Ventilator-Associated Events: Background, Definitions and Surveillance Methods

Shelley S. Magill, MD, PhD
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Overview: the Who, What, When, Why and How of VAE (not necessarily in that order)

- Why “Ventilator-Associated Events” (VAE)?
  - Background and rationale for VAE surveillance
- Who is eligible for VAE surveillance, and when will it be available in the NHSN application?
- What is VAE?
  - Surveillance definitions
- How do I prepare for and conduct VAE surveillance, and what key terms do I need to know?
  - Pearls and pitfalls of VAE surveillance
  - Denominators and VAE rate calculations
  - Tools
  - Take-home points
WHY VAE?
BACKGROUND AND RATIONALE

The Problem

- **Ventilator-associated pneumonia (VAP) is an important complication of mechanical ventilation**
  - But other bad things also happen to patients on ventilators
- **No valid, reliable definition for VAP**
  - Need more accurate diagnostics ...
  - Until those are available, how do we conduct surveillance and track prevention progress?
- **Commonly used definitions include subjective elements and are neither sensitive nor specific for VAP**
  - Not ideal in an era of public reporting of healthcare-associated infection (HAI) rates, comparisons among facilities, pay-for-performance programs
- **Need a new approach**
NHSN Pneumonia (PNEU) Surveillance Definitions

- Combination of x-ray, signs/symptoms and laboratory criteria
  - Three sets of criteria: PNU1, PNU2, PNU3
    - Extra sets of “alternate” PNU1 criteria for children (>1 or ≤12 years) and infants (≤1 year)
  - Chest imaging findings are required
  - Signs and symptoms of pneumonia are required
  - Laboratory evidence is optional—but should be used if available

- To be “ventilator-associated” —
  - Endotracheal tube (ETT)/ventilator must have been in place at some time during the 48 hours preceding or at time of PNEU onset
  - No required amount of time that the ETT/ventilator must have been in place for a PNEU to count as a VAP


Limitations of Current VAP Definitions

- Current definitions (e.g., definitions used for surveillance in NHSN, Clinical Pulmonary Infection Score, European surveillance definitions, etc.) all use combinations of criteria:
  - Chest x-ray
    - Lack specificity for VAP
    - Interobserver variability
    - Not within purview of IP expertise
  - Clinical signs/symptoms
    - Lack sensitivity and specificity
    - Some are highly subjective
    - Documentation varies
  - Microbiological evidence
    - Lack sensitivity and specificity
    - Practices vary among providers
    - Controversy about best practices

References include but are not limited to the following:
VAP Incidence Rates—All Reporting Facilities*

No data

-13% (-13 to -14%)
-13% (-12 to -14%)
-16% (-15 to -17%)
-20% (-19 to -21%)

*Preliminary, unpublished, subject to change. Abstract available at:

Why are VAP incidence rates declining?

- Evidence-based prevention measures
- Other reasons—several ways to lower VAP rates without improving patient care (Klompas et al., AJIC 2012;40:408-10)
  - Strict interpretation of clinical signs included in surveillance definitions
  - Strict interpretation of chest x-ray findings included in surveillance definitions
  - Requirement for consensus approach to VAP determinations or physician approval of cases
  - Practice of transferring out those patients needing prolonged mechanical ventilation
  - Admission of uncomplicated and post-operative patients to unit

Decrease # of VAPs
Increase # of vent days
Goals for Modifying Current NHSN Definitions

- Achieve face validity/clinical credibility
- Improve reliability
- Reduce burden

From VAP to VAE

<table>
<thead>
<tr>
<th>Ventilator-Associated Lower Respiratory Infection (VALORI)</th>
<th>Streamlined VAP (&quot;sVAP&quot;)</th>
<th>Ventilator-Associated Events (VAE)</th>
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<tr>
<td>2009-2010 • Evaluated draft definition in collaboration with the CDC Prevention Epicenters • Definition based on work done by Klompas and others1,2 • Received expert feedback during HHS-sponsored meetings</td>
<td>2011 • Funded Epicenters proposal to evaluate feasibility and preventability of &quot;sVAP&quot;</td>
<td>2011-2012 • Convened VAP Surveillance Definition Working Group, with Critical Care Societies Collaborative and other society/organization representatives (2011-2012)</td>
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**Adult VAP/VAE Surveillance Definitions Working Group Members and Participants**

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<th>Society/Organization</th>
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<tbody>
<tr>
<td>American Association of Critical-Care Nurses</td>
<td>Suzanne Burns, Beth Hammer</td>
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<td>American Association for Respiratory Care</td>
<td>Dean Hess</td>
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<td>American College of Chest Physicians</td>
<td>Robert Balk, David Gutterman</td>
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<td>Association of Professionals in Infection Control and Epidemiology</td>
<td>Linda Greene</td>
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<td>American Thoracic Society</td>
<td>Nicholas Hill, Mitchell Levy</td>
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<td>Council of State and Territorial Epidemiologists</td>
<td>Carole VanAntwerpen</td>
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<td>HICPAC Surveillance Working Group</td>
<td>Daniel Diekema</td>
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<td>Infectious Diseases Society of America</td>
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<td>Clifford Deutschman, Marin Kollef, Pamela Lipsett</td>
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<td>Society for Healthcare Epidemiology of America</td>
<td>Michael Klompas</td>
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<td>U.S. Department of Health and Human Services/Office of Healthcare Quality</td>
<td>Don Wright</td>
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<td>National Institutes of Health</td>
<td>David Henderson</td>
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**VAE Surveillance Definition Algorithm—Tiered Approach**

