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Ventilator-associated events: A new outcome measure

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Continuing Nursing Education

Learning objectives

1. Differentiate the three tiers used to identify ventilator-associated events (VAEs).
2. Identify key elements of VAE surveillance.
3. Discuss the practice implications of VAEs.

Purpose/goal: To provide nurses with information on how to implement surveillance for and prevent ventilator-associated events.

Marinski and the planner of this CNE activity have disclosed no relevant financial relationships with any commercial companies pertaining to this activity. Sole has disclosed she received royalties from sales of her book related to the topic of this article. The article has been peer reviewed to ensure lack of bias. See the end of this article to learn how to earn 1.37 CNE credit.

Expiration: 8/1/17

Although mechanical ventilation saves many lives, it can lead to serious complications, which may result in longer mechanical ventilation periods, longer ICU and hospital stays, higher healthcare costs, and increased risk of disability and death. Ventilator-associated pneumonia (VAP) is one of the most common hospital-acquired infections. Nurses have been implementing targeted interventions to prevent VAP for years. The process is complex, costly, and time intensive.

Until recently, VAP surveillance relied on both subjective and objective criteria. Subjective data—in particular, identifying a new infiltrate on chest X-ray—often led to an inaccurate diagnosis of VAP and potential underreporting. Different clinicians may interpret X-rays differently, resulting in variable results. What's more, many critically ill patients develop chest infiltrates secondary to systemic inflammatory response syndrome, not pneumonia. Because benchmarking was creating using such subjective data, nursing interventions to prevent VAP may be inadequate. Better standardization of surveillance for VAPs and other ventilator-associated events (VAEs) will help drive evidence-based practice and improved quality of care.

New surveillance approach

In January 2013, the National Healthcare Safety Network (NHSN) implemented a new surveillance approach for VAEs. The first step in this approach is to identify ventilator-associated conditions (VACs). Surveillance criteria were developed by the Surveillance Identification Working Group of key stakeholders convened by the Centers for Disease Control and Prevention (CDC). The Working Group developed VAE criteria to promote more accurate identification of adverse outcomes of mechanical ventilation. Negative outcomes go beyond VAP to include pulmonary edema, fluid overload, atelectasis, and acute respiratory distress syndrome.

The event algorithm used with the new surveillance approach relies on readily available objective data and potentially can be automated with data recorded in the electronic medical record (EMR). This automation could improve outcome measurement and help decrease labor costs related to surveillance.

Studies published in 2013 report VAC rates ranging from 10% to 25%, with incidences of 10 to 13.8 cases per 1,000 ventilator days. Patients with VACs have more days on mechanical ventilation, longer ICU and hospital stays, and higher mortality than those without VACs. Nursing has an opportunity to improve these potentially preventable negative outcomes.

Although VAEs currently aren't reported publicly, criteria are designed for future reporting of VACs and infection-related VACs (IVACs), and are likely to affect pay-for-performance. VAP surveillance is designed for internal quality-improvement initiatives. Surveillance isn't recommended for clinical management.

Three-tiered approach to identifying VAEs

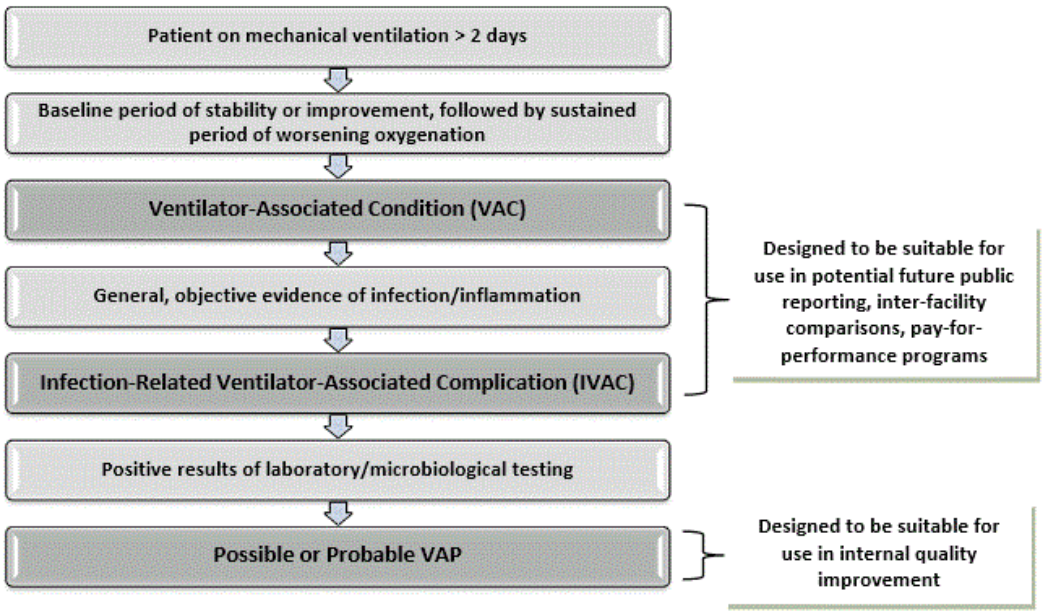
A three-tiered approach simplifies VAE identification.

- Tier 1 focuses on identifying a VAC from worsening oxygenation status that necessitates increased ventilator settings for oxygen (FiO_2), positive end-expiratory pressure (PEEP), or both.
- Tier 2 assesses for IVACs. Objective changes in temperature and/or white blood cell (WBC) counts along with new antibiotic treatment are used to determine an IVAC.
- Tier 3 focuses on possible or probable VAP, as determined by such microbiologic tests as Gram stain and cultures.

