Pediatric Ventilator-Associated Event (PedVAE)

For use in neonatal and pediatric locations only

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Introduction

Mechanical ventilation is an essential, life-saving therapy for patients with critical illness and respiratory failure. Hundreds of thousands of patients receive mechanical ventilation in the United States each year [1-3]. These patients are at high risk for complications and poor outcomes, including death [1-5]. Ventilator-associated pneumonia (VAP), sepsis, acute respiratory distress syndrome (ARDS), pulmonary embolism, barotrauma, and pulmonary edema are among the complications that can occur in patients receiving mechanical ventilation. Such complications can lead to longer duration of mechanical ventilation, longer stays in the intensive care unit (ICU) and hospital, increased healthcare costs, and increased risk of disability and death. In preterm neonates, prolonged mechanical ventilation for respiratory distress syndrome can contribute to the development of chronic lung disease [6]. Prolonged mechanical ventilation in extremely low birthweight infants is also associated with neurodevelopmental delay [7].

Surveillance for ventilator-associated events in the National Healthcare Safety Network (NHSN) prior to 2013 was limited to VAP. Traditional VAP definitions, including the NHSN PNEU definitions (revised in 2002), have well-described limitations [8-11]. These definitions typically require radiographic evidence of pneumonia, although data suggest that chest radiograph findings do not accurately identify VAP. The subjectivity and variability inherent in chest radiograph technique, interpretation, and reporting make chest imaging ill-suited for inclusion in a definition algorithm to be used for the potential purposes of public reporting, inter-facility comparisons, and pay-for-reporting and pay-for-performance programs. Another major limitation of the available VAP definitions is their reliance on specific clinical signs or symptoms, which are subjective and may be poorly or inconsistently documented in the medical record.

The limitations of VAP surveillance definitions have implications for prevention. Valid and reliable surveillance data are necessary for assessing the effectiveness of prevention strategies. It is notable that some effective measures for improving outcomes of patients on mechanical ventilation do not specifically target pneumonia prevention [12-15].

In 2011, CDC organized a working group composed of members of several stakeholder organizations to address the limitations of the NHSN PNEU definitions and propose a new approach to surveillance for Ventilator-Associated Events (VAE) for NHSN, focusing on adult patients [16]. The organizations represented in the working group included the Critical Care Societies Collaborative (the American Association of Critical-Care Nurses, the American College of Chest Physicians, the American Thoracic Society, and the Society for Critical Care Medicine), the American Association for Respiratory Care, the Association of Professionals in Infection Control and Epidemiology, the Council of State and Territorial Epidemiologists, the Healthcare Infection Control Practices Advisory Committee's Surveillance Working Group, the Infectious Diseases Society of America, and the Society for Healthcare Epidemiology of America.

The VAE surveillance definition algorithm developed by the working group was implemented in the NHSN in January 2013 and is available for use in adult locations only. The definition algorithm is based on objective, streamlined, and potentially automatable criteria that identify a broad range of conditions and complications occurring in mechanically ventilated patients in adult locations. Data indicate that streamlined, objective algorithms to detect ventilator-associated events are easily implemented, can make use of electronic health record systems to automate event detection, and identify events that are clinically important and associated with outcomes such as ICU and hospital length of stay and mortality [17, 18]. Research suggests that most VAEs in adult patients are due to pneumonia, ARDS, atelectasis, and pulmonary edema [17]. These are significant clinical conditions that may be preventable. VAE rates and event characteristics in adult inpatient locations reporting data to NHSN in 2014 have been published [19].