- **Tiers 1 and 2: Definitions suitable for potential use in public reporting**
  - Objective, general measures of Ventilator-Associated Conditions (VAC) and Infection-related, Ventilator-Associated Complications (IVAC)
  - Definitions similar to Tier 1 VAC definition evaluated by Klompas et al. identified events associated with longer duration of mechanical ventilation, longer ICU stay, and increased mortality—and were more efficient to apply than current VAP definitions (*PLoS One* 2011;6:e18062, *Crit Care Med* 2012; in press)

- **Tier 3: Internal use definitions**
  - Possible VAP and Probable VAP, incorporating laboratory evidence

***Note that this is NOT a clinical definition algorithm and is not intended for use in the management of patients.***
THE “WHO” AND “WHEN” OF VAE SURVEILLANCE

Who is eligible for VAE surveillance?

- ≥18 years of age
- Inpatients of acute care hospitals, long term acute care hospitals, inpatient rehabilitation facilities
Who is NOT eligible for VAE surveillance?

- Children are not eligible.
- Inpatients of facilities other than acute care hospitals, long-term acute care hospitals and inpatient rehabilitation facilities are not eligible.
- Patients on high frequency ventilation or extracorporeal life support are NOT ELIGIBLE for VAE surveillance.

What about patients receiving other types of life support or alternative modes of mechanical ventilation?

- Patients on high frequency ventilation or extracorporeal life support are EXCLUDED from VAE surveillance.
- Patients who are receiving a conventional mode of mechanical ventilation while in the prone position, and patients who are receiving a conventional mode of mechanical ventilation while receiving nitric oxide therapy or epoprostenol therapy are INCLUDED.
- Patients on Airway Pressure Release Ventilation (APRV) or related modes are INCLUDED, but VAC will be determined by changes in FiO\textsubscript{2} only, since changes in PEEP as indicated in this surveillance algorithm may not be applicable to APRV.

*If you have questions about mechanical ventilation, check with the Respiratory Care or Respiratory Therapy and/or Critical Care departments in your facility.*
When will VAE surveillance be available in NHSN, and what is happening to PNEU/VAP?

- VAE available January 2013.
- In 2013, current VAP protocol will still be used for neonatal and pediatric patients ONLY.
  - Pediatric and Neonatal VAE Surveillance Definition Working Group kick-off meeting held on September 6, 2012
- In 2013, the current PNEU definitions will still be available for off-plan surveillance of VAP in adults or non-ventilated PNEU in adults or children.

“WHAT” IS VAE?
REVIEW OF DEFINITIONS

***Note that these are NOT clinical definitions and are not intended for use in the management of patients.***
VAE Definition Algorithm Summary

**Respiratory status component**
- Patient on mechanical ventilation > 2 days
- Baseline period of stability or improvement, followed by sustained period of worsening oxygenation
- Ventilator-Associated Condition (VAC)

**Infection/inflammation component**
- General evidence of infection/inflammation
- Infection-Related Ventilator-Associated Complication (IVAC)

**Additional evidence**
- Positive results of microbiological testing
- Possible or Probable VAP

No CXR needed!
**VAE Definition Algorithm Summary**

- **Respiratory status component**
  - Patient on mechanical ventilation > 2 days
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  - General evidence of infection/inflammation
  - Infection-Related Ventilator-Associated Complication (IVAC)

- **Additional evidence**
  - Possible results of microbiological testing
  - Possible or Probable VAP

- **Temperature or WBC and New antimicrobial agent**

- **Purulent secretions and/or other positive laboratory evidence**
**Tier 1: VAC**

Patient has a baseline period of stability or improvement on the ventilator, defined by ≥2 calendar days of stable or decreasing daily minimum FiO₂ or PEEP values. The baseline period is defined as the two calendar days immediately preceding the first day of increased daily minimum PEEP or FiO₂.

AND

After a period of stability or improvement on the ventilator, the patient has at least one of the following indicators of worsening oxygenation:

1. Increase in daily minimum FiO₂ of ≥0.20 (20 points) over the daily minimum FiO₂ in the baseline period, sustained for ≥2 calendar days.

2. Increase in daily minimum PEEP values of ≥3 cmH₂O over the daily minimum PEEP in the baseline period, sustained for ≥2 calendar days.
Tier 2: IVAC

On or after calendar day 3 of mechanical ventilation and within 2 calendar days before or after the onset of worsening oxygenation, the patient meets both of the following criteria:

1) Temperature > 38 °C or < 36 °C, OR white blood cell count ≥ 12,000 cells/mm³ or ≤ 4,000 cells/mm³.

AND

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

*See Appendix for eligible agents.

Tier 3: Possible 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)
   - Defined as secretions from the lungs, bronchil, or trachea that contain ≥25 neutrophils and ≤10 squamous epithelial cells per low power field (lpf, x100).
   - If the laboratory reports semi-quantitative results, those results must be equivalent to the above quantitative thresholds.

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

*Excludes the following:
- Normal respiratory/oral flora, mixed respiratory/oral flora or equivalent
- Candida species or yeast not otherwise specified
- Coagulase-negative Staphylococcus species
- Enterococcus species
**Tier 3: Probable 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 (see Table 2):

- Positive culture of endotracheal aspirate*, ≥ 10⁵ CFU/ml or equivalent semi-quantitative result
- Positive culture of bronchoalveolar lavage*, ≥ 10⁵ CFU/ml or equivalent semi-quantitative result
- Positive culture of lung tissue, ≥ 10⁵ CFU/g or equivalent semi-quantitative result
- Positive culture of protected specimen brush*, ≥ 10⁵ CFU/ml or equivalent semi-quantitative result

*Same organism exclusions as noted for Possible VAP.