The first box below summarizes the VAE surveillance definition algorithm. The second box shows the full algorithm.

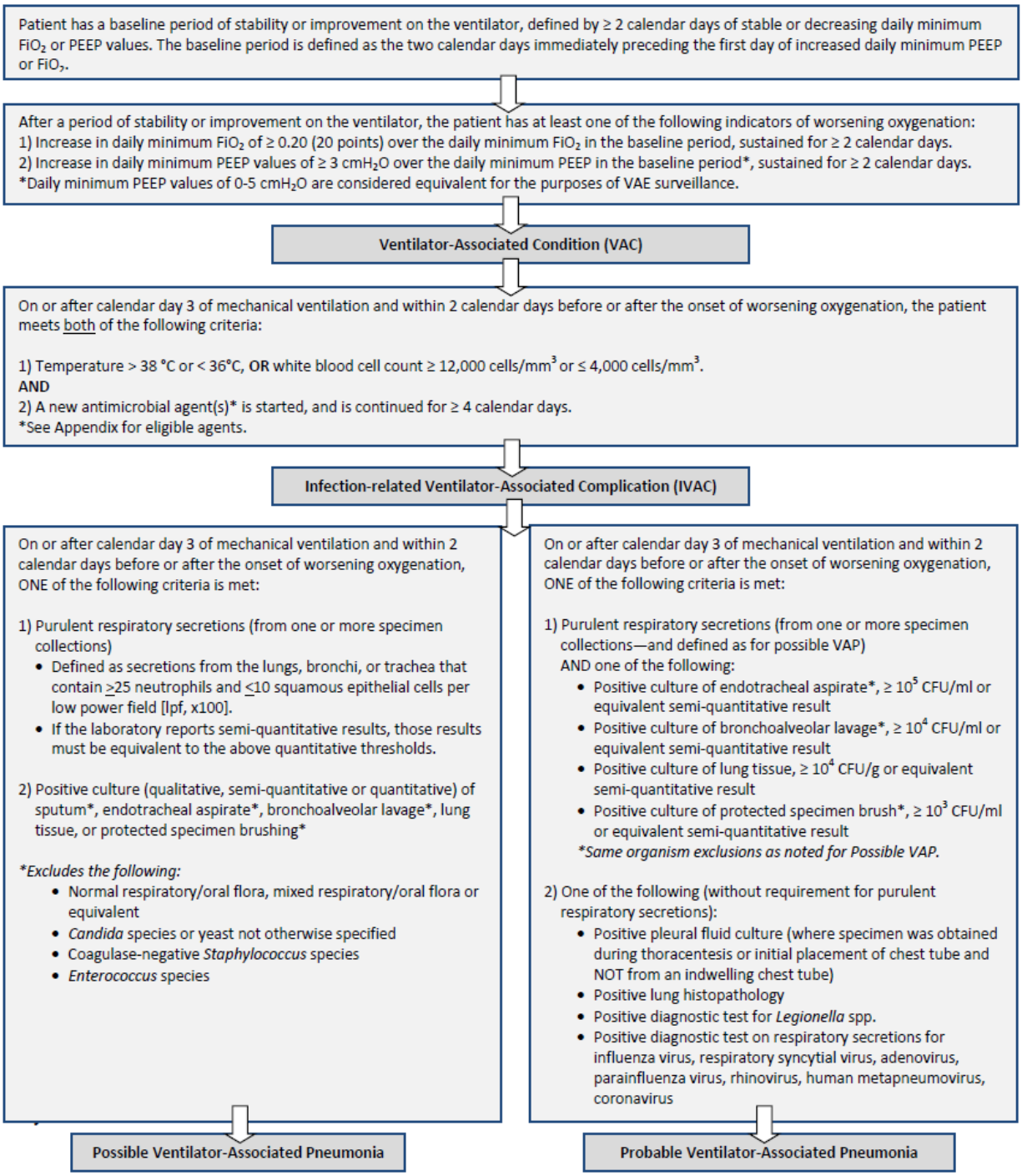
VAE surveillance definition algorithm: Summary

The VAE definition algorithm has three tiers. Tier 1 focuses on respiratory status; tier 2, infection and inflammation; and tier 3, VAP.



Source: Centers for Disease Control and Prevention. www.cdc.gov/nhsn/PDFs/pscManual/10-VAE_FINAL.pdf

Detailed VAE surveillance algorithm



Source: Centers for Disease Control and Prevention. /www.cdc.gov/nhsn/PDFs/pscManual/10-VAE_FINAL.pdf

Surveillance inclusion and exclusion

The Working Group initially designed the new VAE surveillance approach for patients ages 18 and older in acute-care hospitals, long-term acute-care hospitals, and inpatient rehabilitation facilities. Revised 2014 criteria are designed for implementation in adult inpatient locations; surveillance includes patients younger than age 18 who are treated in these adult units. For surveillance in neonatal and pediatric intensive care units, existing NHSN criteria for VAP are used.

Surveillance covers patients receiving a traditional ventilation mode via an endotracheal tube or a tracheostomy. Traditional modes include intermittent mandatory, volume-control, and pressure-control ventilation. Surveillance criteria also include patients receiving nitric oxide or epoprostenol therapy and those with prone positioning as part of treatment. Patients treated with high-frequency ventilation or extracorporeal membrane oxygenation are excluded from surveillance.

