

CNE Ventilator-Associated Pneumonia Bundle

Reconstruction for Best Care

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ABSTRACT

The ventilator-associated pneumonia (VAP) bundle is a focus of many health care institutions. Many hospitals are conducting process-improvement projects in an attempt to improve VAP rates by implementing the bundle. However, this bundle is controversial in the literature, because the evidence supporting the VAP interventions is weak. In addition, definitions used for surveillance are interpreted differently than definitions used for clinical diagnosis. The variance in definitions has led to lower reported VAP rates, which may not be accurate. Because of the

variance in definitions, the Centers for Disease Control and Prevention developed a ventilator-associated event algorithm. Health care institutions are under pressure to reduce the VAP infection rate, but correctly identifying VAP can be very challenging. This article reviews the current evidence related to VAP and provides insight into implementing a suggested revision of the care of patients being treated with mechanical ventilation.

Keywords: bundle, VAP, ventilator-associated bundle, ventilator-associated events, ventilator-associated pneumonia

Ventilator-associated pneumonia (VAP) is a major contributor to morbidity and mortality in the intensive care unit (ICU). Little disagreement exists with this statement in the literature. Many guidelines have been developed to try to deal with this serious condition. The Centers for Medicare & Medicaid Services offers an extensive list of resources for VAP prevention implementation (Table 1).¹ The VAP bundle was proposed in 2005 as part of the 100,000 Lives Campaign, an initiative that was launched by the Institute for Healthcare Improvement (IHI).² This initiative changed the direction of how many institutions approached VAP. “The IHI Ventilator Bundle is a series of interventions related to ventilator care that, when implemented *together*, will achieve significantly better outcomes than when implemented individually.”³ The bundle includes the following components:

1. Elevation of the head of the bed (HOB)
2. Daily sedation vacations and assessment of readiness to extubate

3. Peptic ulcer disease prophylaxis
4. Deep vein thrombosis (DVT) prophylaxis
5. Daily oral care with chlorhexidine (added in 2010)

The VAP bundle was described as evidence-based interventions that would help prevent VAP. However, this premise has been debated by researchers. To operationalize this bundle concept, regulatory bodies developed definitions and guidelines for VAP. The guidelines remain an area of controversy because VAP is a diagnosis that remains elusive and not as easily

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Table 1: The Centers for Medicare & Medicaid Services' Recommendations for Ventilator-Associated Pneumonia Prevention Resources*

Resource	Description
Guidelines for Prevention of Nosocomial Pneumonia (US Department of Health & Human Services, Centers for Disease Control and Prevention [CDC]): http://www.cdc.gov/mmwr/preview/mmwrhtml/00045365.htm	This document updates and replaces the CDC's previously published <i>Guidelines for Prevention of Nosocomial Pneumonia</i> (<i>Infect Control</i> . 1982;3:327–33, <i>Respir Care</i> . 1983;28:221–232, and <i>Am J Infect Control</i> . 1983;11:230–244). This revised guideline is designed to reduce the incidence of nosocomial pneumonia and is intended for use by personnel who are responsible for surveillance and control of infections in acute-care hospitals; the information may not be applicable in long-term-care facilities because of the unique characteristics of such settings.
Guide to the Elimination of Ventilator-Associated Pneumonia (Association for Professionals in Infection Control and Epidemiology [APIC]): http://www.apic.org/Resource_/EliminationGuideForm/18e326ad-b484-471c-9c35-6822a53ee4a2/File/VAP_09.pdf	The purpose of this guide is to provide evidence-based practice guidelines for the elimination of ventilator-associated pneumonia (VAP).
Preventing Ventilator-Associated Pneumonia (APIC): http://www.apic.org/Resource_/EducationalBrochureForm/c32ad147-d1ed-4043-8ad1-8476b710f5e8/File/Preventing-Ventilator-Associated-Pneumonia-Brochure.pdf	This educational brochure developed by APIC discusses strategies to prevent VAP.
Round-the-Clock Intensivists Eliminate Ventilator-Associated Pneumonia, Central Line Infections, and Pressure Ulcers in Intensive Care Unit (US Department of Health & Human Services, Agency for Healthcare Research and Quality [AHRQ]): http://www.innovations.ahrq.gov/content.aspx?id=2625	This innovation profile from the AHRQ discusses how Texas Health Presbyterian Hospital Dallas was able to eliminate VAP, central catheter infections, and pressure ulcers in intensive care units (ICUs).
Safe Critical Care Project: Testing Improvement Strategies (AHRQ): http://www.innovations.ahrq.gov/content.aspx?id=1939	This quality tool provided by AHRQ and developed by the Hospital Corporation of America provides an intervention toolkit for reducing VAP.
Comprehensive Initiative to Create a Culture of Safety Significantly Reduces Harm Caused by Medical Errors, Length of Stay, and Hospital-Acquired Pneumonia and Infections (AHRQ): http://www.innovations.ahrq.gov/content.aspx?id=1819	This innovation profile from AHRQ highlights Sentara Healthcare's implementation of an initiative to create and sustain a culture of safety in 2002. This effort led to significantly improved patient outcomes, including reducing patient harm caused by errors, mortality rates and length of stay in the ICU, and hospital-acquired pneumonia and infection rates.
Evidence-Based Bundle for Adults Is Adapted by Pediatric Intensive Care Units, Reducing Ventilator-Acquired Pneumonia and Lowering Costs (AHRQ): http://www.innovations.ahrq.gov/content.aspx?id=1888	This innovation profile provided by AHRQ highlights Children's Healthcare of Atlanta and how they developed and implemented a program to reduce incidence of VAP in 3 ICUs, including 2 pediatric ICUs and 1 cardiac ICU.
Daily Multidisciplinary Patient Rounds and Best Practice Bundle Decrease Use of Ventilators in the Intensive Care Unit (AHRQ): http://www.innovations.ahrq.gov/content.aspx?id=1810	The implementation of daily multidisciplinary patient rounds and a bundle of best-practice guidelines reduced the use of ventilators for patients in the ICU and enhanced communication among physicians and nurses in a hospital with private practice physicians and no advanced practice nurses.