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

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**Location of Mechanical Ventilation Initiation:**

**Date Initiated:**

*APRV, Yes, No*

**Specific Event:**

☑ VAC ☐ IVAC ☐ Possible VAP ☐ Probable VAP

**Specify Criteria Used:**

**STEP 1: VAC (≥1 REQUIRED)**

☑ Daily min FiO₂ increase ≥ 0.20 (20 points) for ≥ 2 days¹ OR ☐ Daily min PEEP increase ≥ 3 cm H₂O for ≥ 2 days¹ after 2+ days of stable or decreasing daily minimum values.

**STEP 2: IVAC**

☐ Temperature > 36°C or < 36°C OR ☐ White blood cell count ≥ 12,000 or ≤ 4,000 cells/μL

AND

☐ A new antimicrobial agent(s) is started, and is continued for ≥ 4 days

**STEP 3: Possible VAP**

☐ Purulent respiratory secretions² (defined as secretions from the lungs, bronchi, or trachea that contain ≥ 25 neutrophils and ≤ 19 squamous epithelial cells per low power field [PL, x100], or equivalent semi-quantitative results) OR

☐ One of the following (qualitative, semi-quantitative or quantitative)³:

- Positive culture of sputum
- Positive culture of endotracheal aspirate
- Positive culture of bronchoalveolar lavage
- Positive culture of lung tissue
- Positive culture of protected specimen brushing

**STEP 3: Probable VAP**

☐ Purulent respiratory secretions⁴

AND one of the following (meeting quantitative or semi-quantitative threshold as outlined in protocol)⁵:

- Positive culture of endotracheal aspirate
- Positive culture of bronchoalveolar lavage
- Positive culture of lung tissue
- Positive culture of protected specimen brushing

OR

☐ One of the following results (without requirement for purulent respiratory secretions), as outlined in protocol⁶:

- Positive pleural fluid culture
- Positive lung histopathology
- Positive diagnostic test for *Legionella* spp.
- Positive diagnostic test for viral pathogens

**collected after 2 days of mechanical ventilation and within +/- 2 days of onset of increase in FiO₂ or PEEP.**
Do I have to use the entire algorithm? Can I decide to conduct surveillance only for IVAC, for example?

- Conducting in-plan VAE surveillance in 2013 requires assessing patients for **ALL** events:
  - VAC
  - IVAC
  - Possible or Probable VAP

- **Hierarchy of definitions:**
  - If a patient meets criteria for VAC and IVAC, report as IVAC.
  - If a patient meets criteria for VAC, IVAC and Possible VAP, report Possible VAP.
  - If a patient meets criteria for VAC, IVAC and Probable VAP, report Probable VAP.
  - If a patient meets criteria for VAC, IVAC, Possible VAP and Probable VAP, report Probable VAP.

**HOW TO PREPARE FOR AND CONDUCT VAE SURVEILLANCE, AND KEY TERMS**
Preparing for VAE Surveillance

- Read the surveillance protocol.
- Identify surveillance partners in the ICU or other units in which VAE surveillance may take place.
  - Respiratory Therapy
  - Critical Care
- If hospital laboratory reports Gram stain or culture results in a semi-quantitative way, find out from the lab what quantitative ranges correspond to the semi-quantitative scale (for Possible/Probable VAP).
- Develop a plan for organizing the data elements needed to identify VAEs.

Example: Operationalizing VAE

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Ventilator Definition

- **Ventilator** is defined as a device to assist or control respiration continuously, inclusive of the weaning period, through a tracheostomy or by endotracheal intubation
  - Intermittent positive-pressure breathing (IPPB); nasal positive end-expiratory pressure (nasal PEEP); and continuous nasal positive airway pressure (CPAP, hypoCPAP) are not considered ventilators unless delivered via tracheostomy or endotracheal intubation (e.g., ET-CPAP)

*No change from current NHSN ventilator definition*

Episode of Mechanical Ventilation

- A period of days during which the patient was mechanically ventilated for some portion of each consecutive day. A break in mechanical ventilation of at least one full calendar day followed by reintubation and reinitiation of mechanical ventilation during the same hospitalization is a new episode.
Positive End-Expiratory Pressure (PEEP)

- “A technique used in respiratory therapy in which airway pressure greater than atmospheric pressure is achieved at the end of exhalation by the introduction of a mechanical impedance to exhalation.”*
- In patients on conventional mechanical ventilation, PEEP is one of the parameters that can be adjusted depending on the patient’s oxygenation needs.
- A sustained increase in the daily minimum PEEP of ≥ 3 cmH₂O following a period of stability or improvement on the ventilator is one of two criteria that can be used in meeting the VAC definition.


Fraction of Inspired Oxygen (FiO₂)

- The fraction of oxygen in inspired gas.
  - For example, the FiO₂ of ambient air is 0.21; the oxygen concentration of ambient air is 21%.
- In patients on mechanical ventilation, the FiO₂ is one of the key parameters that can be adjusted depending on the patient’s oxygenation needs.
- A sustained increase in the daily minimum FiO₂ of ≥ 0.20 (20%) following a period of stability or improvement on the ventilator is the second of the two criteria that can be used in meeting the VAC definition.
**Tier 1: VAC**

Patient has a baseline period of stability or improvement on the ventilator, defined by ≥ 2 calendar days of stable or decreasing daily minimum FiO₂ or PEEP values. The baseline period is defined as the two calendar days immediately preceding the first day of increased daily minimum PEEP or FiO₂.

