CME

Ventilator-Associated Events: What Does It Mean?

Peggy White, MD,* Elizabeth Mahanna, MD,* Peggy R. Guin, PhD, ARNP, CNS-BC, CNRN, SCRN,† Vaibhav Bora, MBBS,* and Brenda G. Fahy, MD*

Health care–associated infections (HAIs) are a global problem that result in an increase in patient morbidity and mortality.[1,2] Multiple efforts to decrease the occurrence of these complications have taken place, thus improving patient outcome. Recognizing that health care–associated complications are a patient safety issue and a public health threat, the United States, through the Centers for Disease Control and Prevention (CDC), has emphasized the importance of eliminating these complications.[3,4]

Techniques to prevent HAI have involved the development of surveillance methods to detect both endogenous and exogenous sources of infection, as well as data-reporting systems to aid in identifying both causative and modifiable risk factors for HAI. A variety of strategies has resulted from these techniques. One impact of these initiatives has resulted in health care providers in all fields, including anesthesia, becoming engaged in the process of using various avoidance strategies with the goal of preventing and ultimately eradicating HAI. This review will focus on the prevention of complications associated with mechanical ventilation through the use of "care bundles" and discussion of the new definitions and their implications.

Ventilator-associated pneumonia (VAP) is one example of an area in which specific guidelines have been created in an attempt to reduce the incidence of health care–associated complications, by implementing a group of evidence-based care interventions. Loosely termed care bundles, these care interventions are designed to decrease the rate of the targeted complications. In the case of VAP, the targeted rate initially set by the CDC and the Institute for Healthcare Improvement (IHI) was zero. The care bundle preventative strategies for VAP, including its applied rationale based on the evidence, will be discussed, as well as its limitations and shortcomings.

VAP CARE BUNDLE

In 2001, the IHI recognized care of the ventilated patient as a top priority and identified the most significant complications associated with mechanically ventilated patients as VAP, venous thromboembolism, and stress-induced gastrointestinal bleeding. Four elements of care were identified as key factors in reducing these complications, with a fifth element added in 2010. The current IHI care bundle therefore consists of 5 interventions targeted to improve outcomes in mechanically ventilated patients. These include (1) head of bed (HOB) elevation, (2) daily sedation holiday with assessment for possible extubation, (3) daily oral care with chlorhexidine, (4) deep venous thrombosis prophylaxis, and (5) peptic ulcer prophylaxis.[a] The first 3 elements are the components that have been examined for the prevention of VAP (Table 1); the remaining 2 have been studied to reduce overall morbidity and mortality in patients who are mechanically ventilated and are not associated with a decrease in the incidence of VAP.

The IHI VAP bundle has some recognized limitations and has been criticized by a number of authors.[5,6] These criticisms include components of the current bundle and omissions of other areas that have the potential to eliminate VAP.

HOB ELEVATION

In 1999, Drakulovic et al.[7] published a landmark study in which they evaluated the impact of HOB elevation and VAP. The study involved 86 mechanically ventilated patients who were evaluated with the HOB-elevated 45° or in the supine position with the HOB at 0°. All other intensive care unit (ICU) care prevention strategies were kept consistent: nutritional support, pressure ulcer preventive strategies, sterile endotracheal suctioning, standard mechanical ventilation tubing systems, and stress ulcer prophylaxis. In the 45° HOB-elevated group, there was a reduction in suspected VAP from 34% to 8% and a reduction in confirmed VAP from 23% to 5%. Interestingly, there was also an increased incidence of VAP with enteral feeding versus no enteral feeding. The authors theorize that the presence of a nasogastric tube inhibits the ability of the lower esophageal sphincter to contract, thereby increasing the chance of tracheal aspiration. The incidence of VAP was 50% and 9% with enteral feeding, and 10% and 6% with no enteral feeding in the supine and HOB-elevated positions, respectively.[7]

Alexiou et al.[8] performed a meta-analysis evaluating the effect of backrest position on the incidence of VAP. This analysis included 3 randomized controlled trials involving 337 adult patients. Each of the studies examined found a statistically significant reduction in VAP rates with the patient positioned with the HOB elevated compared with the supine position. The study groups, however, were underpowered in regard to determining a statistically significant difference in ICU stay, duration of mechanical ventilation, or mortality.[8]

Controversy over whether HOB position reduces the incidence of tracheal colonization remains.[8,9] Furthermore, the clinicians studying this variable have questioned whether, in clinical practice, the backrest position is maintained regularly at the prescribed level. To address this question further, van Nieuwenhoven et al.[9] used a study design different from that used by Drakulovic et al.[7] Their study used continuous computer analysis of duration of

From the *Department of Anesthesiology, University of Florida College of Medicine, Gainesville, Florida; and †UF Health Shands Hospital, Gainesville, Florida.