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Table 1: The Centers for Medicare & Medicaid Services' Recommendations for Ventilator-Associated Pneumonia Prevention Resources* (Continued)

Resource	Description
Prevent Ventilator-Associated Pneumonia (Pediatric Supplement) (Institute for Healthcare Improvement [IHI]): http://www.ihl.org/resources/Pages/Tools/HowtoGuidePreventVAPPediatricSupplement.aspx	This how-to guide specifically tailored for pediatrics describes key evidence-based care components for preventing VAP, describes how to implement these interventions, and recommends measures to gauge improvement
Implement the IHI Ventilator Bundle (IHI): http://www.ihl.org/resources/Pages/Changes/ImplementtheVentilatorBundle.aspx	This website documents the importance of working to decrease VAP, discusses the key components of the IHI Ventilator Bundle, and provides resources to implement the bundle.
Prevent Ventilator-Associated Pneumonia (IHI): http://www.ihl.org/resources/Pages/Tools/HowtoGuidePreventVAP.aspx	This how-to guide describes key evidence-based care components for the IHI Ventilator Bundle, which has been linked to reductions in VAP in patients in intensive care, describes how to implement these interventions, and recommends measures to gauge improvement.
Prevent Ventilator-Associated Pneumonia (IHI): http://www.ihl.org/resources/Pages/Tools/HowtoGuidePreventVAP.aspx	This website provides tools and resources that will help a hospital work toward preventing VAP. This site also includes resources on measures to guide the improvement.
Ventilator-Associated Pneumonia: Getting to Zero ... and Staying There (IHI): http://www.ihl.org/resources/Pages/ImprovementStories/VAPGettingtoZeroandStayingThere.aspx	This site provides stories from hospitals that have successfully improved their VAP rates. Many of the hospitals highlighted have been able to get to zero and stay there.
Sample Business Case for Reducing Ventilator-Associated Pneumonia (IHI): http://www.ihl.org/resources/Pages/Tools/SampleBusinessCaseforReducingVentilatorAssociatedPneumonia.aspx	This document provides a sample business case for reducing VAP.
Strategies to Prevent Ventilator-Associated Pneumonia in Acute Care Hospitals (Society for Healthcare Epidemiology of America/Infectious Diseases Society of America [SHEA/IDSA]): http://www.jstor.org/stable/10.1086/591062	The intent of this document is to highlight practical recommendations in a concise format designed to assist acute-care hospitals in implementing and prioritizing their VAP prevention efforts. Refer to the SHEA/IDSA "Compendium of Strategies to Prevent Healthcare-Associated Infections" Executive Summary and Introduction and accompanying editorial for additional discussion.
Ventilator-Associated Pneumonia (VAP): Best Practice Strategies for Caregivers (Kimberly-Clark Health Care): http://en.haiwatch.com/data/upload/tools/VAP_CEU_Booklet_Z0406.pdf	This best-practice document was developed by Kimberly-Clark Health Care and discusses the principles and strategies that make best practice possible. It outlines these strategies and discusses their impact on VAP.
Ventilator-Associated Pneumonia (American Hospital Association, Hospitals in Pursuit of Excellence): http://www.hpoe.org/resources/case-studies/1078	The site provides case studies, initiatives, campaigns, toolkits, methodologies, and other tools and resources to support reduction in VAP.
Preventing Ventilator-Associated Pneumonia in the United States: A Multicenter Mixed-Methods Study (University of Michigan): http://www.med.umich.edu/psep/Preventing%20Ventilator-Associated_ICHE.pdf	This study determines what practices are used by hospitals to prevent VAP and, through qualitative methods, to understand more fully why hospitals use certain practices and not others.

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Table 1: The Centers for Medicare & Medicaid Services' Recommendations for Ventilator-Associated Pneumonia Prevention Resources* (Continued)

Resource	Description
Preventing Health Care Acquired Infections (Society of Hospital Medicine): http://www.hospitalmedicine.org/AM/Template.cfm?Section=CME&Template=/CM/HTMLDisplay.cfm&ContentID=4124	This toolkit provides practical strategies, guidelines, and tools for reducing VAP.
Ventilator-Associated Pneumonias (VAP) (Johns Hopkins Medicine): http://www.hopkinsmedicine.org/armstrong_institute/improvement_projects/ventilator_associated_pneumonias/estimator.html	This Web site describes and links to the VAP Opportunity Estimator, which estimates yearly numbers of deaths, dollars, and ICU days attributable to VAPs within an ICU, hospital, or health care system. In addition, the Opportunity Estimator quantifies the potential impact of VAP interventions by calculating the number of infections, deaths, dollars, and ICU days that could be prevented if the VAP rate was reduced.