**AND**

After a period of stability or improvement on the ventilator, the patient has at least one of the following indicators of worsening oxygenation:

1. Increase in daily minimum FiO₂ of ≥ 0.20 (20 points) over the daily minimum FiO₂ in the baseline period, sustained for ≥ 2 calendar days.

2. Increase in daily minimum PEEP values of ≥ 3 cmH₂O over the daily minimum PEEP in the baseline period, sustained for ≥ 2 calendar days.

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2-day period of stability (PEEP or FiO₂)

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2-day period of worsening, based on PEEP or FiO₂
Date of Event / Event Date

- The date of onset of worsening oxygenation (day 1 of the required \( \geq 2 \) day period of worsening oxygenation). *It is not the date in which all VAE criteria are met.*

<table>
<thead>
<tr>
<th>Vent Day</th>
<th>PEEP min</th>
<th>FiO(_2) min</th>
<th>Temp min</th>
<th>Temp max</th>
<th>WBC min</th>
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</table>

Event Date = Vent Day 4 (first day of worsening oxygenation)
Why is the Event Date important?

- **Defining the “VAE Window Period”**
  - Period during which criteria for other events—IVAC, Possible, Probable VAP—must be met

- **Detecting multiple VAEs in the same patient**
  - Each VAE is 14 days in duration (arbitrary—to standardize).
  - Day 1 is the Event Date—so if June 1 is date of onset of worsening oxygenation and a VAC is reported, a second VAE cannot be detected and reported until June 15.
  - May not “upgrade” a VAE based on data collected outside the VAE Window Period but within the 14-day event period.
  - May not report a new VAE until that 14 day period has elapsed (keep in mind that 14 day period is event date to event date—so baseline period can occur during previous event period).

---

VAE Window Period

- This is the period of days around the event date (i.e., the day of onset of worsening oxygenation) within which other VAE criteria must be met. It is usually a 5-day period and includes the 2 days before, the day of, and the 2 days after the VAE event date (i.e., the first day of worsening oxygenation, the day of VAE onset).
VAE Window Period: Important Note

- There is an exception, however, in which the VAE Window Period is only 3 or 4 days, as follows:

In cases where the VAE event date corresponds to MV day 3 or day 4, the window period described above may only be a 3-day or a 4-day window, because it can NOT include any days before the 3rd day of MV. For example, if the VAE event date is MV day 3, then the window period includes only the day of VAE onset and the 2 days after VAE onset (because the 2 days before VAE onset are before the 3rd day of MV).
**Exception: VAE Window Period**

*When the event occurs early in course of mechanical ventilation*

<table>
<thead>
<tr>
<th>MV Day No.</th>
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<th>4</th>
<th>5</th>
<th>6</th>
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<tbody>
<tr>
<td>VAE Day</td>
<td>-2</td>
<td>-1</td>
<td>1</td>
<td>2</td>
<td>3</td>
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</tr>
<tr>
<td>Worsening oxygenation</td>
<td>Day 1 of stability or improvement</td>
<td>Day 2 of stability or improvement</td>
<td>Day 1 of worsening oxygenation</td>
<td>Day 2 of worsening oxygenation</td>
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<tr>
<td>Temperature or WBC abnormality</td>
<td>Documented within this shaded period</td>
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<tr>
<td>Antimicrobial agent</td>
<td>Started within this shaded period, and then continued for at least 4 days</td>
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<td>Purulent respiratory secretions, positive culture, positive histopathology</td>
<td>Collected within this shaded period</td>
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**Infection-related Ventilator-Associated Complication (IVAC)**

Patient meets criteria for VAC

AND

On or after calendar day 3 of mechanical ventilation and within 2 calendar days before or after the onset of worsening oxygenation, the patient meets both of the following criteria:

1) Temperature > 38 °C or < 36°C, OR white blood cell count ≥ 12,000 cells/mm³ or ≤ 4,000 cells/mm³.

AND

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

*See Appendix for eligible agents.
### Defining the VAE Window Period

<table>
<thead>
<tr>
<th>Vent Day</th>
<th>PEEP min</th>
<th>FiO2 min</th>
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<th>WBC min</th>
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2-day period before onset of worsening

Event Date, day 1 of worsening

2-day period after onset of worsening

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### Defining the VAE Window

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In this case—there is only 1 day before onset of worsening (because cannot count 1st 2 days of MV)

Event Date, day 1 of worsening

2-day period after onset of worsening

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What’s wrong with this VAE Window Period?
Look for abnormal temp or white count during VAE Window Period

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<tr>
<th>Vent Day</th>
<th>PEEP min</th>
<th>FiO₂ min</th>
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**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 of worsening oxygenation, the patient meets both of the following criteria:

1) Temperature $> 38^\circ C$ or $< 36^\circ C$, OR white blood cell count $\geq 12,000$ cells/mm³ or $\leq 4,000$ cells/mm³.

AND

2) A new antimicrobial agent(s)* is started, and is continued for $\geq 4$ calendar days.