Some patients receive airway pressure-release ventilation (APRV) or related modes (bilevel positive airway pressure, BiVent, biphasic, pressure control ventilation with pressure support, and DuoPAP). In APRV and related modes, PEEP isn't adjusted as in traditional mechanical ventilation, and worsening oxygenation is gauged only from FiO_2 changes.

Data collection

VAE surveillance data are collected daily. Although most surveillance is done retrospectively, data can be collected prospectively to identify events earlier. Spreadsheets or other types of worksheets can be used to collect data. On its website, CDC provides a sample worksheet that can be adapted for daily use. (See the box below.) In this article, we use the worksheet to record data for Mrs. K, whose case we discuss later in this article.

CDC data collection worksheet

The data collection worksheet below aids identification of ventilator-associated events. The authors have added Mrs. K's data to the worksheet.

Ventilator-Associated Event Data Collection Worksheet

PATIENT ID Mrs. K

		Step 1: VAC (change in A or B)		Step 2: IVAC (VAC, plus C or D, and E)					Step 3: PoVAP (IVAC, plus F or G) —OR— PrVAP (IVAC, plus [F and Gii] or IVAC, plus H)						
		A.	B.	C. Temp		D. WBC		E.	F.	G. Positive culture[b,c]		H. Other positive PrVAP criteria[a]			
Date	Vent Day	PEEP Min	FiO_2 Min	Min [<36°C]	Max [>38°C]	Min [≤4K]	Max [≥12K]	QAD (✓)	Purulent respiratory secretions[a] (✓)	i. Any sputum cx, or qual cx of BAL, ETA, PSB, lung tissue (✓)	ii. Meets semi-quant or quant criteria (BAL, PSB, ETA, lung tissue cx)[d] (✓)	Pleural fluid (✓)	Path (✓)	*Legionella* or viral diagnostic (✓)	VAE (VAC, IVAC, PoVAP, PrVAP)
12/18	1	5	.40												
12/19	2	5	.40												
12/20	3	5	.40		38.5		10.0K								
12/21	4	8	.40		39.0		10.9K		x	x	Endotracheal aspirate 10^3				Possible VAP
12/22	5	8	.40					x							
12/23	6	8	.40					x							
12/24	7	5	.40					x							
								x							

Source: Centers for Disease Control and Prevention.
www.cdc.gov/nhsn/PDFs/vae/VAE_DataCollectionWorksheet_FINAL_20121107.pdf

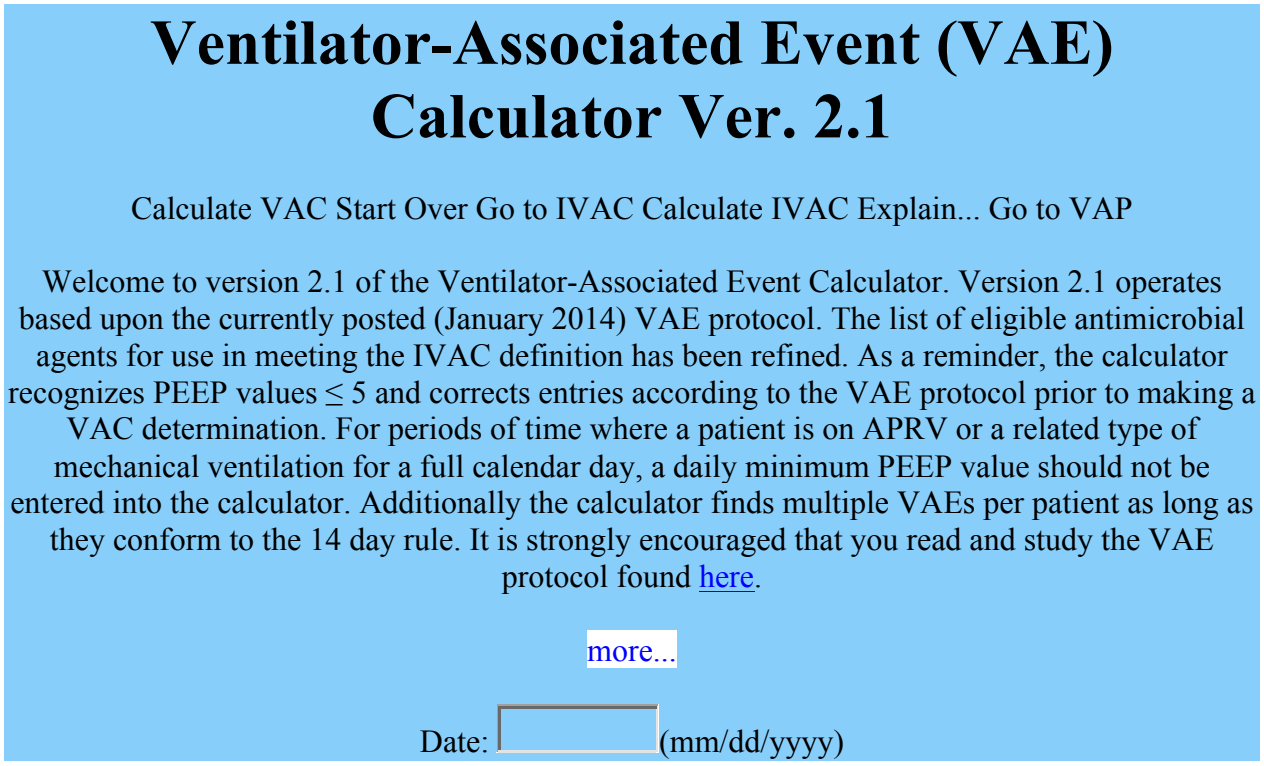
Until a VAC is identified, only the daily minimum FiO_2 and PEEP are recorded. Once a VAC is identified, the patient's temperature, WBC count, and respiratory specimen Gram staining and culture results are assessed. The worksheet can be modified easily for less complexity.