*Reprinted from the Centers for Medicare & Medicaid Services.¹

defined as was initially thought by regulatory bodies. Practitioners need to understand the controversy, so that they can make appropriate decisions in directing practice.

History of the VAP Guidelines

The Centers for Disease Control and Prevention (CDC) published guidelines to prevent nosocomial pneumonia. The guidelines⁴ published by the CDC in 1983 for the prevention of nosocomial pneumonia were fundamental infection-control measures. These guidelines focused on perioperative prevention measures, hand washing, and handling of respiratory fluids, medications, and equipment, which are now routine measures in institutional infection control. In 1997, the guidelines⁵ were revised and included measures to decrease aspiration, prevent cross-contamination or colonization of health care workers' hands, and ensure appropriate disinfection of respiratory equipment; the use of vaccines to protect against certain infections; and hospital staff education. New investigational measures such as reducing oropharyngeal and gastric colonization of pathogenic microorganisms also were included.⁵

In 2003, these guidelines⁶ were again updated, expanded, and replaced with guidelines for preventing health care-associated pneumonia. The changes in the recommendations focused on preventing bacterial pneumonia, especially VAP. Orotracheal intubation was recommended over nasotracheal intubation when initiating mechanical ventilation. The use of noninvasive ventilation was recommended to reduce the duration and need for

mechanical ventilation. Changing breathing circuits when visibly contaminated or malfunctioning was endorsed. Also recommended was the use of an endotracheal (ET) tube with a dorsal lumen to allow drainage of upper airway respiratory sections that have pooled above the ET tube balloon. Recommendations to use gastric acid suppressive drugs for peptic ulcer disease prophylaxis or interventions for DVT prophylaxis were never included in any guidelines for VAP prevention. These guidelines continue to evolve as the definitions for VAP change in an effort to clarify a very complicated clinical condition. However, a clinical definition for VAP is different from a surveillance definition, which makes the application of a guideline very challenging.

Definitions in the VAP Guidelines

The 2003 CDC guidelines⁶ strongly recommended that surveillance should be conducted for bacterial pneumonia in patients in the ICU who are being treated with mechanical ventilation to facilitate identification of trends and for interhospital comparison. However, microbiological surveillance, VAP surveillance, and clinical diagnosis of VAP differ significantly. The clinical diagnosis of VAP is neither sensitive nor specific.⁷ Clinical suspicion for VAP requires intubation for more than 48 hours. Most infection-control professionals and hospital epidemiologists use definitions developed by the CDC National Health and Safety Network, which are based on 3 groups of criteria: radiographic, clinical, and optional microbiological

criteria.⁸ The definition of VAP may be the most subjective of the common device-associated infections.

Radiographic Criteria

Radiographic signs include 2 or more serial chest radiographs with new or progressive and persistent pulmonary infiltrates, consolidation, or cavitation. The difficulty in using the chest radiograph as the only radiographic test in determining VAP is that opacities may not follow usual anatomic distribution and can be distorted or hidden by pleural effusions, atelectasis, or pulmonary edema.⁹ Relying solely on the chest radiograph limits accuracy and does not include the use of computed tomographic scans in diagnosing VAP.^{9,10}

Microbiological Criteria

Microbiological criteria are optional, but if used, at least one of the following must be present: a positive blood culture not related to another source of infection, positive growth in a culture of pleural fluid, a positive quantitative culture from bronchoalveolar lavage (BAL) ($>10^4$ colony-forming units [CFU]/mL) or $>10^3$ CFU/mL from a protected brush specimen, 5% or more cells with intracellular bacteria on direct microscopic examination of gram-stained BAL fluid, or histopathological evidence of pneumonia.⁶ That the microbiological criteria are optional in a definition for an infection is interesting, but the intent was to use these criteria for surveillance use and not for clinical diagnosis, which may be because of the difficulty in obtaining accurate information about microbiological growth with the diagnosis of VAP. Endotracheal suctioning does not retrieve a deep enough sample. Protected brush sampling is a better technique, but it is a blind sampling process and accesses limited areas of the lungs. Bronchoalveolar lavage is considered the better method for microbiological sampling, because the sample is obtained under direct visualization using fiber-optic technology and it samples a larger number of alveolar units.¹¹

However, BAL also has its weakness. The sensitivity of quantitative BAL fluid cultures ranges from 42% to 93%, implying that BAL fluid is not diagnostic for VAP in approximately 25% of cases.¹¹ The specificity of quantitative BAL fluid cultures ranges from 45% to 100%, which implies that an incorrect diagnosis (a false-positive result) occurs in 20% of cases.¹¹ Reasons for the varying sensitivity and

specificity are related to many variables, some of which are standardization of the procedure, dilutional effects, technique, and choice of sampling site. Even the best technique for sampling may not give definitive microbiological data in up to 25% of cases.¹¹

Clinical Criteria

Clinical signs for VAP must include at least one of the following: temperature higher than 38°C with no other recognized cause, leukopenia (white blood cell count $<4000/\mu\text{L}$) or leukocytosis (white blood cell count $>12000/\mu\text{L}$), purulent respiratory secretions, or altered mental status for adults 70 years or older.⁶ In addition, clinical signs must include at least 2 of the following: new onset of purulent sputum or change in character of sputum; increased respiratory secretions, increase in suctioning, or new onset or worsening cough, dyspnea, tachypnea, or bronchial breath sounds; or worsening gas exchange as evidenced by desaturation, $\text{PaO}_2/\text{fraction of inspired oxygen (FIO}_2) \leq 240$ mm Hg, increased oxygen requirements, or increased ventilation demands.⁶