*See Appendix for eligible agents.
IVAC Antimicrobial Criterion

- Probably the most complicated portion of the VAE surveillance definition algorithm
- Rules for meeting this criterion are not perfect—but we need a standardized method for assessment of antimicrobial therapy, without needing knowledge of dosing, renal function, indication for therapy, etc.

Figuring out if a “new” antimicrobial agent(s) has been given

- **New antimicrobial agent**: Defined as any agent listed in the protocol Appendix that is initiated on or after the third calendar day of mechanical ventilation AND in the VAE Window Period (i.e., the period typically defined by the 2 calendar days before, the day of, and the 2 calendar days after the onset date of the VAE).
  - The agent is considered new for the purposes of this definition if it was NOT given to the patient on either of the 2 days preceding the current start date.
  - A new agent must be continued for ≥ 4 consecutive days.
  - There is no requirement that the same new antimicrobial agent be given on the 4 consecutive days.
  - New agent must be administered IV, IM, via digestive tract or via respiratory tract
What antimicrobial drugs are in the Appendix?

- Go to page 20 of the protocol.
- Broad range of agents that could be used to treat healthcare-associated infections—mostly antibacterials, antifungals, limited antivirals
  - Including agents that are not used to treat respiratory infections (e.g., oral vancomycin, fidaxomicin)
  - To emphasize that an “IVAC” does not mean that the “infection related” event is respiratory in origin
- Drugs that are not included = anti-HIV agents, anti-TB agents, agents used to treat viral hepatitis, agents used to treat herpes virus infections, anti-parasitics

Figuring out if ≥4 days of therapy have been given:
Qualifying Antimicrobial Days (QAD)

- A day on which the patient was administered an antimicrobial agent that was determined to be “new” within the VAE Window Period.
- Four consecutive QADs are needed to meet the IVAC antimicrobial criterion—starting within the VAE Window Period.
QADs: Same Agent

- Days between administrations of a new antimicrobial agent also count as QADs as long as there is a gap of no more than 1 calendar day between administrations of the same drug. For example, if levofloxacin is given on VAE Day 1, has not been given in the 2 preceding calendar days, and is given again on VAE Days 3, 5 and 7, there are 7 QADs—because the days between levofloxacin doses also count as QADs.

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<tr>
<th>VAE Day</th>
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QADs: Different Agents

- By contrast, days between administrations of different antimicrobial agents do NOT count as QADs
  - For example, if levofloxacin is given to the patient on VAE Days -2 and -1 only, no antimicrobials are given on VAE Day 1, and meropenem is given only on VAE Day 2 (remember there is no VAE Day 0), then there are not 4 consecutive QADs. VAE Days -2 and -1 count as 2 consecutive QADs, but VAE Day 1 cannot be counted as a QAD because it is a day between different antimicrobial agents.

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</table>
**New antimicrobial agent started and continued for 4 days**

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<th>Vent Day</th>
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Possible VAP

Patient meets criteria for VAC and IVAC

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)
   - Defined as secretions from the lungs, bronchi, or trachea that contain >25 neutrophils and ≤10 squamous epithelial cells per low power field [lpf, x100].
   - If the laboratory reports semi-quantitative results, those results must be equivalent to the above quantitative thresholds.

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

*Excludes the following:
- Normal respiratory/oral flora, mixed respiratory/oral flora or equivalent
- Candida species or yeast not otherwise specified
- Coagulase-negative Staphylococcus species
- Enterococcus species
Probable VAP

VAC, IVAC plus the following...

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 (see Table 2):
- Positive culture of endotracheal aspirate*, ≥ 10⁵ CFU/ml or equivalent semi-quantitative result
- Positive culture of bronchoalveolar lavage*, ≥ 10⁵ CFU/ml or equivalent semi-quantitative result
- Positive culture of lung tissue, ≥ 10⁵ CFU/g or equivalent semi-quantitative result
- Positive culture of protected specimen brush*, ≥ 10⁵ CFU/ml or equivalent semi-quantitative result

*Same organism exclusions as noted for Possible VAP.

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

Purulent Respiratory Secretions

- Gram stain polymorphonuclear leukocyte ("polys", "PMN", neutrophil) counts and squamous epithelial cell counts
- Can be used alone to meet Possible VAP definition, or in combination with a semi-quantitative or quantitative culture result (with the appropriate growth) to meet the Probable VAP definition
How do I relate my lab’s semi-quantitative Gram stain reporting to the quantitative thresholds in the algorithm?

- Ask your laboratory manager/director first—he/she may be able to tell you
- If your laboratory does not have this information, we are working to provide guidance on this issue* ...
  1+ = occasional or rare = <1 cell per low power field (lpf, x100)
  2+ = few = 1-9 cells per lpf, x100
  3+ = moderate = 10-25 cells per lpf, x100
  4+ = heavy = >25 cells per lpf, x100
  - This means that in the absence of information from your lab, “purulent respiratory secretions” are defined by “heavy”, 4+ or ≥25 neutrophils per low power field (lpf, x100) AND “rare”, “occasional”, “few”, 1+ or 2+, or ≤10 squamous epithelial cells per lpf, x100
  - This is preliminary! Please make sure to review the protocol in 2013 for updates.