CDC calculator

The CDC provides an online calculator for identifying VAEs. In this article, the authors describe how they use this calculator in case scenarios.

CDC VAE calculator

This screenshot from www.cdc.gov/nhsn/VAE-calculator/vae_multi_v1.html shows the CDC's VAE calculator, which is based on the same three tiers used to identify VAC, IVAC, and possible or probable VAP.



Ventilator-Associated Event (VAE) Calculator Ver. 2.1

Calculate VAC Start Over Go to IVAC Calculate IVAC Explain... Go to VAP

Welcome to version 2.1 of the Ventilator-Associated Event Calculator. Version 2.1 operates based upon the currently posted (January 2014) VAE protocol. The list of eligible antimicrobial agents for use in meeting the IVAC definition has been refined. As a reminder, the calculator recognizes PEEP values ≤ 5 and corrects entries according to the VAE protocol prior to making a VAC determination. For periods of time where a patient is on APRV or a related type of mechanical ventilation for a full calendar day, a daily minimum PEEP value should not be entered into the calculator. Additionally the calculator finds multiple VAEs per patient as long as they conform to the 14 day rule. It is strongly encouraged that you read and study the VAE protocol found here.

more...

Date: (mm/dd/yyyy)

Print Close

Source: Centers for Disease Control and Prevention.

Tier 1: Identifying VAC

Before a VAC is identified, the patient must have at least 2 calendar days with stable or decreasing FiO_2 or PEEP settings. A VAC is identified if, after this baseline period, the patient needs an increase in the minimum daily FiO_2 of 0.20 or more than baseline, or if PEEP must be increased 3 cm H_2O or more. Therefore, the patient must be ventilated for at least 4 days before a VAC can be determined; the earliest a VAC can be identified is day 3. Because many patients receive small amounts of physiologic levels of

PEEP (up to 5 cm H_2O), VAC criteria dictate that the minimum must be increased to 8 cm H_2O for at least 2 days.