Although these criteria are widely used and recognized, many studies use different cutoff points for fever and leukocytosis, and individual interpretation of other clinical signs and radiographic data increase subjectivity in VAP diagnosis.¹² A Clinical Pulmonary Infection Score (CPIS) was developed to serve as a tool to help facilitate the diagnosis of VAP; however, no well-designed studies to validate the CPIS in acute lung injury or trauma are available. The CPIS uses a scoring system that includes clinical criteria (eg, temperature, blood leukocyte levels, tracheal secretions/purulence, and oxygenation-to- $\text{PaO}_2/\text{FIO}_2$ ratio) and radiographic criteria ranging from no infiltrate to diffuse patchy infiltrates to localized infiltrates.¹³ The CPIS also has user variability.¹³ The multiple attempts to define VAP for guideline use indicate the challenges of capturing the essence of this clinical entity.

Implementation of the VAP Bundle Components

Although the VAP definition was not clear, the VAP bundle was introduced, and implementation was expected.² To evaluate the effectiveness of the VAP bundle in its entirety, clinicians must evaluate the evidence used to support the effectiveness of each component of the bundle.

HOB Elevation

Elevation of the HOB to prevent aspiration has been a nursing standard for many years. Although intuitively this intervention seems logical, the evidence to support its efficacy in patients being treated with mechanical ventilation is not clear. In the original IHI proposal, the suggested elevation for HOB was a range of 30° to 45°. This range was established in earlier studies performed from 1992 to 1999¹⁴⁻¹⁷ testing the HOB elevation to prevent aspiration.^{18,19} These studies used either randomized 2-group or 2-period cross-over design, but the number of patients was small and the conclusions were variable but seemed to favor the 30° to 45° HOB elevation.¹⁹ The patients in the study by Drakulovic et al¹⁷ were in a complete horizontal position and receiving supine enteral nutrition, which is not the standard of care in most ICUs.²⁰ The evidence from these studies is not clear in that the designs were weak, the results were not significant in 3 of the 4 studies, and the best degree of HOB elevation was never established.

Four more studies were conducted from 2006 to 2010.²¹⁻²⁴ More patients were enrolled in 3 of the 4 studies, and the designs ranged from prospective descriptive to a randomized controlled trial (RCT); however, this trial had only 30 patients. Results from these studies were somewhat stronger but still variable.¹⁹ Metheny et al²¹ suggested that HOB elevation less than 30° was a significant risk factor for aspiration, while the authors of 2 other studies^{22,23} suggested that the 45° elevation was either not feasible in critically ill patients or poorly accepted by patients.¹⁹ Therefore, a recommendation for the degree of HOB elevation remains an elusive target.

Because of the variable evidence related to HOB elevation in prevention of VAP, a Bed Head Elevation Study Group was formed by the European Society of Intensive Care Medicine in 2010.¹⁸ This group of intensive care experts reviewed data in 3 meta-analyses to determine the quality of evidence for clinically suspected VAP, microbiologically confirmed VAP, and ICU mortality.^{17,22,23} All 3 meta-analyses revealed that the quality of evidence for all 3 areas was low, with wide confidence intervals.¹⁸ These data led the study group to the following conclusions: (1) whether a 45° HOB elevation is effective or harmful is uncertain; (2) maintaining a certain elevation 24 hours a day is not feasible because of nursing tasks,

medical interventions, and patient wishes; and (3) a semiupright position can be recommended only as a preferred position. This review also indicated inconsistency in measuring and maintaining exact HOB elevation, and no study was able to replicate clinical practice.¹⁸ Additional adverse effects of 45° HOB elevation, such as venous stasis in lower extremities and hemodynamic instability, were also considered by this study group, but the evidence was inconclusive as to the occurrence of these adverse effects.¹⁸ In consideration of these scientific results, the evidence to favor HOB elevation to help prevent VAP is not apparent. Clinicians also must realize that the guidelines for HOB elevation with VAP are somewhat contradictory to those guidelines used to prevent pressure ulcers, which favor lower HOB elevation.¹⁹ The clinician is now challenged as to what the proper intervention is for patients being treated with mechanical ventilation.

Oral Hygiene Care

Oral hygiene care is another nursing domain that can affect development of VAP. The oropharynx is colonized with potential pathogens such as *Staphylococcus aureus*, *Streptococcus pneumoniae*, *Prevotella* species, *Bacteroides fragilis*, and more than 700 other microbes, many of which have not been identified yet.²⁵ Within 48 hours after a patient is admitted to the ICU, the flora of the oral cavity undergoes a transformation to predominantly gram-negative microbes, which can be more virulent.²⁶ Oral hygiene care methods, including mouthwashes, gel, toothbrush, or combination techniques, have been used to combat possibly pathogenic flora.