---

Lower Respiratory Culture Results

- Appropriate specimen types include:
  - Sputum, endotracheal aspirate, bronchoalveolar lavage, protected specimen brushings, lung tissue, pleural fluid
- Exclude the following as a pathogen unless isolated from lung tissue or pleural fluid
  - *Candida* species or yeast not otherwise specified
  - Coagulase negative *Staphylococcus* species
  - *Enterococcus* species
- Exclude the following culture results (or similar) ...
  - Normal respiratory flora / Normal oral flora
  - Mixed respiratory flora / Mixed oral flora
  - Altered oral / respiratory flora
Positive Culture Result Reporting

- **Qualitative**
  - Identification of organism with no quantity assigned
  - Example: “Organism 1: Staphylococcus aureus”

- **Semi-quantitative**
  - Identification of organism with estimated quantity
  - Example: 1+, 2+, 3+, 4+
  - Example: Rare, Few, Moderate, Heavy

- **Quantitative**
  - Identification of organism with exact quantity expressed
  - Example: $10^4$ cfu/ml (colony forming units/milliliter)

How do I relate my lab’s semi-quantitative culture result reporting to the quantitative thresholds in the algorithm?

- Ask your laboratory manager/director first—she/he may be able to tell you
- If your laboratory does not have this information, we are working to provide guidance on this issue* ...
  - For the purposes of this surveillance, we will assume that a semi-quantitative result of “moderate” or “heavy” growth, or 2+, 3+ or 4+ growth (in a culture of lung tissue, BAL, PSB, or ETA) meets the Probable VAP surveillance definition.
  - *This is preliminary! Please make sure to review the protocol in 2013 for updates.*

Non-Culture-Based Results: Probable VAP

- Pathogens *(Legionella spp., selected viruses)* identified utilizing non-culture-based diagnostic testing may qualify as criterion for meeting Probable VAP.
  - Antigen testing
  - PCR
  - Direct Fluorescent Antibody Testing
  - Serology

- Many other pathogens (including respiratory pathogens such as *Mycoplasma* and *Chlamydophila*) that may be detected using non-culture-based techniques are *not* currently included in Probable VAP criteria.

Histopathology (Lung) Results

- Identification of abscess formation or foci of consolidation with intense neutrophil accumulation in bronchioles and alveoli
- Evidence of lung parenchyma invasion by fungi (hyphae, pseudohyphae or yeast forms)
- Evidence of infection with viral pathogens (immunohistochemical assays, cytology, microscopy)
### Probable VAP

**VAC, IVAC plus the following...**

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 (see Table 2):
- Positive culture of endotracheal aspirate*, ≥ 10⁵ CFU/ml or equivalent semi-quantitative result
- Positive culture of bronchoalveolar lavage*, ≥ 10⁵ CFU/ml or equivalent semi-quantitative result
- Positive culture of lung tissue, ≥ 10⁵ CFU/g or equivalent semi-quantitative result
- Positive culture of protected specimen brush*, ≥ 10⁵ CFU/ml or equivalent semi-quantitative result

*Some organism exclusions as noted for Possible VAP.

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

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**Note:**

- ETA >25/<10
- **Staph aureus**
- Purulent respiratory secretions OR ETA culture positive for *S. aureus*
### Purulent respiratory secretions AND positive quantitative or semi-quantitative ETA culture *(meeting specified threshold)*

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Pathogen Reporting

- Pathogens may be reported for Possible VAP and Probable VAP, according to the usual pathogen and antimicrobial susceptibility reporting methods utilized in NHSN for other events.
  - Exception: excluded pathogens
- Pathogens are not reported for VAC or for IVAC.

What about positive blood cultures that occur around the same time as a VAE?

- Secondary BSI = A culture-confirmed BSI associated with a documented HAI at another site (i.e., meets CDC criteria of infection at another site such as UTI).
  - If the primary infection is cultured, the Secondary BSI must yield culture of a same organism as the primary HAI site, regardless of antibiogram.
What about positive blood cultures that occur around the same time as a VAE?

- **Secondary BSI may be reported for Possible and Probable VAP.**
  - When at least one organism from the blood culture specimen matches an organism from an appropriate respiratory tract specimen collected during the VAE Window Period
  - And when the blood culture was collected within the 14 day event period
- **Secondary BSI may not be reported for Possible and Probable VAP when a respiratory culture was not performed.**
  - Possible VAP met with purulent respiratory secretions
  - Probable VAP met with histopathology criterion
- **Secondary BSIs are not reported for VAC or IVAC.**

---

Key Things to Remember about Numerator Data Collection

- **For most patients**—will only need to record daily minimum PEEP and FiO₂ while on ventilator. Nothing else!
- **Only need to assess temperature and white blood cell count information for patients who fulfill VAC criteria**
  - And only need to look at these values during the VAE Window Period (3-5 days)
- **Only need to look at antimicrobial administrations for patients with VAC AND abnormal temp or white count**
  - New during the VAE Window Period (3-5 days)
- **Only need to assess lab/microbiology/pathology data for patients with IVAC**
  - Collected during the VAE Window Period (3-5 days)
Denominator Data

- **Device (ventilator) days and patient days are used for denominators.**
  - Collect data daily at the same time each day.
  - Daily counts are summed and only the total for the month is reported in NHSN.

- **Ventilator days – number of patients in the chosen location who are managed with a ventilatory device**
  - Ventilator days for all patients are counted to include those on ventilator < 3 days, those receiving excluded therapies and pediatric patients housed in adult locations.
  - Number of patients on APRV mode of ventilation or related modes are included in total and also indicated separately.