VAE surveillance was not initially made available for use in neonatal and pediatric locations, based on the recommendations of a separate working group that CDC organized in 2012 to consider whether the VAE surveillance approach could also be used in neonatal and pediatric inpatient populations. This working group included representatives from the following organizations: the American Academy of Pediatrics (AAP) Committee on the Fetus and Newborn, the AAP Committee on Infectious Diseases, the AAP Section on Critical Care, the AAP Section on Pediatric Pulmonology, the American Association of Critical-Care Nurses, the American College of Chest Physicians Pediatric Chest Medicine Network, the American Thoracic Society Scientific Assembly on Pediatrics, the American Association for Respiratory Care, the Children's Hospital Association, the Association of Professionals in Infection Control and Epidemiology, the Council of State and Territorial Epidemiologists, the Pediatric Infectious Diseases Society, the Pediatric Cardiac Intensive Care Society, the Society for Healthcare Epidemiology of America, the Society of Critical Care Medicine, and the Vermont-Oxford Network. In mid-2013, this working group determined that there were insufficient data to inform development of a pediatric VAE definition. Further working group discussions were postponed until 2015, following publication of the results of a study on pediatric VAE definition criteria [20]. This study demonstrated that events defined by changes in the fraction of inspired oxygen (FiO_2) and mean airway pressure (MAP) were associated with increases in patient length of stay as well as mortality [20]. After additional discussion with the working group, CDC decided to move forward with pediatric VAE (PedVAE) development and implementation in NHSN.

NOTE: The PedVAE definition algorithm is for use in surveillance. It is not a clinical definition algorithm and is not intended for use in the clinical management of patients. Examples provided throughout this protocol are for illustration purposes only and are not intended to represent actual clinical scenarios.

Settings

Inpatient locations eligible to participate in PedVAE surveillance are those neonatal and pediatric locations in acute care hospitals, long term acute care hospitals, and inpatient rehabilitation facilities where denominator data (ventilator and patient days) can be collected for patients. Such locations may include critical/intensive care units (ICU), specialty care areas (SCA), step-down units, and wards. A complete listing of neonatal and pediatric inpatient locations can be found in Chapter 15 *CDC Locations and Descriptions*.

Non-acute care mapped locations in acute care facilities (chronic care units in acute care facilities) are not eligible to participate in PedVAE surveillance.

It is not required to monitor for PedVAEs after discharge if a patient is transferred to another facility while still on mechanical ventilation. However, if discovered, any PedVAE with a date of event on the day of discharge or the day after discharge is attributed to the discharging location and should be included in any PedVAE reported to NHSN by the discharging location. No additional ventilator days are reported.

Inclusion and Exclusion Criteria

Patients INCLUDED in PedVAE surveillance:

- All patients in the neonatal and pediatric inpatient locations found in Chapter 15, regardless of patient's age
- Patients on a ventilator (as defined below) who are receiving
    - a conventional mode of mechanical ventilation (for example, synchronized intermittent mandatory ventilation)
    - high-frequency oscillatory or jet ventilation
- Patients on a ventilator (as defined below) who are receiving a conventional mode of mechanical ventilation or high frequency oscillatory or jet ventilation
    - while in the prone position
    - while receiving surfactant, corticosteroids, nitric oxide therapy, helium-oxygen mixtures (heliox), or epoprostenol therapy

Patients EXCLUDED from PedVAE surveillance:

- All patients in the adult inpatient locations found in Chapter 15, regardless of patient's age
- Patients on extracorporeal life support or paracorporeal membrane oxygenation are excluded from PedVAE surveillance during periods of time when the support is in place for the entire calendar day

Definitions

Ventilator: Any device used to support, assist, or control respiration (inclusive of the weaning period) through the application of positive pressure to the airway when delivered via an artificial airway, specifically an oral/nasal endotracheal or tracheostomy tube.

Ventilation and lung expansion devices that deliver positive pressure to the airway (for example, CPAP, BiPAP, Bi-level, IPPB, and PEEP) via non-invasive means (for example, nasal prongs, nasal mask, full face mask, total mask, etc.) are not considered ventilators unless positive pressure is delivered via an artificial airway (oral/nasal endotracheal or tracheostomy tube).

PedVAE: PedVAEs are identified by deterioration in respiratory status after a period of stability or improvement on the ventilator (Figure 1).

Patients must be mechanically ventilated for at least 4 calendar days to fulfill PedVAE criteria (where the day of intubation and initiation of mechanical ventilation is day 1).