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Address for correspondence Brenda G. Fahy, MD, Department of Anesthesiology, University of Florida College of Medicine, 1600 SW Archer Rd., P.O. Box 100254, Gainesville, FL 32610. Address e-mail to bfahy@anest.ufl.edu.

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[a]Implement the Institute for Healthcare Improvement Ventilator Bundle. Available at: http://www.ihi.org/resources/Pages/ImprovementStories/WhatIsaBundle.aspx. Accessed October 2, 2014.

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Table 1. Summary of Evidence for Initial VAP Prevention Bundle

Authors	Year	Type of study	No. subjects	Primary outcome	Findings	Comments/limitations
HOB elevation						
Drakulovic et al.[7]	1999	RCT	86, MV	HOB elevation on VAP	HOB at 30–45° reduces confirmed or suspected VAP; increased incidence of VAP with enteral tube feedings	Prevents VAP by decreasing the risk of aspiration of gastrointestinal contents or oropharyngeal and nasopharyngeal secretions; improves patients' ventilation; NGT inhibits lower esophageal sphincter to contract, increasing tracheal aspiration
Alexiou et al.[8]	2009	Meta-analysis of 3 RCTs	337, MV	HOB elevation on VAP	HOB at 45° had significantly lower incidence of clinically diagnosed VAP	No difference in patients positioned in prone versus supine position; study groups underpowered for statistical significance for difference in ICU stay, duration of MV, or mortality
van Nieuwenhoven et al.[9]	2006	Prospective, multicentered RCT	221, MV	Feasibility of semirecumbent position for ICU patients and influence on VAP	HOB at targeted 45° not reached; achieved difference in treatment position (28° vs 10°) did not prevent VAP	No differences in numbers of patients undergoing enteral feeding, receiving stress ulcer prophylaxis, or developing pressure sores or in mortality rates or duration of ventilation and ICU stay between the groups
Sedation holiday						
Kress et al.[10]	2000	Single-center RCT	221	Sedation holiday	Subjects in DSI group had fewer days of MV than group without DSI	Single-center study provided basis for larger, MC trials; laid the foundation for future studies of SAT
Schweickert et al.[11]	2004	Subanalysis of data set in Kress study	128, MV (subset of Kress et al., 2000)	Sedation holiday's impact on the incidence of complications of critical illness	Subjects in DSI group had fewer complications of critical illness	Blinded, retrospective chart review; complications included VAP, upper GI bleed, bacteremia, barotrauma, VTE, cholestasis, or sinusitis requiring surgery
Girard et al.[12]	2008	Multicenter RCT	128, MV	Daily use of SBT and SAT in patient on MV	Subjects in the daily SBT and SAT group had fewer days of MV, less benzodiazepine use, morbidity and mortality	Authors concluded that SBT and SAT should be a routine standard of practice
Strøm et al.[13]	2010	Single-center RCT	140, MV who needed ventilation >24 h	Intubated patient with and without sedation; no. of days without MV in a 28-day period, ICU and hospital LOS	Decrease in days of MV, reduced ICU, and hospital LOS	No sedation of critically ill patients receiving MV is associated with an increase in days without ventilation; a multicenter study is needed to establish whether this effect can be reproduced in other facilities
Klompas et al.[14]	2015	Multicenter QI project (13 academic and community hospitals) within prospective study of VAE in 12 ICUs	5164, MV; 3425 episodes of MV	VAE risk per episode of MV impact of SBT and SAT on VAE	SBT, SAT associated with fewer days of MV, decreased hospital LOS, decreases in VAE	Lack of randomization; first prospective, longitudinal multicenter QI project; improvements seen in 6 of 7 hospitals and 8 of the 12 units participating in the collaborative; future studies should explore whether interventions targeting conditions seen with VAE (pneumonia, pulmonary edema, atelectasis, ARDS) can decrease VAE rates further
Oral decontamination						
Klompas et al.[15]	2014	Meta-analysis of 16 RCTs	3630, MV	VAP, mortality, duration of MV, ICU and hospital LOS, antibiotic prescribing	CHG reduced VAP in cardiac surgery patients but not in noncardiac surgery patients; CHG does not affect patient-centered outcomes in either population	Lack of standardization of the criteria for the diagnosis of VAP, difficulty blinding, and no control groups with no oral care; clinically significant end points such as ARDS, mean duration of MV, LOS, and mortality rates were not explored
Chlebicki and Safdar[16]	2007	Meta-analysis of 7 RCTs	1650	Incidence of VAP, ICU LOS, hospital LOS, duration of MV, time from intubation to VAP occurrence	30% reduction in the risk of VAP with chlorhexidine, more pronounced in cardiac surgery patients	Small sample size, lack of standardization of the criteria for the diagnosis of VAP, difficulty blinding, and no control groups with no oral care