- **Patient days = number of patients in the chosen location**

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**Denominator Form**

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Analysis

- **VAE Rate per 1000 ventilator days** =
  \[
  \frac{\text{Number of VAEs}}{\text{Number of Ventilator Days}}
  \]

- **Ventilator Utilization Ratio** =
  \[
  \frac{\text{Ventilator Days}}{\text{Patient Days}}
  \]

Remember ... Tips for Getting Started

- **Get familiar with the protocol and review FAQs.**
- **Establish relationships with Respiratory Therapy and/or Critical Care:**
  - Discuss options for collection of minimum daily PEEP and FiO₂ for each MV day (IP, RT, electronically generated).
  - May want to ask about frequency with which excluded therapies (HFV, extracorporeal support) are used, and APRV.
- **Determine your laboratory’s approach to Gram stain and culture result reporting.**
- **Explore use of tools for data collection and for learning the definitions and making VAE determinations.**
**Ventilator-Associated Event Data Collection Worksheet**

**Step 1: VAE Change B or C**

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<th>E. Other Bacterial Infection</th>
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**Step 2: VAE B, C, plus D, E, and F**

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**Step 3: VAE B, C, plus D, E, and F**

<table>
<thead>
<tr>
<th>Date</th>
<th>Source</th>
<th>Temp</th>
<th>BMI</th>
<th>A. Scarlet Fever</th>
<th>C. Staphylococcus</th>
<th>E. Other Bacterial Infection</th>
<th>F. Other Infection</th>
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**Other positive VAE indicator**

**Notes:**
- A. Scarlet Fever
- C. Staphylococcus
- E. Other Bacterial Infection
- F. Other Infection
- VAE B, C, plus D, E, and F

**Ventilator-Associated Events (VAE) Antimicrobial Worksheet**

**Patient ID:**

**Date of mechanical ventilation (MVV) initiation:**

<table>
<thead>
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<th>VAE Day</th>
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<tr>
<td>9</td>
<td>1/18/2012</td>
</tr>
<tr>
<td>10</td>
<td>1/19/2012</td>
</tr>
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</table>

**Event Order (Days 1-9):**

- Day 1: Initiate VAE
- Day 2: Initiate VAE
- Day 3: Initiate VAE
- Day 4: Initiate VAE
- Day 5: Initiate VAE
- Day 6: Initiate VAE
- Day 7: Initiate VAE
- Day 8: Initiate VAE
- Day 9: Initiate VAE
- Day 10: Total consecutive days (GADs)

**Are there at least 4 consecutive GADs starting in the VAE Window Period?**
- Yes
- No

**Notes:**
- Use antibiotics for possible and probable VAP
- No additional VAE, report as VAP
**Key Take-Home Points**

- Patient must be ventilated more than 2 calendar days.
- Patient must have ≥2 calendar days of stability or improvement of oxygenation followed by ≥2 calendar days of worsening oxygenation.
- Earliest date of event for VAE is mechanical ventilation day 3 (first day of worsening oxygenation).
- First possible day that VAC criteria can be fulfilled is mechanical ventilation day 4.
More Key Take-Home Points

- Event Date defines the VAE Window Period:
  - 2 days before, day of and 2 days after the Event Date – 5 days
  - May be shorter if worsening occurs early in the course of ventilation
- All other criteria (for IVAC, Possible VAP, Probable VAP) must be identified within the VAE Window Period.
- The “VAE clock” starts over again when ...
  - The patient begins a new episode of mechanical ventilation
  - A new event period starts (i.e., 14 days have elapsed since previous VAE Event Date)
  - The patient comes off of an excluded therapy (such as HFV or ECMO) and goes back on conventional mode of ventilation

Acknowledgments

- Patients and staff in NNIS and NHSN participating facilities
- VAP Surveillance Definition Working Group
- Other subject matter experts
- HHS Office of Healthcare Quality
- CDC Prevention Epicenters
- CDC VALORI/draft sVAP project collaborators
- CDC/DHQP colleagues

The findings and conclusions in this presentation are those of the author and do not necessarily represent the views of the Centers for Disease Control and Prevention.
Thank you!

smagill@cdc.gov

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Telephone, 1-800-CDC-INFO (232-4636)/TTY: 1-888-232-6348
E-mail: cdcinfo@cdc.gov Web: www.cdc.gov

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

National Center for Emerging and Zoonotic Infectious Diseases
Division of Healthcare Quality Promotion

ADDITIONAL SLIDES
QUESTION: When should I use PNEU/VAP instead of VAE?

A. Never—starting in 2013, always use VAE
B. When surveillance is to be conducted in mechanically-ventilated children
C. When surveillance is to be conducted for healthcare-associated pneumonia that is not associated with mechanical ventilation
D. B and C
E. None of the above

QUESTION: In 2013, when should I use PNEU/VAP instead of VAE?

A. Never—starting in 2013, always use VAE
B. When surveillance is to be conducted in mechanically-ventilated children
C. When surveillance is to be conducted for healthcare-associated pneumonia that is not associated with mechanical ventilation

D. B and C
E. None of the above
QUESTION: If I am conducting VAE surveillance in-plan, I need to assess daily minimum and maximum temperatures for the following patients:

A. All patients in the ICU
B. All patients in the ICU who are on a ventilator
C. Patients who I have determined meet the VAC definition
D. Patients who have met the VAC definition and also have an abnormal white blood cell count
E. Patients who the clinical care providers have diagnosed with VAP
F. None of the above

QUESTION: If I am conducting VAE surveillance in-plan, I need to evaluate daily minimum and maximum temperatures for the following patients:

A. All patients in the ICU
B. All patients in the ICU who are on a ventilator
C. Patients who I have determined meet the VAC definition
D. Patients who have met the VAC definition and also have an abnormal white blood cell count
E. Patients who the clinical care providers have diagnosed with VAP
F. None of the above
QUESTION: When evaluating patient data to see if the IVAC definition is met, I should focus only on antibiotics that are used to treat respiratory infections

☐ True
☐ False
QUESTION: A patient in my ICU met the IVAC definition. On the VAE Event Date, there was also a positive blood culture that grew *Pseudomonas aeruginosa*. The patient has a central line. Other than fever, there are no other signs/symptoms of infection. How should I report this event?