Research has focused on interventions to promote oral hygiene in this population and minimize microbes that can lead to infection. In one study,²⁶ the use of chlorhexidine reduced the rate of VAP in patients who did not have pneumonia at baseline. DeRiso et al²⁷ concluded that oropharyngeal decontamination with chlorhexidine oral rinse reduces the total nosocomial respiratory tract infection rate and results in decreases in the use of nonprophylactic systemic antibiotics in patients undergoing cardiac surgery. Clinicians should recognize that these results apply only to patients undergoing heart surgery. A systematic review and meta-analysis of 7 trials with 2144 patients by Chan et al²⁸ concluded that oral application of antiseptics significantly reduced the incidence

of VAP (relative risk: 0.56; 95% confidence interval: 0.39-0.81). The Cochrane Oral Health Group²⁹ recently reviewed 35 RCTs of oral hygiene care, of which only 14% were well conducted and described. A total of 17 RCTs provided moderate-quality evidence for using either chlorhexidine mouthwash or gel.²⁹ The results of these studies showed a 40% reduction in the odds of VAP developing in patients who are critically ill. No evidence existed to show a decrease in ICU mortality rate, the number of ventilator days, or duration in ICU days.²⁹ The combination of using chlorhexidine and toothbrushing did not demonstrate a difference from using chlorhexidine alone.²⁹

Another variable is the frequency in the use of chlorhexidine in conjunction with additional oral care. Some oral care solutions and gels contain bicarbonate, which may contribute to the deactivation of chlorhexidine and negate its positive effects, providing another example in which the evidence supporting an intervention is not clear.

Prophylaxis Interventions

Two interventions in the bundle are specifically directed at prevention of complications associated with mechanical ventilation: DVT and peptic or stress ulcer disease. Deep vein thrombosis can be a complication of mechanical ventilation due to increased venous stasis in the lower extremities,¹⁸ but it also can be a complication of other conditions such as sepsis, cancer, trauma, postoperative course, peripheral vascular disease, and immobility. Prophylaxis for DVT has been shown to reduce the incidence of venous thromboembolism in hospitalized patients. In a retrospective observational study³⁰ of 175 655 patients admitted to 134 ICUs in Australia and New Zealand, crude mortality rates were lower in patients receiving DVT prophylaxis than in those who did not receive prophylaxis (6.3% vs 7.6%, respectively). The American College of Chest Physicians³¹ has issued evidence-based guidelines that state that patients who are critically ill should be assessed for their DVT risk at admission to the ICU. Although a direct correlation between DVT formation and VAP does not exist, pulmonary embolism in a patient being treated with mechanical ventilation is a part of the ventilator-associated event (VAE), and preventive interventions should be implemented.

Stress ulcer prophylaxis is a component of the VAP bundle that also may or may not have a direct impact on VAP rates, but it does impact associated risk factors that are related to patients being treated with mechanical ventilation in the ICU. In a multicenter prospective cohort study, Cook et al³² identified 2 strong independent risk factors for gastrointestinal (GI) bleeding: respiratory failure and coagulopathy. The incidence of GI bleeding among patients with one or both of these risk factors was 3.7% compared with 0.1% among patients with neither risk factor. Thus, stress ulcer prophylaxis in patients being treated with mechanical ventilation may be important for the prevention of GI bleeding, though its role in decreasing VAP is not clear.

An interesting perspective about this intervention is the mechanism of how drugs that suppress gastric acid may increase the virulence of possible pathogens. Several studies^{32,33} suggest that suppressive agents for gastric acid may increase the frequency of nosocomial infection as compared to agents that do not alter gastric acid. Some research has postulated that increased pH promotes GI bacterial growth (especially gram-negative bacteria); therefore, esophageal reflux and aspiration of gastric content along the ET tube may lead to endobronchial colonization or pneumonia.³⁴ A meta-analysis of 10 RCTs concluded that stress ulcer prophylaxis with a histamine-2-receptor antagonist (H₂RA) as compared with sucralfate resulted in no difference in effectiveness in treating overt GI bleeding but had higher rates of gastric colonization and VAP.³⁵

A question of differences arises between the use of H₂RA and the use of proton pump inhibitors. A retrospective study³⁶ comparing ranitidine with pantoprazole among cardiac surgery patients concluded that the use of pantoprazole for stress ulcer prophylaxis was associated with higher risk of nosocomial pneumonia compared with ranitidine. However, Lin et al³⁷ did not find a significant difference between H₂RAs and proton pump inhibitors in terms of stress ulcer prophylaxis, incidence of pneumonia, or mortality among patients admitted to the ICU. Prevention of peptic ulcer disease as a complication of mechanical ventilation has no relationship with the prevention of VAP, and stress ulcer prophylaxis may actually increase the incidence of gram-negative aspiration pneumonia.

Daily Sedation Vacations and Assessment of Readiness to Extubate

Early extubation may decrease incidence of VAP. Daily sedation vacations allow for proper assessment of the patient's readiness to be extubated. Kress et al³⁸ concluded that patients who received daily interruption of sedative drug infusions had decreased number of mechanical ventilator days as well as decreased length of stay in the ICU. Appropriate timing of sedation interruptions depends on a patient's stability, including evaluation of hemodynamics and the ability of the patient to protect the airway. Daily sedation vacations were paired with spontaneous breathing trials, resulting in earlier extubation and fewer ventilator days as well as decreased ICU and hospital days.³⁹ Of the 5 interventions proposed in the VAP bundle, this intervention is the most likely to help decrease the occurrence of VAP, because it has been demonstrated that it expedites earlier extubation. The sooner the ET tube is removed, the possibility of infection developing is lower.

The previous 4 components either have marginal evidence to support a role in decreasing VAP or had no relationship to VAP. With this lack of clear evidence, clinicians started to challenge the validity of the VAP bundle and its effectiveness.