ARDS = acute respiratory distress syndrome; CHG = change; DSI = daily sedative interruption; GI = gastrointestinal; HOB = head of bed; ICU = intensive care unit; LOS = length of stay; MC = multicenter; MV = mechanical ventilation; NGT = nasogastric tube; QI = quality improvement; RCT = randomized controlled trial; SAT = spontaneous awakening trial; SBT = spontaneous breathing trial; VAE = ventilator-associated event; VAP = ventilator-associated pneumonia; VTE = venous thromboembolism.

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the level of HOB elevation by measuring degrees from the supine position. The control group had HOB elevation at 10° rather than supine. This was a multicenter study that included 3 university hospitals, enrolled 221 patients, and compared the HOB elevated from supine with 2 levels, 29° and 23° vs 10° and 15°. The goal position of 45° HOB elevation was never met. This study revealed no difference in VAP between the 2 groups. The authors theorized that the backrest position of 0° in the study by Drakulovic et al.[7] was responsible for the difference in outcomes.[9] Despite the conflicting results, HOB elevation to >30° remains the standard of care.

SEDATION HOLIDAY

An article by Kress et al.[10] in 2000 sparked many studies centered around the idea of daily sedative interruption (DSI) that facilitated the "daily wake up and breathe" concept. Kress et al. found that the patients in the DSI group underwent fewer days of mechanical ventilation compared with the standard care group without DSI. This single-center study provided the basis for larger, multicenter trials, particularly given the limitations of the study. In 2004, Schweickert et al.[11] did a subanalysis of the initial data set in the Kress et al. study and found that the subjects in the DSI group had fewer complications of critical illness. The study by Kress et al. (2000) laid the foundation for future studies on the topic, which is now known as a spontaneous awakening trial (SAT).

Girard et al.[12] performed one of the first multicenter randomized controlled trials that evaluated the daily use of spontaneous breathing trials (SBTs) and SAT in ventilated patients. Patients in the daily SBT and SAT groups underwent fewer days of mechanical ventilation, consumed fewer benzodiazepines, and had lower morbidity and mortality. The authors concluded that SBT and SAT result in better overall outcome for mechanically ventilated patients in intensive care than current standard approaches and should become routine practice.[12] Strøm et al.[13] took it one step further and studied intubated patients with and without sedation. These authors found a decrease in days of mechanical ventilation and a reduction in ICU and hospital length of stay (LOS).[13]

In response to the implementation of the ventilator-associated event (VAE) definition, Klompas et al.[14] studied the relation of SBT and SAT standardized protocols and their impact on VAE. Twenty ICUs were included in this study, including 5164 episodes of mechanical ventilation. The use of daily SBT and SAT was associated with fewer days of mechanical ventilation, decreased hospital LOS, and decreases in VAE compared with patients in the surveillance-only group. This study has some limitations, including lack of randomization, but the results are not surprising and are consistent with previous studies evaluating days of mechanical ventilation and SBT. Daily SBT and SAT should remain the standard of care in the management of mechanically ventilated patients.[14]