A. Report an IVAC (no pathogen) and a CLABSI (pathogen=PA)
B. Report an IVAC (pathogen=PA)
C. Report an IVAC and secondary BSI (pathogen=PA)
D. Report a CLABSI (pathogen=PA)
E. Report an IVAC (no pathogen)
F. None of the above

QUESTION: A patient in my ICU met the IVAC definition. On the VAE Event Date, there was also a positive blood culture that grew *Pseudomonas aeruginosa*. The patient has a central line. Other than fever, there are no other signs/symptoms of infection. How should I report this event?

A. Report an IVAC (no pathogen) and a CLABSI (pathogen=PA)
B. Report an IVAC (pathogen=PA)
C. Report an IVAC and secondary BSI (pathogen=PA)
D. Report a CLABSI (pathogen=PA)
E. Report an IVAC (no pathogen)
F. None of the above
QUESTION: I have a patient in my ICU who met the IVAC definition. On VAE Day 4, the patient had an open lung biopsy performed. The lung tissue culture grew *Aspergillus fumigatus*. The pathology report noted invasive fungal hyphae. How should I report this event?

A. Report as a Probable VAP, because the patient had a positive lung tissue culture.
B. Report as a Probable VAP, because the patient had positive lung histopathology.
C. Report as a Possible VAP, because the patient had a positive qualitative culture of lung tissue.
D. Report as an IVAC, because the lung biopsy culture was done outside the VAE window.
E. Report as an IVAC, because fungal pathogens are excluded from VAE reporting.
QUESTION: A patient in my ICU was admitted to the hospital on May 20 with *C. diff* colitis. The patient was intubated on May 25. Criteria for VAC were met, with an event date of June 1. The patient was changed from oral vancomycin on May 20 to oral fidaxomicin on June 1; fidaxomicin was given twice daily from June 1 through June 6. The patient spiked a fever to 102.4°F on June 2. How should I report this event?

- Report as VAC
- Report as IVAC
- Do not report an event—respiratory deterioration was due to worsening *C. diff* colitis that was present on admission
- None of the above
### Explanation

<table>
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### What are HFV and extracorporeal life support, and why are they excluded?

- **HFV**: any form of ventilation using very high respiratory rates (>150 breaths per minute) and very low tidal volumes
  - Several different forms
  - Usually used in patients with refractory hypoxemia
  - PEEP and FiO2 changes as outlined in VAE definition protocol not really applicable to patients on HFV
- **Extracorporeal life support**: also known as “ECMO,” or extracorporeal membrane oxygenation
  - Method of providing circulatory and respiratory support to patients with severely damaged hearts and lungs
  - Involves oxygenating the blood outside of the patient’s body, then returning the oxygenated blood to the patient’s body


http://en.wikipedia.org/wiki/High-frequency_ventilation#High-frequency_oscillatory_ventilation
http://en.wikipedia.org/wiki/Extracorporeal_life_support
What is APRV, and why is it included?

- A mode of mechanical ventilation characterized by continuous application of positive airway pressure with an intermittent pressure release phase
- Used in patients with Acute Lung Injury and Acute Respiratory Distress Syndrome, but also after major surgery to treat/prevent atelectasis
- Although PEEP as outlined in VAE definition algorithm does not really apply to APRV, FiO₂ does—and so patients on APRV are included in algorithm.
- Other names: BiLevel, Bi Vent, BiPhasic, PCV+, DuoPAP

Location of Attribution

- The inpatient location where the patient was assigned on the date of the VAE, which is further defined as the date of onset of worsening oxygenation.
  - Essentially the same as current approach in NHSN

Transfer Rule

- If a VAE develops on the day of transfer or the day following transfer from one inpatient location to another in the same facility or to a new facility (where the day of transfer is day 1), the event is attributed to the transferring location.

### Vent Day Location PEEP min FiO₂ min Temp min Temp max WBC min WBC max Abx Spec Polys/Epis Org
1 MUC 10 60 None
2 MICU 5 40 None
3 SICU 5 40 36.9 37.6 12.1 12.1 None Pleural Fluid Staph aureus
4 SICU 8 60 38.1 39.2 14.5 16.8 Yes -- -- --
5 SICU 8 50 38.4 38.9 12.6 15.9 Yes -- -- --
6 SICU 7 40 36.5 37.8 11.1 13.6 Yes -- -- --
7 SICU 5 40 Yes -- -- --
8 SICU 5 40

Transfer from MICU to SICU on MV Day 2, event date is MV Day 4—therefore attributed to SICU (more than 1 day since transfer)
Transfer from MICU to SICU on MV Day 3, event date is MV Day 4—therefore attributed to MICU (within 2 days of transfer)

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<th>FiO₂ min</th>
<th>Temp min</th>
<th>Temp max</th>
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