CDC Response to VAP Bundle Concerns

Because of the mounting concerns about a reliable definition of VAP, the CDC convened a working group of stakeholder organizations in 2011 to address the limitations of the National Healthcare Safety Network *pneumonia* definitions. Representatives from critical care nursing, physician, and respiratory therapist organizations as well as infection control and epidemiology societies were included in the work group. The revised definition was separated into 3 levels to better describe the conditions and complications that are associated with adult patients being treated with mechanical ventilation and assist with improved surveillance of this patient population. The VAE algorithm includes (1) ventilator-associated condition, (2) infection-related ventilator-associated condition, and (3) possible and probable VAP (see Figure 1).⁴⁰

This VAE algorithm is more complex than the original CDC definition. Klompas,⁴¹ who is an epidemiologist and a member of the CDC

work group, provides insight into the changes in the definition. The algorithm was designed to broaden the focus of surveillance to include complications of ventilator care and to attempt to make surveillance more objective, thereby decreasing the amount of "gaming" the system.⁴¹ It provides time frames as to when to look for changes and defines specific changes in FiO_2 and positive end-expiratory pressure instead of the original "worsening oxygenation" statement. The ventilator-associated condition definition is nonspecific to capture more pulmonary (eg, atelectasis, acute respiratory distress syndrome) and nonpulmonary complications (eg, pulmonary edema, interstitial disease) that result in prolonged higher ventilator support settings.⁴¹ With this definition, the goal of having zero VAP rates may not be realistic. In the third tier of the algorithm, the infection-related ventilator-associated condition accommodates the variable of possible versus probable VAP. This option is intended to capture events that are ventilator related but are not clearly caused by infection, which is an issue that has been a major point of debate in defining VAP. Radiological criteria have not been included in the VAE algorithm criteria, because interpretation of chest radiographs can be subjective and complex. The new algorithm will assist in a more meaningful benchmarking process and reflect differences in patients and processes of care more clearly.⁴¹

Impact of Regulatory Pressure

When IHI introduced the VAP bundle, regulatory bodies at all levels (federal, national, state, and corporate) started to consider how this bundle would be integrated into practice. This regulatory interest in the VAP bundle caused institutions to begin implementing the bundle to be in compliance. However, benchmarking the quality of care of patients being treated with mechanical ventilation has been challenging. The clinical criteria for VAP are intended to guide clinical care. These criteria assist with the diagnostic process when presence of infection may not be clearly documented and may be used to optimize patient care and decrease mortality rate. However, these criteria are subjective and leave room for interpretation, which may differ between reasonable clinicians and surveyors. Applying subjective criteria more strictly can result in lower VAP rates.⁴¹

More than 50% of nonteaching medical ICUs in the United States have reported VAP rates of 0.⁴² However, this statistic may not be