ORAL DECONTAMINATION

The recommendation for chlorhexidine daily care introduced in 2010 also has shortcomings. First and foremost is the lack of standardization of care for this parameter. The recommendations are for daily care; however, the studies with chlorhexidine performed the oral care between 2 and 4 times a day. Other limitations include limited sample populations and a lack of interobserver reliability when diagnosing VAP. In a recent meta-analysis by Klompas et al.,[15] they recognized these limitations and opted to perform a meta-analysis involving 16 studies. This meta-analysis revealed that chlorhexidine reduced VAP in cardiac surgery patients but not in noncardiac surgery patients.[15] This finding complicates the data substantially because cardiac surgery patients have on average a shorter duration of mechanical ventilation than other noncardiac patients: 1 day versus 2 days to 2 weeks.[15] Other confounding variables in this study include a lack of standardization of the criteria for the diagnosis of VAP, difficulty blinding, and no control groups with no oral care. Furthermore, clinically significant end points, such as acute respiratory distress syndrome, mean duration of mechanical ventilation, LOS, and mortality rates, were not explored.[15] In another meta-analysis, Chlebicki and Safdar[16] evaluated only randomized controlled trials and found a 30% reduction in the risk of VAP with the use of chlorhexidine. Again, this effect was more pronounced in cardiac surgery patients. In light of these meta-analyses, further large randomized trials in a more heterogeneous patient population are needed to determine what, if any, benefits chlorhexidine care bring to noncardiac surgery, mechanically ventilated patients.

PEPTIC ULCER PREVENTION

One of the variables, peptic ulcer disease prophylaxis, decreases morbidity for mechanically ventilated patients because of its prophylactic effects on the development of stress-induced peptic ulcer disease and/or gastritis. However, this reduction is at the cost of an increased incidence of VAP. As a result, the IHI guidelines now recommend against the use of H2 blockers and proton pump inhibitors in patients who are at low risk for stress-induced peptic ulcer disease and/or gastritis.[17,18]

OTHER INTERVENTIONS

Additional guidelines include components that are not represented in the 5 elements of the IHI bundle yet have been shown to reduce VAP. This includes recommendations for the use of noninvasive positive pressure ventilation when possible,[19,20] subglottic suctioning,[18,20] and maintenance of cuff pressures to at least 20 cm of water.[19] Subglottic suctioning has been evaluated in 2 meta-analyses, both of which have shown a decreased risk of VAP by almost half, decreased ventilator days, and decreased ICU days.[20,21] Each of these studies involved oral endotracheal tubes and although theoretically of benefit, it remains unknown whether tracheostomy tubes with subglottic suction ports will also reduce VAP and days on mechanical ventilation. The variable of 20 cm of water pressure to maintain endotracheal tube cuff pressures is based on a study by Rello et al.[22] from 1996. This study revealed a trend toward increased VAP in patients whose cuff pressures were persistently measured <20 cm of water. In addition, VAP was increased in patients not receiving antibiotics who had cuff pressures persistently <20 cm of water.[22]

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Criticism of the current guidelines to prevent VAP also extends to components not included in the guidelines that may be effective in eradicating VAP.[5,6] This includes use of an ultrathin cuff membrane and tapered endotracheal tube cuffs.[23] Both of these types of cuffs are designed to decrease the rate of microaspiration. Using the ultrathin cuff membrane of 7 μm instead of larger than 50 μm decreases the amount of channels that form in cuff folds when the cuffs are less than maximally inflated. These design features have been shown to decrease the amount of fluid leakage past the cuff in an in vitro study by Dullenkopf et al.[24] In another randomized study of cardiac patients, Poelaert et al.[25] showed a decrease in VAP after multivariate analysis with the use of an ultrathin membrane cuff; it should be noted that this cuff was also tapered. Tapered cuffs may have a protective advantage by having one point on the cuff that is the exact diameter of the trachea with no folds present.[24]