Mean Airway Pressure (MAP): The average pressure exerted on the airway and lungs from the beginning of inspiration until the beginning of the next inspiration [21]. In patients on mechanical ventilation, MAP is the most powerful influence on oxygenation and is determined by positive end-expiratory pressure (PEEP), peak inspiratory pressure (PIP), inspiratory time, and frequency [22]. A sustained increase in the daily minimum MAP of ≥ 4 cmH_2O following a period of stability or improvement on the ventilator is one of two criteria that can be used in meeting the PedVAE definition.

Fraction of Inspired Oxygen (FiO_2): The fraction of oxygen in inspired gas. For example, the FiO_2 of ambient air is 0.21; the oxygen concentration of ambient air is 21%. In patients on mechanical ventilation, the FiO_2 is one of the key parameters that can be adjusted depending on the patient's oxygenation needs and is typically in the range of 0.21 (oxygen concentration of 21%) to 1.0 (oxygen concentration of 100%). A sustained increase in the daily minimum FiO_2 of ≥ 0.25 (25 points) following a period of stability or improvement on the ventilator is one of the two criteria that can be used in meeting the PedVAE definition.

Daily Minimum MAP: The lowest value of MAP during a calendar day. For the purposes of surveillance:

- When determining the daily minimum MAP value, round MAP values in the following manner: a MAP of 10.00 – 10.49 is rounded to 10 and a MAP of 10.50 – 10.99 is rounded to 11. For example, a patient who is intubated and started on mechanical ventilation at 21:30 on June 1, with a MAP of 10.35 cmH_2O at 21:30 and a MAP of 10.54 cmH_2O at 23:30 would have a daily minimum MAP of 10 cmH_2O on June 1.
- In patients < 30 days old, MAP values of 0-8 cmH_2O are considered equivalent; therefore, any day on which the daily minimum MAP was 0-8 cmH_2O would be assigned a daily minimum value of 8 cmH_2O.
- In patients ≥ 30 days old, MAP values of 0-10 cmH_2O are considered equivalent; therefore, any day on which the daily minimum MAP was 0-10 cmH_2O would be assigned a daily minimum value of 10 cmH_2O.

EXAMPLE: The patient (< 30 days old) is intubated at 18:00. MAP values through the remainder of the calendar day are as follows:

Time	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**
MAP (cmH_2O)	12.35	11.15	9.28	9.43	11.42	11.35

In this example, the daily minimum MAP for the purposes of PedVAE surveillance is 9 cmH_2O. MAP readings of 9.28 and 9.43 are rounded to 9.

EXAMPLE: The patient is intubated at 18:00. MAP values are as follows through the remainder of the calendar day:

Time	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**
MAP (cmH_2O)	12	12	10	12	10	12

In this example, the daily minimum MAP for the purposes of PedVAE surveillance is 10 cmH_2O. This is the lowest value recorded during the calendar day. When making daily minimum MAP determinations the value does not need to be maintained for > 1 hour.

EXAMPLE: MAP values are as follows through the course of a calendar day for a patient ≥ 30 days old:

Time	**01:00**	**04:00**	**08:00**	**12:00**	**16:00**	**20:00**
MAP (cmH_2O)	9 (10)	11	9 (10)	11	11	12

In this example, the daily minimum MAP is 10 cmH_2O. Although 9 cmH_2O is the lowest value recorded, in patients ≥ 30 days old MAP values of 0-10 cmH_2O are considered equivalent; therefore, the daily minimum MAP of 9 cmH_2O at 01:00 and 08:00 would be assigned a daily minimum value of 10 cmH_2O.