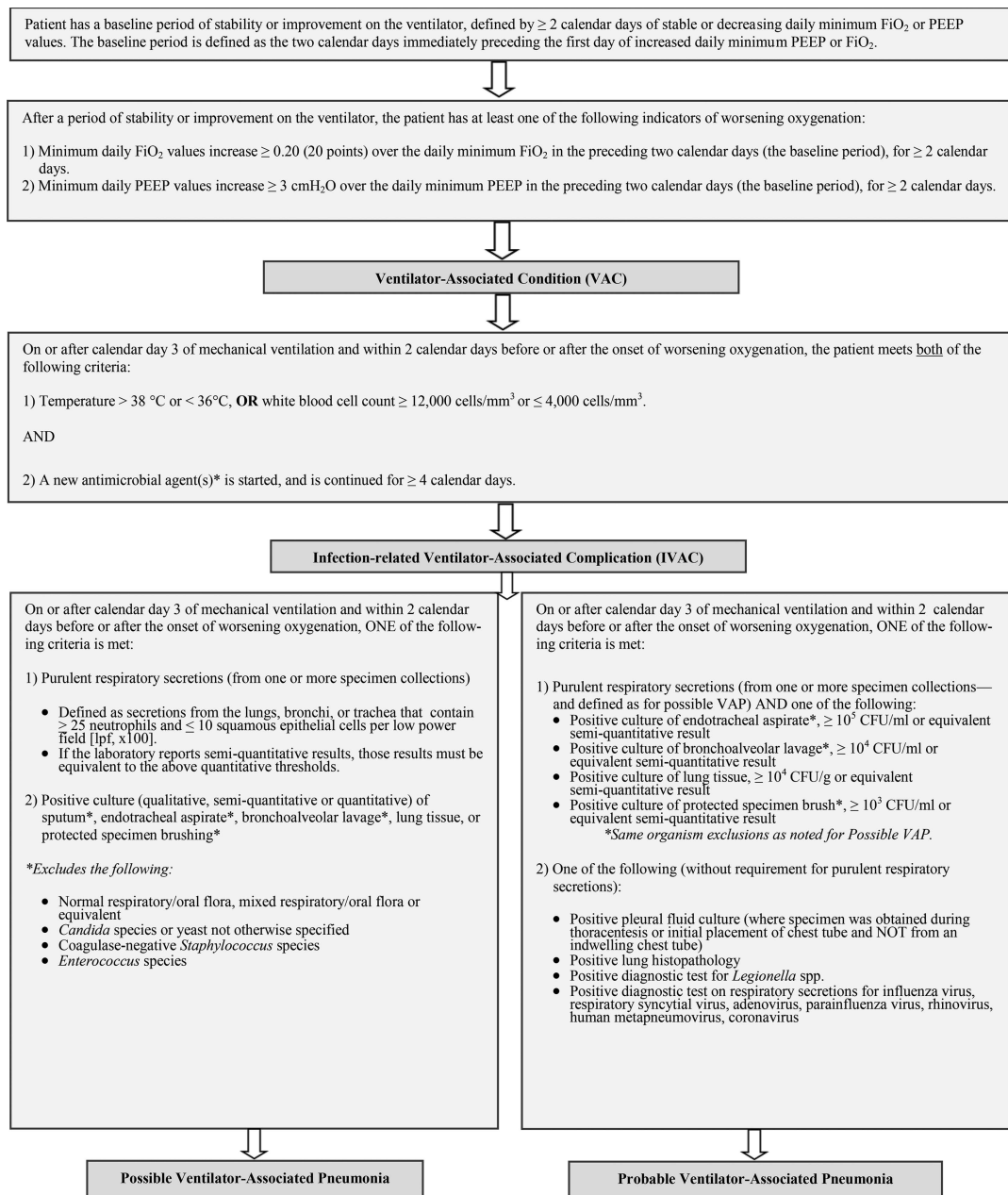


Figure 1: Ventilator-associated events surveillance definition algorithm. Abbreviations: CFU, colony-forming units; FiO₂, fraction of inspired oxygen; PEEP, positive end-expiratory pressure; VAP, ventilator-associated pneumonia. Reprinted from the Centers for Disease Control and Prevention.⁴⁰

a true reflection of lower VAP rates but rather surveillance discrepancies using traditional clinical VAP diagnostic criteria.⁴³ Many experts doubt that a 0 VAP rate realistically can be achieved.⁴³ An autopsy series revealed that one third to one half of patients who met clinical

criteria for VAP did not have pneumonia.⁴³ Concern arises over whether VAP rates were truly reduced or whether strict diagnostic criteria were applied and alternative diagnoses such as ventilator-associated tracheobronchitis (VAT) or sepsis syndrome were used.^{43,44} Dallas et al⁴⁵

conducted a prospective study to clarify the difference between VAT and VAP. The only difference in the definition between VAT and VAP in this study was that VAP included the presence of infiltrates on chest radiograph.⁴⁵ Given the sensitivity of portable chest radiographs, infiltrates may have been present but not identified, because routine chest computed tomography scans were not done. Nonetheless, no significant differences were found in ICU or hospital length of stay, duration of treatment with mechanical ventilation, hospital mortality rate, tracheostomy, or antibiotic use between the VAT and VAP groups. When the 9 patients with VAT who subsequently developed VAP were removed from the analysis, the authors⁴⁵ still found no significant differences between the VAT and VAP groups for any of the outcomes measured. Similar clinical presentations to VAP can occur with other conditions, such as heart failure, sepsis, pulmonary embolism, acute respiratory distress syndrome, and alveolar hemorrhage. In addition, other noninfectious interstitial processes can appear similar on chest radiographs, such as cryptogenic organizing pneumonia.

The IHI bundle has been credited with reducing VAP rates across the country. Because VAP rates in institutions may be linked to reimbursement and accreditation, institutions have an incentive to “game the system,” so that VAP rates appear to be improving.⁴³ Significant time, effort, and expense have been used to try to implement the bundle. Process improvement has driven many projects surrounding the VAP bundle implementation. The health care industry has responded with new devices to assist institutions with ensuring that the IHI recommendations are monitored. An example is a device to continually monitor HOB elevation.⁴⁶ However, these efforts are being directed to a bundle that seems to have minimal evidence to support its use but is required for compliance. Should the bundle and its content be reconsidered?

Reconstruction of the VAP Bundle to Promote Best Care

As the efficacy and validity of the VAP bundle has been examined, expert clinicians have called for a deconstruction of the bundle.⁹ This argument hinges on the issue that surveillance and clinical definitions are in conflict, but the expectation of regulatory bodies is that this bundle be implemented even though

the evidence behind the bundle components is variable. Organizing care around a specific diagnosis is a valid concept. The positive results of the bundle implementation have been attributed to the fact that it heightened awareness of VAP with the multidisciplinary team and focused on the care of patients being treated with mechanical ventilation.⁴⁷ However, careful consideration must be given to the specific care that is recommended to help prevent and/or combat that diagnosis. Regulatory bodies are now reconsidering the adherence to the VAP bundle as a reportable statistic. The Joint Commission has decided not to include the bundle in the 2014 National Patient Safety Goals, and the Centers for Medicare & Medicaid Services has not included VAP on the list of nonreimbursable diagnoses at this time,^{48,49} which is an opportunity for nursing and advanced practice nurses to assist with the reconstruction of best care for patients being treated with mechanical ventilation. Nursing interventions may primarily focus on prevention. Clinicians must recognize that measures to prevent a condition will be different but complementary to measures used to combat or treat a condition.