Early tracheostomy has been evaluated as a strategy to decrease several variables, including the rate of VAP, the total days of mechanical ventilation, ICU LOS, and mortality.[26–28] There is controversy over whether the benefits would be realized by all types of patients or whether it is only applicable to selected subgroups of patients.[26–28] Many of these studies are limited by small sample size and, when grouped together in a meta-analysis, have shown conflicting results.[23,26,29] In 2009, the EAST practice Management Guideline Work Group published guidelines for trauma patients after review of the literature.[30] This group concluded that early tracheostomy decreased the total number of ventilator days in head injury patients; they found that it may also decrease the number of ventilator days and VAP in nonhead injury patients. This work group recommended early tracheostomy for trauma patients. In 2012, Tong et al.[26] conducted a retrospective study concluding that early tracheostomy lead to a decreased number of days on mechanical ventilation and shorter ICU stays and hospital LOS without a reduction in VAP. In contrast, Young et al.[27] conducted a randomized trial in the United Kingdom and found no difference in 30-day mortality or 1- to 2-year survival in patients receiving early tracheostomy. Another recent meta-analysis showed that early tracheostomy decreased all-cause mortality in the ICU, resulting in an 18% reduction in the relative risk of death.[28]

Heated moisture exchangers and heated humidifiers have also been examined as possible therapies to reduce the incidence of VAP. Studies and meta-analysis are conflicted on whether they decrease VAP. Lorente et al.[23] categorized these therapies as "worth considering."

Early mobilization is another strategy that has been found to be safe in mechanically ventilated patients and has been shown to improve outcome.[31,32] Early mobilization has been shown to decrease total days of mechanical ventilation, ICU days, and the incidence of VAP across a wide range of mechanically ventilated patients, including patients in the neuro-ICU.[31–33]

NEW DEFINITIONS: VENTILATOR-ASSOCIATED EVENTS

Health care delivery systems are benchmarked on HAI complications, including VAPs, using defined criteria as illustrated in Figure 1.[34] For the past few decades, these CDC-established criteria for VAP surveillance allowed comparison of intra- and interhospital VAP rates. These CDC VAP definitions and methods presented challenges because no single set of criteria was established that applied to both clinical and surveillance purposes. This lack of a single gold diagnostic standard contributed to differences in surveillance data, with a wide range of reporting variability for the incidence of VAP.[35–41] In addition, new criteria for the clinical diagnosis continue to be published.[42]

Because of the challenges presented by the VAP definition and concerns that increases in morbidity and mortality[43] are

2002 Centers for Disease Control and Prevention (CDC) Definition for Ventilator Associated Pneumonia (VAP)

Development of a new or worsening abnormal chest x-ray within 48 hours of mechanical ventilation

AND

Global Criteria

ONE or more of the following system criteria is present:

- Fever
- Decreased white blood cell count or increased white blood cell count
- Altered mental status: >70 years of age

AND

Pulmonary Specific Criteria

ONE or more of the following pulmonary specific criteria is met:

- Change in character of pulmonary secretions
- Onset of clinical criteria (shortness of breath, rales)
- Bronchial breath sounds
- Decreasing oxygenation

Note: Additional criteria includes laboratory evidence of infection

Adapted from Raoof et al. [31]

Figure 1. 2002 Centers for Disease Control and Prevention (CDC) definition for ventilator-associated pneumonia (VAP). Adapted from Raoof and Baumann.[34]

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associated with other complications related to mechanical ventilation beyond VAP,[44] the CDC convened a workgroup to examine these issues.[45] This workgroup was charged with improving the surveillance process for complications related to mechanical ventilation. The outcome from this workgroup was a new approach to the VAP definition that involved broader and different surveillance parameters than the previous VAP definition. The surveillance variables were intervention-based rather than disease-based and therefore encompassed more clinically relevant events (e.g., atelectasis), as well as nonpulmonary events (e.g., pulmonary edema).

This new approach used a broader term than VAP: VAE and required implementation of the National Healthcare Safety Network (NHSN), the CDC's new surveillance program in January 2013. In contrast to VAP, VAE includes complications related to mechanical ventilation with 3 different tiers of classifications for VAE (Fig. 2).[45–47] Rather than being disease-based, this new classification system relies on specific interventions for stratification.[48]

The foundational tier defines a ventilator-associated condition (VAC) as one that occurs when a patient, after at least 2 days of stable ventilator settings, experiences at least 2 days of deteriorating oxygenation that requires minimal daily increases in the fraction of inspired oxygen (FIO_2) or positive end-expiratory pressure. The next tier further delineates VAC into an infection-related VAC (IVAC), which meets the definition of a VAC with the additional component of an abnormal temperature or white blood cell count and the initiation of an antimicrobial agent that is continued for a minimum of 4 days. The last tier further delineates the etiology as a "possible" or "probable" VAP when the criteria for an IVAC, in conjunction with other laboratory evidence of an infection, is present.