EXAMPLE: You are reviewing a < 30-day old patient's ventilator data on Wednesday morning to determine the daily minimum MAP values for Monday and Tuesday. The neonatal ICU (NICU) monitors and records MAP every 30 minutes. You see that the lowest MAP on Monday (9 cmH_2O) was recorded at 23:30 when the episode of mechanical ventilation was initiated for this patient. The patient remained at this MAP for an additional 30 minutes on Tuesday morning and was then at MAP 12 cmH_2O for the rest of the day on Tuesday. What do you record as the daily minimum MAP for Monday and for Tuesday? The lowest (and only) value of 9 cmH_20 is recorded as the daily minimum MAP for Monday. On Tuesday, the daily minimum MAP should also be recorded as 9 cmH_2O, as it is the lowest value recorded on Tuesday.

Day	**Time**	**MAP (cmH_2O)**
Monday	23:30	9
Tuesday	00:00	9
Tuesday	00:30	9
Tuesday	01:00	12

Day	Time	MAP (cmH_2O)
Tuesday	01:30	12
Tuesday	02:00 through 23:30	12

Daily Minimum MAP determinations are made using documented MAP values specific to the calendar day and independently of the MAP values recorded on the previous calendar day or the next calendar day.

EXAMPLE: You are reviewing a < 30-day old patient's ventilator data on Thursday morning to determine the daily minimum MAP values for Tuesday and Wednesday. The neonatal ICU (NICU) monitors and records MAP every 8 hours. You see that the lowest MAP on Tuesday is 8 cmH_20, last recorded at 23:30. The first recorded MAP on Wednesday, at 07:30, is 12 cmH_20 and the patient remains at that MAP for the remainder of the calendar day on Wednesday. What do you record as the daily minimum MAP for Tuesday and for Wednesday? On Tuesday, the daily minimum MAP is 8 cmH_20, as it is the lowest value recorded on that calendar day. On Wednesday, the daily minimum MAP is 12 cmH_20, as it is the lowest value recorded on that calendar day. Only MAP values documented during the given calendar day are taken into consideration when determining the daily minimum MAP for that calendar day.

Day	Time	MAP (cmH_2O)
Tuesday	07:30	9
Tuesday	15:30	8
Tuesday	23:30	8
Wednesday	07:30	12
Wednesday	15:30	12
Wednesday	23:30	12

Daily Minimum FiO_2: The lowest value of FiO_2 during a calendar day that is set on the ventilator and *maintained for > 1 hour*. This requirement that the daily minimum FiO_2 be the lowest setting maintained for > 1 hour will ensure that units monitoring and recording FiO_2 settings hourly or more frequently than once per hour are able to apply the PedVAE surveillance FiO_2 criterion in a standardized way.

If ventilator settings are monitored and recorded less frequently than once per hour (for example, every 2 hours or every 4 hours), the daily minimum FiO_2 is simply the lowest value of FiO_2 set on the ventilator during the calendar day.

EXAMPLE: FiO_2 is set at the following values through the course of a calendar day:

Time	00:00	04:00	08:00	12:00	16:00	20:00
FiO_2	1.0	0.6	0.4	0.5	0.55	0.6

In this example, the daily minimum FiO_2 for the purposes of PedVAE surveillance is 0.4. FiO_2 settings are monitored and recorded every 4 hours. Each setting has been maintained for > 1 hour; therefore, the lowest recorded FiO_2 setting for the calendar day is the daily minimum FiO_2.

If there is no documentation of values maintained for > 1 hour (for example, the lowest value of FiO_2 is set late in the calendar day, mechanical ventilation is discontinued early in the calendar day, FiO_2 settings are changed very frequently throughout the calendar day), the daily minimum FiO_2 will default to the lowest value of FiO_2 set on the ventilator during the calendar day (regardless of how long that setting was maintained).

- For example, a patient who is intubated and started on mechanical ventilation at 23:00 on June 1, with a FiO_2 setting of 0.30 from 23:00 to 00:00, would have a daily minimum FiO_2 of 0.30 on June 1 for the purposes of PedVAE surveillance.

In units tracking FiO_2 settings every hour or more frequently than every hour, there must be sufficient consecutive recordings of a specific FiO_2 setting to meet the minimum required duration of > 1 hour.