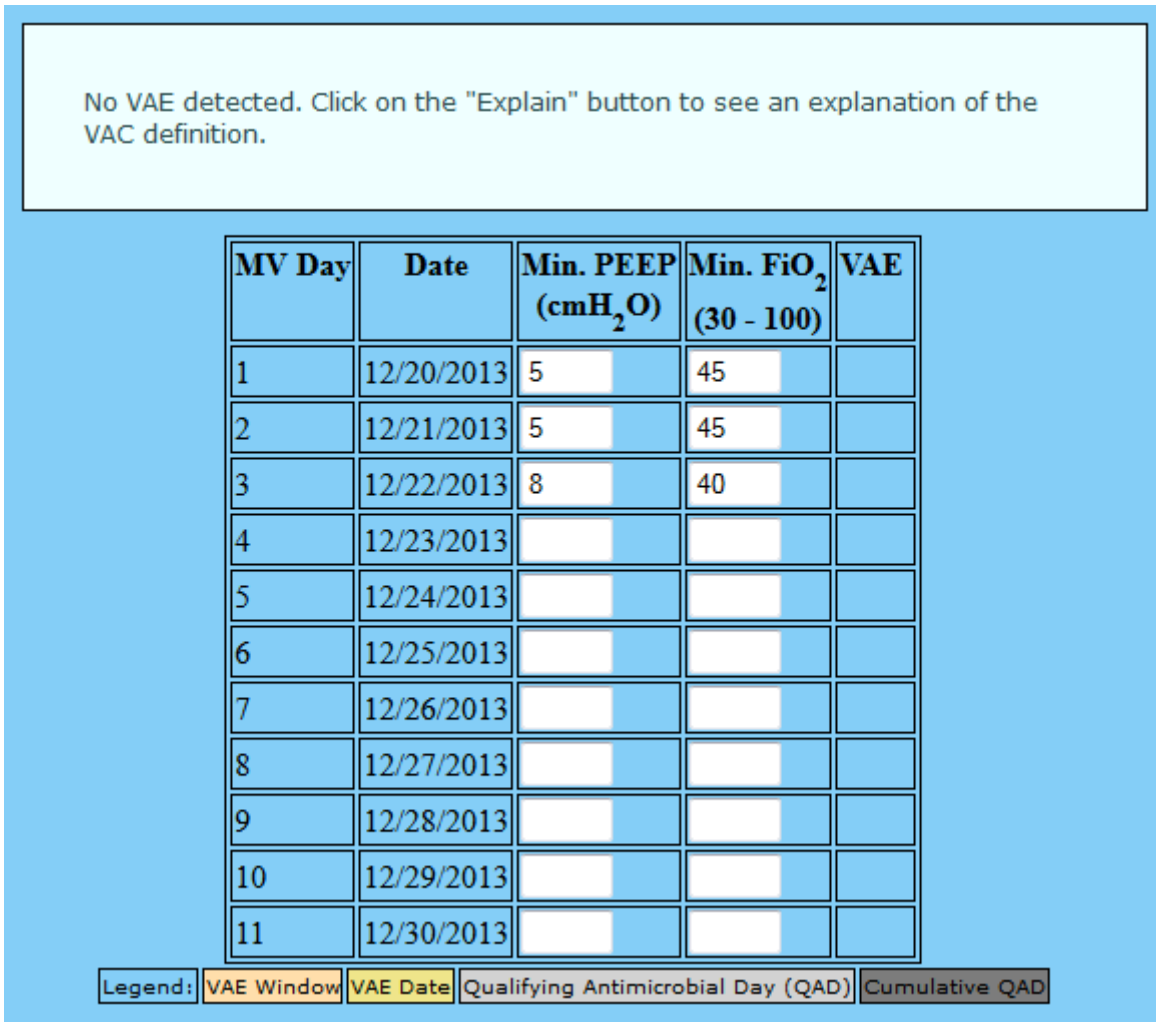
The case of Mr. J

Mr. J, age 63, is admitted to the cardiovascular surgical unit after mitral valve repair. He has a history of hypertension and heart failure. Postoperatively, he can't be extubated and is receiving mechanical ventilation with an FiO_2 of 0.45 and PEEP of 5 cm H_2O. On day 2, his ventilator settings are the same. On day 3, FiO_2 is decreased to 0.35 while PEEP is increased to 8 cm H_2O. On day 4, Mr. J is extubated.

Does the PEEP increase from 5 to 8 cm H_2O mean Mr. J has a VAC? No, because he was extubated on day 4 and not treated for at least 2 days at the higher PEEP value. The VAE calculator shows changes in his ventilator settings and surveillance results. (See the box below.)

Does Mr J. meet VAC criteria?

The authors have input Mr. J's PEEP and FiO_2 values into the VAE calculator, which shows he doesn't meet VAC criteria.



Calculator based on www.cdc.gov/nhsn/VAE-calculator/vae_multi_v1.html

The case of Mrs. K, part 1

Mrs. K, age 75, was admitted to the medical ICU after a cardiac arrest in the emergency department. Within 2 minutes of the arrest, she was treated successfully with an automatic external defibrillator and subsequently required intubation and mechanical ventilation. Initial oxygenation settings were FiO_2 0.40 and PEEP 5 cm H_2O. She couldn't be weaned from the ventilator and, on day 4, required a PEEP adjustment to 8 cm H_2O to maintain O_2 saturation above 90%. Her PEEP stay at 8 cm H_2O for 3 days before she could be weaned from the ventilator. The VAE calculator was used to determine if Mrs. K had a VAC. (See the box below.)

Does Mrs K. meet VAC criteria?

The authors input Mrs. K's PEEP and FiO_2 values into the VAE calculator, which shows she had developed a VAC. She had 3 days at stable ventilator settings followed by 2 days at higher PEEP settings.

MV Day	Date	Min. PEEP (cmH_2O)	Min. FiO_2 (30 - 100)	VAE
1	12/18/2013	5	40	
2	12/19/2013	5	40	
3	12/20/2013	5	40	
4	12/21/2013	8	40	VAC
5	12/22/2013	8	40	
6	12/23/2013	8	40	
7	12/24/2013	5	40	
8	12/25/2013			
9	12/26/2013			
10	12/27/2013			
11	12/28/2013			
12	12/29/2013			
13	12/30/2013			

Legend: VAE Window | VAE Date | Qualifying Antimicrobial Day (QAD) | Cumulative QAD

Calculator based on www.cdc.gov/nhsn/VAE-calculator/vae_multi_v1.html

Tier 2: Identifying IVAC

After VAC detection, the next step is to determine if the condition is related to an infection. This requires assessment of objective measures that commonly indicate an infection. The patient must have a change either in temperature (above 38° C [100.4° F] or below 36° C [96.8° F]) or in the WBC count ($\geq$ 12,000 cells/mm^3 or $\leq$ 4,000 cells/ mm^3). Also, the patient must be started on a new antimicrobial agent that's continued for 4 or more calendar days. These criteria must be met on or after day 3 of mechanical ventilation and within 2 calendar days before or after onset of worsening oxygenation, known as the 5-day IVAC window. For a list of eligible antimicrobial agents, visit www.cdc.gov/nhsn/PDFs/pscManual/10-VAE_FINAL.pdf#page=23.

Mrs. K, continued

Mrs. K developed a fever on days 3 and 4 of mechanical ventilation. Her WBC count didn't exceed the threshold of 12,000 cells/mm^3. As ordered, the nurse obtained an endotracheal specimen for Gram stain and culture. The Gram stain was positive for purulence and Mrs. K was started on cefipime, which was continued for 5 days.

Mrs. K has an IVAC, as indicated by a temperature above 38° C (100.4° F) and administration of a new qualifying antibiotic for at least 4 days. The VAE calculator identifies the IVAC. (See the box below.)

Identifying Mrs. K's IVAC

The VAE calculator with new data for Mrs. K shows she has developed an IVAC.

MV Day	Date	Hide... Min. PEEP (cmH_2O)	Hide... Min. FiO_2 (30 - 100)	VAE	T<36° or T>38°	WBC≤4,000 or WBC≥12,000 cells/mm^3	Add... Remove... CEFEPIME	QAD
1	12/18/2013	5	40		☐	☐	☐	
2	12/19/2013	5	40		☐	☐	☐	
3	12/20/2013	5	40		☑	☐	☐	
4	12/21/2013	8	40	IVAC	☑	☐	☐	
5	12/22/2013	8	40		☐	☐	☑	yes
6	12/23/2013	8	40		☐	☐	☑	yes
7	12/24/2013	5	40		☐	☐	☑	yes
8	12/25/2013				☐	☐	☑	yes
9	12/26/2013				☐	☐	☑	yes
10	12/27/2013				☐	☐	☐	

Legend: VAE Window | VAE Date | Qualifying Antimicrobial Day (QAD) | Cumulative QAD

Calculator based on www.cdc.gov/nhsn/VAE-calculator/vae_multi_v1.html

Tier 3: Identifying possible or probable VAP
The next step after VAC detection is to determine if the patient has possible or probable VAP. For a possible VAP, the patient must have purulent secretions or a positive respiratory specimen culture within the 5-day window of worsening oxygenation. Purulent secretions are determined from a Gram stain, not from yellow or green respiratory secretions. Purulence criteria are secretions that contain 25 or more neutrophils and 10 squamous or fewer epithelial cells per low power field microscope. If a semiquantitative Gram stain is done, purulence is defined as 4+ neutrophils and no more than 2+ squamous epithelial cells.