One of the other criticisms concerning VAE reporting is that at times, studies are single center and/or retrospective[44,49] and may not be able to be extrapolated to other health care facilities and patient populations. Another concern is the acuity of patients in different facilities; for instance, a large university hospital versus a small rural hospital, and other conditions that could occur requiring an increase in ventilator support such as acute myocardial infarction, sepsis, pulmonary embolism, and pneumothorax, to name a few. A patient with abdominal sepsis that requires aggressive fluid administration may require ventilator changes that could meet the criteria of a VAE. Other circumstances that could also be labeled a VAE due to changes in ventilator settings could involve a patient from the ICU requiring operative intervention with massive fluid resuscitation or a patient requiring the closing of an open abdomen. These statistics also could be

I. Infection-related ventilator-associated complication (IVAC)

On or after calendar day 3 of mechanical ventilation and within 2 calendar days before or after the onset or worsening oxygenation, defined as daily minimal increase of:

Inspired oxygen (FiO_2) OR a daily minimum increase in positive end expiratory pressure (PEEP) > 3 cm of H_2O

AND

Both of the following clinical and treatment criteria:

Temperature > 38°C, OR

White blood cell count ≥12 999 cells/mm^3 or ≤4000 cells/mm^3.

AND

A new antimicrobial agent(s)* is started and continued ≥4 days.

II. Possible ventilator-associated pneumonia (VAP)

On or after calendar day 3 of mechanical ventilation and within 2 calendar days before or after the onset of worsening oxygenation, ONE of the following criteria is met:

1) Purulent respiratory secretions (positive Gram stain)

- Defined as secretions from the lungs, bronchi, or trachea that contain ≥25 neutrophils and ≤10 squamous epithelial cells per low power field [1pf, x 100].
- If the laboratory reports semi-quantitative thresholds, those results must be equivalent to the above quantitative thresholds.

OR

2) **Positive culture for a bacterial pathogen** (qualitative , semi-quantitative or quantitative of sputum*, endotracheal aspirate*, bronchoalveolar lavage*, lung tissue, or protected specimen brushing*

**Excludes the following non-pathogens:*

- Normal respiratory/oral flora, mixed respiratory/oral flora
- *Candida* species or yeast not otherwise specified
- *Coagulase-negative *Staphylococcus* species
- Enterococcus species

III. Probable ventilator-associated pneumonia (VAP)

On or after calendar day 3 of mechanical ventilation and within 2 calendar days before or after the onset of worsening oxygenation, ONE of the following criteria is met:

1) Purulent respiratory secretions (from one or more specimen collections, and defined as for possible VAP)

AND

One of the following:

- Positive culture of endotracheal aspirate*,≥10^5 CFU/ml or equivalent semi-quantitative result
- Positive culture of bronchoalveolar lavage*,≥10^4 CFU/ml or equivalent semi-quantitative result
- Positive culture of lung tissue,≥10^4 CFU/g or equivalent semi-quantitative result
- Positive culture of protected specimen brush*,≥10^3 CFU/ml or equivalent semi-quantitative result

OR

2) One of the following (without requirement for purulent respiratory secretions):

- Positive pleural fluid culture (where specimen was obtained during thoracentesis or initial placement of chest tube and NOT from an indwelling chest tube)
- Positive lung histopathology
- Positive diagnostic test for *Legionella* spp.
- Positive diagnostic test on respiratory secretions for influenza virus, respiratory syncytial virus, adenovirus, parainfluenza virus, rhinovirus, human metapneumovirus, coronavirus

Figure 2. Centers for Disease Control—2013 surveillance definitions for ventilator-associated pneumonia. Algorithm from Grgurich et al[46] (waiting on Copyright).