Body Position

Body position has an impact on gravitational forces that influence the leakage of secretions around the ET tube.⁵⁰ The semirecumbent position has been the standard practice, but the best degree of HOB elevation has not been determined by the evidence. The 30° HOB elevation is the recommended position that may decrease aspiration. The weakness of this rationale is that secretions above the ET tube balloon can pool and lead to microaspiration. Two other aspects of this intervention should be considered: (1) what is the role of HOB elevation to help prevent skin breakdown and (2) is the semirecumbent position the best position to prevent leakage around the ET tube? Metheny and Frantz¹⁹ described the conflict between guidelines for HOB elevation to prevent aspiration (recommendation of 45° elevation) and guidelines for pressure ulcer prevention (recommendation of no more than 30° elevation). Ironically, the Joint Commission National Patient Safety Goal 14 is prevention of health care–associated pressure ulcers.⁵¹ Clinicians are faced with a perplexing decision as to which regulatory body directive to follow, that is, the VAP bundle or prevention of

pressure ulcer formation. The recommendation of the Bed Head Elevation Study Group is to maintain HOB elevation at 30° or more, as long as this positioning does not pose risks or conflicts with other nursing or medical interventions or patients' wishes.¹⁸ Measuring compliance with HOB elevation could be seen as a poor use of time and resources. This HOB position would seem to be a prudent compromise with the many conflicts in the evidence and compliance with the intent of regulatory directives.

Searching for a new paradigm also may be an alternative solution for the HOB elevation issue. Is semirecumbency the best position for patients being treated with mechanical ventilation? A VAP animal model using sheep placed half the animals in a semirecumbent position and the other half in a head-down position that was rotated side to side at intervals. The head-down group showed no evidence of VAP, bacterial colonization, or impaired PaO₂/FIO₂ ratio.⁵² The theory is that using gravitational force may move secretions away from the ET tube by maintaining the ET tube/trachea orientation at or below horizontal position.⁵² This model is now being tested in humans.^{53–55} Nursing researchers may want to consider testing this model so that nursing could contribute evidence to demonstrate a better body position.

Reconstructing Other Bundle Components

The other components of the VAP bundle also should be evaluated in the reconstruction effort. Oral care is important for this patient population for 2 reasons: control of bacterial flora and maintenance of patient comfort. Use of chlorhexidine may help control bacterial growth, but the current technology used to detect microbes may not be able to identify all species.⁵⁰ Clinicians are advised to examine the effect of routine hygiene methods on the efficacy of chlorhexidine. This consideration may be another area for further nursing research. Drugs to suppress gastric acid should not be included in any plan to prevent VAP, because the use of these drugs may increase gram-negative bacterial growth. The International Nosocomial Infection Control Consortium reported that the international VAP prevention program recommended avoiding drugs that suppress gastric acid and avoiding gastric distention.^{56,57} Drugs that suppress gastric acid are effective in preventing GI bleeding and treating

gastric reflux disease and may need to be included in the care of patients with a history of gastric issues or GI bleeding. Physical examination and closer evaluation for gastric distension on chest radiographs are easy additions to a VAP prevention plan. Prophylaxis for DVT is important and monitored separately. It should not be included in a VAP prevention program because it will not influence VAP development.

Daily interruption in sedation and assessment of readiness for extubation are probably the most productive interventions in the VAP bundle. Process-improvement programs related to moderating the use of sedative agents should continue. Removing the ET tube as soon as safely possible will eliminate an important factor that contributes to the cascade of events that may lead to VAP. Decreasing the number of days of treatment with mechanical ventilation may decrease the risk of VAP, but no published studies demonstrate this relationship.⁵⁰ Even if a decrease in VAP is not clear, decreasing the use of sedative agents may help decrease the occurrence of delirium and its associated complications.⁵⁸ Advanced practice nurses play a pivotal role in enhancing the communication and implementation of this intervention, and further research should be pursued.

Advances in Technology

Advances in technology also need to be included in a VAP prevention plan. Subglottic suctioning using a specialized ET tube with a separate dorsal lumen designed to suction secretions collected around the ET tube cuff was not included in the original VAP bundle but has been recommended by various organizations.⁸ The difficulty with this tube is maintaining patency, because the dorsal lumen has a tendency to clog as a result of the tenacious nature of the secretions. Microbiological and molecular biological techniques continue to evolve and are becoming increasingly more effective in the detection of new microbes of the presumed 700+ species in the mouth.^{25,50}

Interventions to prevent biofilm formation are another area of research that may play a role in VAP prevention. Biofilm, a community of microorganisms that attaches to a surface and develops a structure to support replication, may play a significant role in the development of VAP.⁵⁹ Silver-coated ET tubes have been shown to decrease or delay VAP but not ventilator or ICU days.⁶⁰ Novel inventions such

as a mucus shaver, a catheter that is inserted into an ET tube and shaves mucus/secretions from the inner lumen of the tube, may assist with decreasing the formation of biofilm.⁶¹ These types of technological innovations will continue to evolve and may provide solutions.

Conclusion

The intention of the VAP bundle was to improve patient care. It has promoted multidisciplinary teams to coordinate interventions, which resulted in better care. The coordination of care was probably the predominant force in the improvement of care of patients being treated with mechanical ventilation, as varying levels of evidence support the bundle interventions. Unfortunately, institutions have invested significant time and effort implementing the bundle to meet regulatory body compliance requirements, but they seem to be reconsidering the effectiveness of the bundle. Perhaps studying the European model, which decreased VAP by 56% through emphasizing good infection-control techniques, using noninvasive ventilation when appropriate, and other efforts will further improve care.⁵⁶ The new CDC definition may result in more objective benchmarking and maintain the focus on patients and not statistics. Advanced practice nurses can play a major role in the innovation and critical evaluation of the evidence behind these interventions and assist in developing evidence-based practice.

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