Respiratory cultures can be done on specimens of sputum, endotracheal aspirate, bronchoalveolar lavage (BAL), protected specimen brushing (PSB), or lung tissue. A positive culture may be qualitative, semiquantitative, or quantitative. Certain microorganisms are excluded if they're positive on culture—normal respiratory flora, *Candida* species or yeast, coagulase-negative *Staphylococcus* species, and *Enterococcus* species. However, these same organisms are considered positive for probable or possible VAP if cultured from pleural fluid or lung tissue.

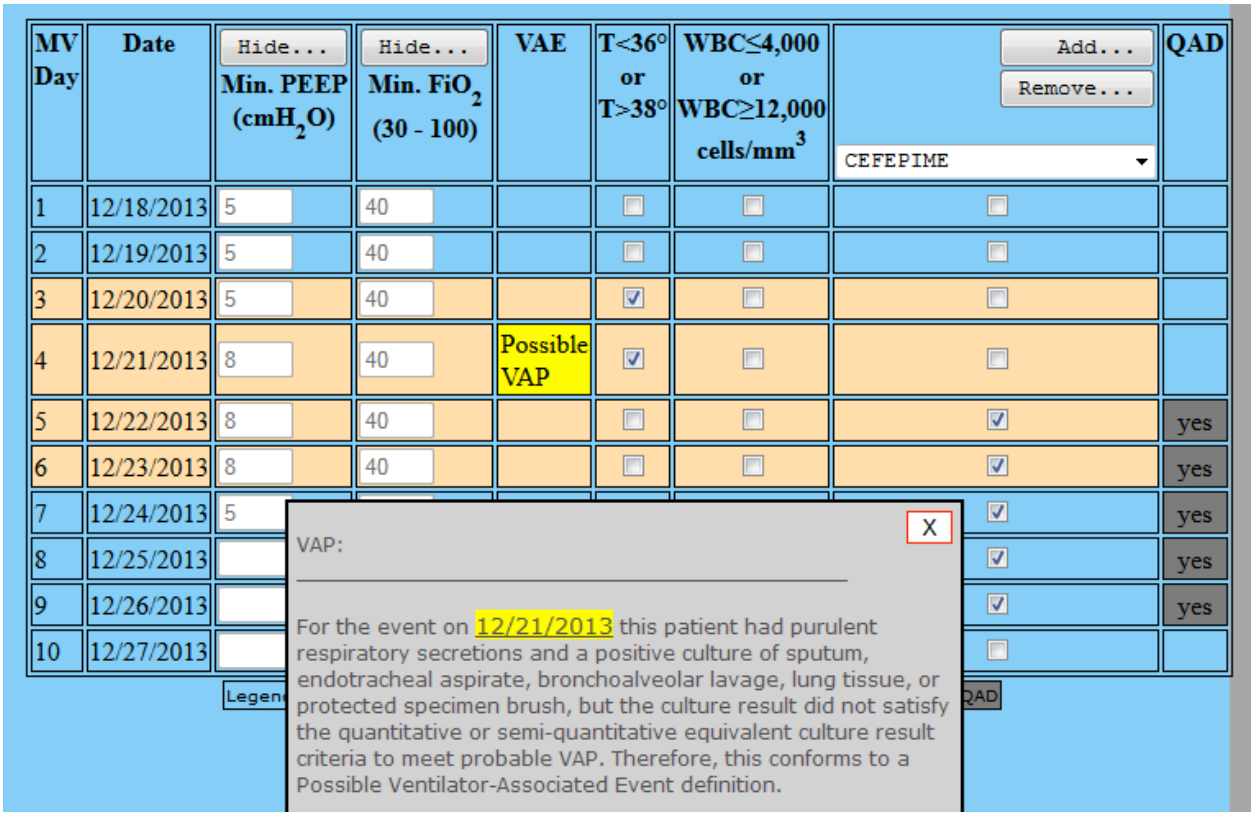
To qualify for a probable VAP, the patient must have purulent secretions within the 5-day window and quantitative analysis (or an equivalent semiquantitative result) of a respiratory specimen that meets colony-forming unit (CFU) thresholds, as determined by specimen type:

- endotracheal aspirate $\geq 10^5$ CFU/mL
- BAL $\geq 10^4$ CFU/mL
- PSB $\geq 10^3$ CFU/mL
- lung tissue $\geq 10^4$ CFU/mL.

Some laboratory results don't require purulent secretions. These include a positive culture of pleural fluid from thoracentesis, positive lung histopathology, positive *Legionella* species test, and a positive diagnostic test on respiratory secretions for such viruses as influenzae and respiratory syncytial virus.

Mrs. K, continued
Mrs. K's endotracheal aspirate culture groww *Pseudomonas aeruginosa* at 10^3 CFU/mL. The positive culture indicates possible (not probable or definite) VAP because it doesn't meet the threshold for endotracheal aspirate cultures. (See the box below.)