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manipulated by the choice of ventilator settings; for example, the use of Airway Pressure Release Ventilation and higher-than-necessary F_{IO_2} settings to avoid VAEs. These differences are likely to impact VAE rates, making comparative surveillance data from hospitals a challenge to compare. Figure 2 presents CDC 2013 surveillance definitions for VAP.

BENCHMARKING SHORTCOMINGS

The goal of benchmarking quality of care for pulmonary complications in mechanically ventilated patients has eluded quality and regulatory advocates for many years.[50–53] The previous definition and classification of VAP was largely based on subjective data: systemic signs, interpretation of chest radiograph, respiratory secretions, and microbiological interpretation, and has been shown to have low sensitivity, specificity, and positive predictive value.[34,54,55] Part of the purpose of shifting classification from the more subjective VAP to the more objective definitions of VAC, IVAC, and possible/probable VAP is in an attempt to improve interobserver reliability and allow for more uniform categorization.[45] The latter criteria would then encompass other complications of mechanical ventilation including but not limited to atelectasis and pulmonary edema. The intention is to create a database that will allow the critical care community to develop more accurate and uniform methods of prevention with interfacility reliability that correlates with improved patient outcomes, including hospital LOS and mortality.[45,56]

With the proposed new reporting criteria, reporting is on a voluntary basis, with the population targeted as adults in acute care facilities receiving >3 days of traditional mechanical ventilation. Patients receiving unconventional modes of mechanical ventilation, including high-frequency oscillatory ventilation or extracorporeal life support, are not included in the current reporting while receiving these modes of mechanical ventilation. Reporting can occur after ventilator management has shifted to a more traditional mode of mechanical ventilation. The emphasis of this reporting revolves around prevention and obtaining meaningful, objective data that can easily be tracked by a facility-appointed quality health administrator.[45] The NHSN proposes that with electronic medical records, data mining will now be easier and less labor intensive. This depends on many factors, including the capabilities of each facility's electronic medical records and workflow, because electronic medical records were not primarily designed for this type of data mining. To assist with reporting, the NHSN has on its Web site a VAC calculator and samples of flow sheets that can be used to track daily ventilator usage, changes to the positive end-expiratory pressure and F_{IO_2}, white blood cell count, temperature, and antimicrobial agents administered for suspected pulmonary infection.[b] The denominator of ventilator days is calculated at the same time each day, and a cumulative total is obtained once a month to provide an average of ventilator days for that time frame.[c]

There are concerns that the denominator can be manipulated by having a disproportionate number of patients who are extubated at day 3, thus increasing the total number of ventilator days and skewing the incidence to be lower. The surveillance data would more accurately reflect a truer incidence of complications if the actual hours required to be mechanically ventilated was a parameter. Furthermore, there is the concern of applying an automated computer-generated surveillance definition across institutions.[55] Application of this surveillance definition has the risk of missing a clinically significant VAP that may not require noteworthy alterations in ventilator settings to trigger it as an event. When Skrupky et al.[55] applied the NHSN surveillance definitions, only 14.5% of clinically significant VAPs as defined by the American College of Chest Physicians were diagnosed. There were some limitations to this study with retrospective application of the NHSN definitions rather than a prospective data collection that would allow a clinical assessment of VAP performed by clinicians to address its clinical relevance. In this study, the VAPs were clinically diagnosed rather than confirmed by the gold standard of histologic examination.[55] This one study emphasizes the importance of clinical evaluation and decision making based on experienced clinicians providing bedside care for the critically ill patient. This "judgment" based on experience should be recognized when applying a "stamp of quality" to these new definitions. In addition, clinicians within health care facilities and among different hospitals may have different preferences for ventilator modes and settings, techniques for weaning from mechanical ventilation, and decision making for further workup for infectious etiologies. These differences are likely to impact VAE rates, making comparative surveillance data from hospitals a challenge to compare.

