumonia in patients using a closed vs. open suction system. Journal of clinical nursing. 2003 Jul 1;12(4):484-9. [Full text]
29. Fulbrook, P., & Mooney, S. (2003). Care bundles in critical care: a practical approach to evidence based practice. Nurse Crit Care. 2003 Nov-Dec; 8(6):249-255. [Full Text]
30. Kollef MH. Prevention of hospital-associated pneumonia and ventilator-associated pneumonia. Critical care medicine. 2004 Jun 1;32(6):1396-405. [Full text]
31. Diaz E, Ulldemolins M, Lisboa T, Rello J. Management of ventilator-associated pneumonia. Infectious disease clinics of North America. 2009 Sep 30;23(3):521-33. [Full Text]
32. American Thoracic Society, Infectious Diseases Society of America. Guidelines for the management of adults with hospital-acquired, ventilator-associated, and healthcare-associated pneumonia. Am J Respir Crit Care Med. 2005;171:388-416. [Full text]
33. Amanullah S. Ventilator-Associated Pneumonia Overview of Nosocomial Pneumonias. [Full text]
34. Dale CM, Angus JE, Sinuff T, Rose L. Ethnographic Investigation of Oral Care in the Intensive Care Unit. Am J Crit Care. 2016 May 1;25(3):249-56. [PubMed]
35. Rello J, Afonso E, Lisboa T, Ricart M, Balsera B, Rovira A, Valles J, Diaz E. A care bundle approach for prevention of ventilator associated pneumonia. Clinical Microbiology and Infection. 2013 Apr 1;19(4):363-9. [Full text]
36. Crunden, E., Boyce, C., Woodman, H., & Bray, B. (2005). An evaluation of the impact of the ventilator care bundle. Nurs Crit Care, 10(5), 242-246. [Full text]

37. Peña-López Y, Pujol M, Campins M, González-Antelo A, Rodrigo JÁ, Balcells J, Rello J. Implementing a care bundle approach reduces ventilator-associated pneumonia and delays ventilator-associated tracheobronchitis in children: differences according to endotracheal or tracheostomy devices. International Journal of Infectious Diseases. 2016 Nov 30;52:43-8. [Full text]

38. Labeau S, Vandijck DM, Claes B, Van Aken P, Blot SI, Executive Board of the Flemish Society for Critical Care Nurses. Critical care nurses' knowledge of evidence-based guidelines for preventing ventilator-associated pneumonia: an evaluation questionnaire. Am J Crit Care. 2007 Jul 1;16(4):371-7. [PubMed]

39. Lerma FÁ, García MS, Lorente L, Gordo F, Añón JM, Álvarez J, Palomar M, García R, Arias S, Vázquez-Calatayud M, Jam R. Guidelines for the prevention of ventilator-associated pneumonia and their implementation. The Spanish "Zero-VAP" bundle. Med Intensiva. 2014 May 31;38(4):226-36. [Full Text]

40. Klompas M, Branson R, Eichenwald EC, Greene LR, Howell MD, Lee G, Magill SS, Maragakis LL, Priebe GP, Speck K, Yokoe DS. Strategies to prevent ventilator-associated pneumonia in acute care hospitals: 2014 update. Infect Control Hosp Epidemiol. 2014 Sep;35(S2):S133-54. [Full text]

41. Sedwick MB, Lance-Smith M, Reeder SJ, Nardi J. Using evidence-based practice to prevent ventilator-associated pneumonia. Crit Care Nurse. 2012 Aug 1;32(4):41-51. [PubMed]

42. Rosenthal VD, Rodrigues C, Madani N, Mitrev Z, Ye G, Salomao R, Ulger F, Guanche-Garcell H, Kanj SS, Cuéllar LE, Higuera F. Effectiveness of a multidimensional approach for prevention of ventilator-associated pneumonia in adult intensive care units from 14 developing countries of four continents: findings of the International Nosocomial Infection Control Consortium. Crit Care Med. 2012 Dec 1;40(12):3121-8. [Full text]

43. Keyt H, Faverio P, Restrepo MI. Prevention of ventilator-associated pneumonia in the intensive care unit: a review of the clinically relevant recent advancements. Indian J Med Res. 2014 Jun;139(6):814. [PubMed]

44. Azab SF, Sherbiny HS, Saleh SH, Elsaeed WF, Elshafiey MM, Siam AG, Arafa MA, Alghobashy AA, Bendary EA, Basset MA, Ismail SM. Reducing ventilator-associated pneumonia in neonatal intensive care unit using "VAP prevention Bundle": a cohort study. BMC infectious diseases. 2015 Aug 6;15(1):314. [Full text]

45. American Association of Critical-Care Nurses. AACN Practice Alert: Ventilator Associated Pneumonia. AACN Advanced Critical Care. 2005 Jan 1;16(1):105-9. [Full text]

46. Cason CL, Tyner T, Saunders S, Broome L. Nurses' implementation of guidelines for ventilator-associated pneumonia from the Centers for Disease Control and Prevention. Am J Crit Care. 2007 Jan 1;16(1):28-37. [PubMed]

47. Kiyoshi-Teo, H., Cabana, M. D., Froelicher, E. S., & Blegen, M. A. (2014). Adherence to institution-specific ventilator-associated pneumonia prevention guidelines. Am J Crit Care. 2014 May; 23(3): 201-215. [PubMed]

48. Leone M, Garcin F, Bouvenot J, Boyadjev I, Visintini P, Albanèse J, Martin C. Ventilator-associated pneumonia: breaking the vicious circle of antibiotic overuse. Crit Care Med. 2007 Feb 1;35(2):379-85. [PubMed]

49. Lorente L, Blot S, Rello J. Evidence on measures for the prevention of ventilator-associated pneumonia. European Respiratory Journal. 2007 Dec 1;30(6):1193-208. [Full text]

50. Munro CL, Grap MJ. Oral health and care in the intensive care unit: state of the science. Am J Crit Care. 2004 Jan 1;13(1):25-34. [PubMed]

51. Shrestha RK, Dahal RK, Mishra SK, Parajuli K, Rijal BP, Sherchand JB, Kirikae T, Ohara H, Pokhrel BM. Ventilator Associated Pneumonia in Tertiary Care Hospital, Maharajgunj, Kathmandu, Nepal. Journal of Institute of Medicine. 2014 Jan 13;36(2). [Full text]

52. Ding S, Kilickaya O, Senkal S, Gajic O, Hubmayr RD, Li G. Temporal trends of ventilator-associated pneumonia incidence and the effect of implementing health-care bundles in a suburban community. Chest. 2013 Nov 30;144(5):1461-8. [PubMed]

53. Jubran A, Tobin MJ. Methods of discontinuing mechanical ventilation. [Full text]

54. Zack JE, Garrison T, Trovillion E, Clinkscale D, Coopersmith CM, Fraser VJ, Kollef MH. Effect of an education program aimed at reducing the occurrence of ventilator-associated pneumonia. Crit Care Med. 2002 Nov 1;30(11):2407-12. [Full text]

55. Gonçalves FA, Brasil VV, Ribeiro LC, Tipple AF. Nursing actions for the prevention of ventilator-associated pneumonia. Acta Paulista de Enfermagem. 2012;25(SPE1):101-7. [Full text]