Possible VAP for Mrs. K
The new data entered into the VAE calculator show that although Mrs. K's sputum culture was purulent, the amount of bacteria in the specimen didn't meet the threshold for probable VAP.



Calculator based on www.cdc.gov/nhsn/VAE-calculator/vae_multi_v1.html

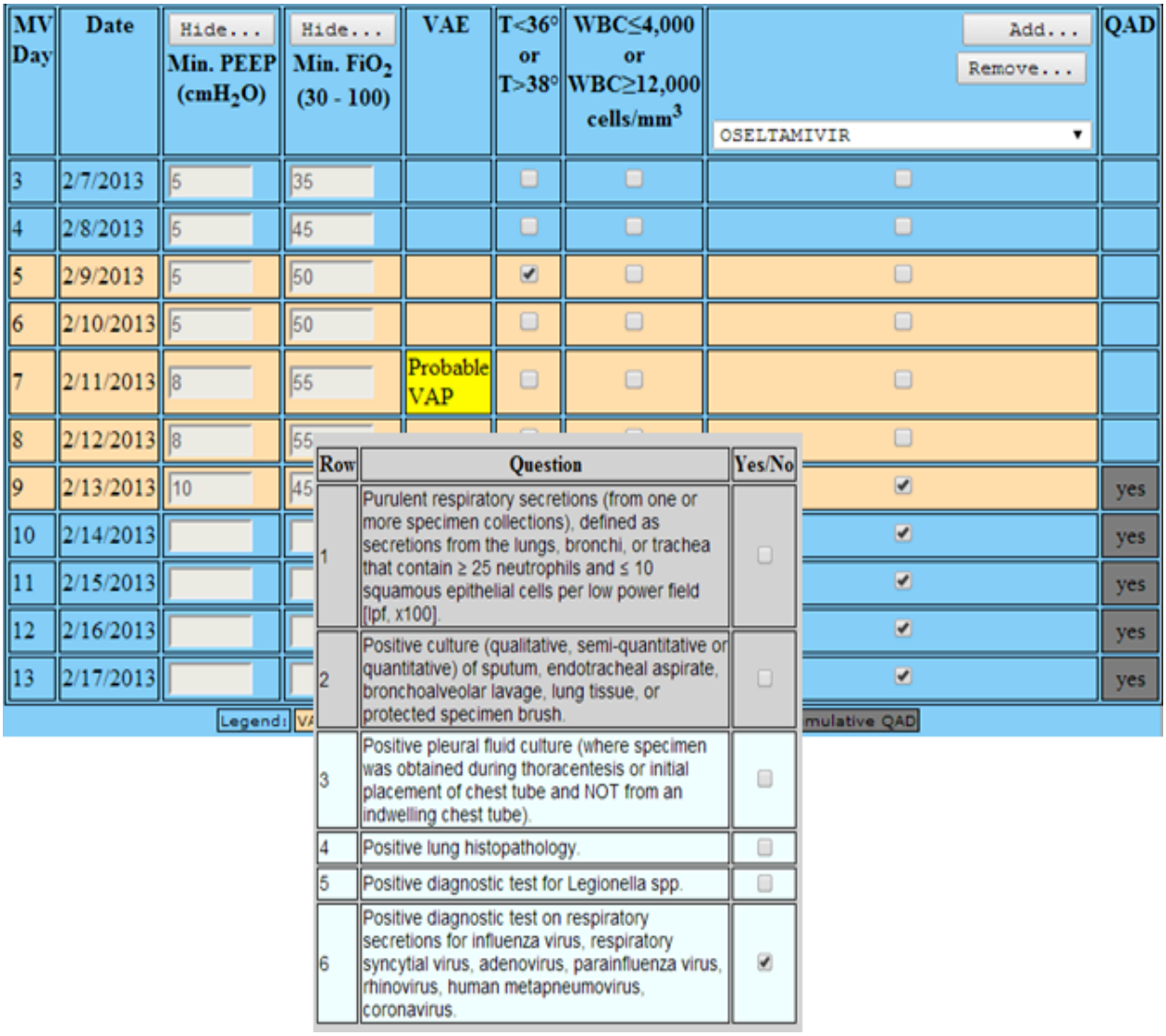
The case of Mr. B
Mr. B, age 65, has a primary medical history of lymphoma. He is admitted to the medical ICU for hypotension after presenting to the ED with nausea, vomiting, and diarrhea. He also has a productive cough.

In the ICU, he is intubated and mechanically ventilated for respiratory distress within 24 hours. His rapid influenza screen is negative. Initial ventilator settings are FiO_2 0.70 and PEEP 5 cm H_2O. On days 2 and 3, FiO_2 is decreased to 0.35. But on days 4 and 5, Mr. B requires an increase to 0.45, then to 0.50.

On day 7, he meets VAC criteria because his PEEP is increased from 5 to 8 cm H_2O. He meets IVAC criteria because his temperature exceeds 38° C (100.4° F) and he receives a new qualifying antibiotic within the 5-day window.

The next step is to evaluate him for VAP. Because Mr. B had a positive influenza culture within the 5-day window, he meets the criteria for probable VAP. (See the box below.)

Probable VAP for Mr. B
Data entered into the VAE calculator show Mr. B has probable VAP. He tests positive for influenza virus. (*Note:* Purulent respiratory secretions aren't required to qualify for influenza.)