The most likely controversial issue surrounding these newer NHSN definitions is the expected or acceptable VAC and IVAC/probable VAP rates. More data need to be collected surrounding the application of these new definitions, the impact they will have on facility ratings, and the issue of reimbursement has yet to be addressed.[34] Although the goal may be a zero incidence of VAC and IVAC/probable VAP, one may ask, "Is a goal of zero unobtainable using these new definitions?" More research needs to be done to better establish a reasonable rate of VAC and IVAC/probable VAP.[49] One of the other issues with changing the definitions is that it impedes comparison with historical data and thus may thwart further goals as hospitals attempt to institute measures and evaluate progress in process improvements.[49,50,57]

Klompas et al.[58] conducted a multicenter retrospective study evaluating the objective data contained in the VAE definition and found it a "superior predictor of hospital mortality" compared with the VAP definition. Interestingly, this study noted that the data collection process was quick, at an estimated 1.8 minutes per patient to apply the new definition versus 39 minutes per patient for the VAP definition. Note that the authors based this estimate on the experience from their own systems, which may not be available or applicable to another hospital system or electronic medical records. During their investigation, these authors also found the association of escalating ventilator settings with increased mortality with a reported reliability comparable with the correlation of Pao_2/F_{IO_2} ratios to mortality in traditional studies. There was little interfacility variability based on patient population and hospital size, and consistent VAC rates were found

[b]National Healthcare Safety Network Surveillance for Ventilator-associated Events. Available at: http://www.cdc.gov/nhsn/acute-care-hospital/vae/. Accessed September 26, 2014.

[c]CDC Device-associated Module (VAE). Available at: http://www.cdc.gov/nhsn/PDFs/pscManual/10-VAE_FINAL.pdf. Accessed October 2, 2014.

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across institutions (VAP rate 0%–4% and VAC rates 7%–9%). A subsequent retrospective review of >8100 patients by the same lead author found the incidence of VAP rate ranged from 0.2 to 26.3 per 1000 ventilator days, depending on subjective interpretation of leukocytosis, purulent sputum, and microbiologic analysis. In the same patient analysis, the VAC incidence was 12 per 1000 ventilator days.[54]

CONCLUSIONS

The classification of complications from mechanical ventilation has shifted from the more subjective VAP to more objective definitions of VAE, VAC, IVAC, and possible/probable VAP. The purpose of this change in focus is to have better interobserver reliability and more uniform categorization. It is unclear, however, whether this new taxonomy will accomplish this goal, because the evidence can still be manipulated. Furthermore, the ventilator care bundles lack definitive evidence to support their use for preventing VAP. More studies are needed to determine their usefulness with these new definitions of VAE.

We seem to have an ongoing quagmire that may be easily lost in translation of the new definitions. The algorithm used for VAE surveillance is not meant to provide a clinical definition or to direct clinical care, yet it remains to be seen whether the ultimate goal of reducing complications of mechanical ventilation can be appreciated from this new system or whether we will become "data rich and information poor?"

DISCLOSURES

Name: Peggy White, MD.
Contribution: This author attests to the integrity of the manuscript as being original work. Her contributions include review of articles for this manuscript, data analysis, and manuscript preparation. This author helped prepare the manuscript.
Attestation: Peggy White approved the final manuscript.
Name: Elizabeth Mahanna, MD.
Contribution: This author attests to the integrity of the manuscript as being original work. Her contributions include review of articles for this manuscript, data analysis, and manuscript preparation. This author helped prepare the manuscript.
Attestation: Elizabeth Mahanna approved the final manuscript.
Name: Peggy R. Guin, PhD, ARNP, CNS-BC, CNRN, SCRN.
Contribution: This author attests to the integrity of the manuscript being original work. She reviewed articles for this manuscript and contributed to the writing of the manuscript. She made substantial contributions to help prepare the final manuscript.
Attestation: Peggy R. Guin approved the final manuscript.
Name: Vaibhav Bora, MBBS.
Contribution: This author assisted by analyzing studies for inclusion and helped prepare the manuscript.
Attestation: Vaibhav Bora approved the final manuscript.
Name: Brenda G. Fahy, MD.
Contribution: This author outlined the scope of the manuscript, reviewed pertinent literature, and prepared the manuscript. She made substantial contributions to manuscript preparation. She is the archival author.
Attestation: Brenda G. Fahy approved the final manuscript. She attests to the integrity of the original data and the analysis reported in this manuscript.
This manuscript was handled by: Sorin J. Brull, MD.

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