MV Day	Date	Hide... Min. PEEP (cmH_2O)	Hide... Min. FiO_2 (30 - 100)	VAE	T<36° or T>38°	WBC≤4,000 or WBC≥12,000 cells/mm^3	Add... Remove... OSELTAMIVIR	QAD
3	2/7/2013	5	35		☐	☐	☐	
4	2/8/2013	5	45		☐	☐	☐	
5	2/9/2013	5	50		☑	☐	☐	
6	2/10/2013	5	50		☐	☐	☐	
7	2/11/2013	8	55	Probable VAP	☐	☐	☐	
8	2/12/2013	8	55				☐	
9	2/13/2013	10	45				☑	yes
10	2/14/2013						☑	yes
11	2/15/2013						☑	yes
12	2/16/2013						☑	yes
13	2/17/2013						☑	yes

Legend: VA... mulative QAD

Row	Question	Yes/No
1	Purulent respiratory secretions (from one or more specimen collections), defined as secretions from the lungs, bronchi, or trachea that contain ≥ 25 neutrophils and ≤ 10 squamous epithelial cells per low power field [lpf, x100].	☐
2	Positive culture (qualitative, semi-quantitative or quantitative) of sputum, endotracheal aspirate, bronchoalveolar lavage, lung tissue, or protected specimen brush.	☐
3	Positive pleural fluid culture (where specimen was obtained during thoracentesis or initial placement of chest tube and NOT from an indwelling chest tube).	☐
4	Positive lung histopathology.	☐
5	Positive diagnostic test for Legionella spp.	☐
6	Positive diagnostic test on respiratory secretions for influenza virus, respiratory syncytial virus, adenovirus, parainfluenza virus, rhinovirus, human metapneumovirus, coronavirus.	☑

Calculator based on www.cdc.gov/nhsn/VAE-calculator/vae_multi_v1.html

Implementing VAE surveillance

VAE surveillance is a new concept. Hospitals and ICUs that previously saw drastic reductions in their VAP rates using traditional surveillance may be shocked when the new NHSN surveillance system identifies new cases and higher VAP rates. Because VAE surveillance identifies pulmonary complications in addition to VAP (including atelectasis, acute respiratory distress syndrome [ARDS], and pulmonary edema), higher rates should be expected. Case review by critical care team members, including infection preventionists, can help identify causes, potential nursing interventions, and additional prevention efforts needed.

All healthcare team members who care for ventilated patients should receive education about the new NHSN surveillance and criteria. This can be done through scheduled multiprofessional educational sessions using case studies. The CDC website offers resources that can help educators and infection preventionists plan educational sessions. (See www.cdc.gov/nhsn/acute-care-hospital/vae/.)

Other critical implementation steps include:

- determining who will conduct surveillance—infection preventionists, respiratory care practitioners, or others
- determining if surveillance should be done prospectively (for early VAE identification) or retrospectively
- developing the tools needed for surveillance; tools available on the CDC website can be used or modified
- once data are collected, sharing findings with frontline clinicians who care for ventilated patients. Posting VAP rates is common in many units during VAP surveillance. Implementing similar efforts to share and trend data with staff members should be considered.

Practice implications

"One-size-fits-all" VAP prevention efforts aren't adequate for addressing VAE. The ventilator intervention bundle nurses have been using for years includes elevating the head of the bed, performing regular antiseptic oral care, assessing daily for readiness to wean from mechanical ventilation, stress-ulcer prophylaxis, and venous thromboembolism prevention. These interventions should be continued—but additional ones may be needed to address other causes of VAE. For example, early mobility, turning, and pulmonary hygiene (such as suctioning) may be required to prevent atelectasis. Careful fluid intake and output monitoring and assessment of lung sounds and pulmonary secretions can help identify and prevent fluid overload. Daily assessment of the PaO_2/FiO_2 ratio may help slow the trend toward developing ARDS. Crucially, patients should be treated therapeutically without considering VAE rates.

Risk factors for VAE include:

- benzodiazepines given before intubation
- greater opioid exposure
- administration of paralytics.

Strategies to reduce the risk of VAEs associated with these medications include use of sedation scales to titrate sedation medications and collaboration with team members, including intensivists and pharmacists, to determine medication needs

Facilities can test surveillance approaches using the CDC calculator. Consider checking findings from those conducting surveillance with 10% of patients. If your case is complex, you can post questions on the CDC website.

Identify causes of VAEs in your facility's patient populations and potential prevention efforts. Consult clinical nurse specialists, if available for your unit, to help identify appropriate nursing interventions. Work with information systems staff to identify strategies for automating data collection. Because much data is available from the EMR, automation can provide real-time surveillance of actual and potential VAE cases.

Controversies

Since VAE surveillance has been implemented, some researchers and practitioners have questioned whether the criteria accurately identify VAP. They report little agreement with VAP as identified with the new criteria compared to previous criteria, and contend that chest X-rays add important diagnostic information. Using statistical models, they note that the new criteria are prone to manipulation of PEEP, FiO_2, or both. (Theoretically, the revised criteria have been developed so the system can't be gamed. But it's possible for units to adjust $Fi\,O_2$ or PEEP in smaller increments to avoid VAE detection.) However, these researchers have focused solely on VAP and haven't recognized the importance of identifying complications that result in oxygenation changes.

Here to stay
The new NHSN surveillance approach—based on a streamlined, objective algorithm that's easily implemented—helps clinicians more accurately detect and manage VAEs and VACs. What's more, the EMR can be used to automate VAE detection. Not only is VAE surveillance here to stay; it's likely to become a public reporting measure.

Mary Lou Sole is an interim dean and Orlando Health Distinguished Professor at the University of Central Florida College of Nursing in Orlando. Amy Marinski is an infection preventionist at Orlando Health in Orlando, Florida.

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