- In units tracking FiO_2 every 15 minutes, 5 consecutive recordings of FiO_2 at a certain level would be needed to meet the required > 1 hour minimum duration (for example, 09:00, 09:15, 09:30, 09:45, and 10:00).
- In units tracking FiO_2 every 30 minutes, 3 consecutive recordings of FiO_2 at a certain level would be needed to meet the required > 1 hour minimum duration (for example, 09:00, 09:30, and 10:00).
- In units tracking FiO_2 every hour, 2 consecutive recordings of FiO_2 at a certain level would be needed to meet the required > 1 hour minimum duration (for example, 09:00 and 10:00).

EXAMPLE: The patient is intubated at 18:00. FiO_2 is set at the following values through the remainder of the calendar day:

Time	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**
FiO_2	1.0	0.8	0.5	0.5	0.8	0.8

In this example, the daily minimum FiO_2 for the purposes of PedVAE surveillance is 0.5. FiO_2 settings are being monitored and recorded every hour. There are two consecutive hours where the FiO_2 setting is noted to be 0.5 (20:00 and 21:00), and therefore the required minimum duration of > 1 hour is met.

EXAMPLE: The patient is intubated at 18:00. FiO_2 is set at the following values through the remainder of the calendar day:

Time	**18:00**	**19:00**	**20:00**	**21:00**	**22:00**	**23:00**
FiO_2	0.8	0.8	0.5	0.8	0.5	0.8

In this example, the daily minimum FiO_2 for the purposes of PedVAE surveillance is 0.8. FiO_2 settings are being monitored and recorded every hour. Although the lowest FiO_2 is 0.5, it is recorded at two non-consecutive time points only (20:00, and then 22:00), and so the required > 1 hour minimum duration is not met. There are two consecutive hours where the FiO_2 setting is noted to be 0.8 (18:00 and 19:00), and therefore the required minimum duration of > 1 hour is met to allow use of this setting as the daily minimum FiO_2 for PedVAE surveillance.

EXAMPLE: You are reviewing a patient's ventilator settings on Friday morning to determine the daily minimum FiO_2 value for Thursday. The patient was intubated and initiated on mechanical

ventilation at 21:45 hours on Thursday. The pediatric ICU (PICU) monitored and recorded FiO_2 settings for the patient every 15 minutes during the remainder of the day on Thursday. Based on the information recorded in the table below, what should you record as the daily minimum FiO_2 for Thursday? In this example, since there is no setting that is maintained for > 1 hour during the calendar day, the daily minimum FiO_2 for Thursday is 0.70 (70%). This is the lowest value of FiO_2 set on the ventilator during the calendar day.

Day	Time	FiO_2
Thursday	21:45	Intubated; 1.0
	22:00	1.0
	22:15	0.90
	22:30	0.90
	22:45	0.70
	23:00	0.80
	23:15	0.85
	23:30	0.85
	23:45	0.85

Daily Minimum FiO_2 determinations are made using documented FiO_2 values specific to the calendar day and independently of the FiO_2 values recorded on the previous calendar day or the next calendar day.

EXAMPLE: You are reviewing a patient's ventilator data on Thursday morning to determine the daily minimum FiO_2 values for Tuesday and Wednesday. The neonatal ICU (NICU) monitors and records FiO_2 every 8 hours. You see that the lowest FiO_2 on Tuesday is 0.70 (70%), last recorded at 23:30. The first recorded FiO_2 on Wednesday, at 07:30, is 0.95 (95%) and the patient remains at that FiO_2 for the remainder of the calendar day on Wednesday. What do you record as the daily minimum FiO_2 for Tuesday and for Wednesday? On Tuesday, the daily minimum FiO_2 is 0.70 (70%), as it is the lowest value recorded on that calendar day. On Wednesday, the daily minimum FiO_2 is 0.95 (95%), as it is the lowest value recorded on that calendar day. Only FiO_2 values documented during the given calendar day are taken into consideration when determining the daily minimum FiO_2 for that calendar day.

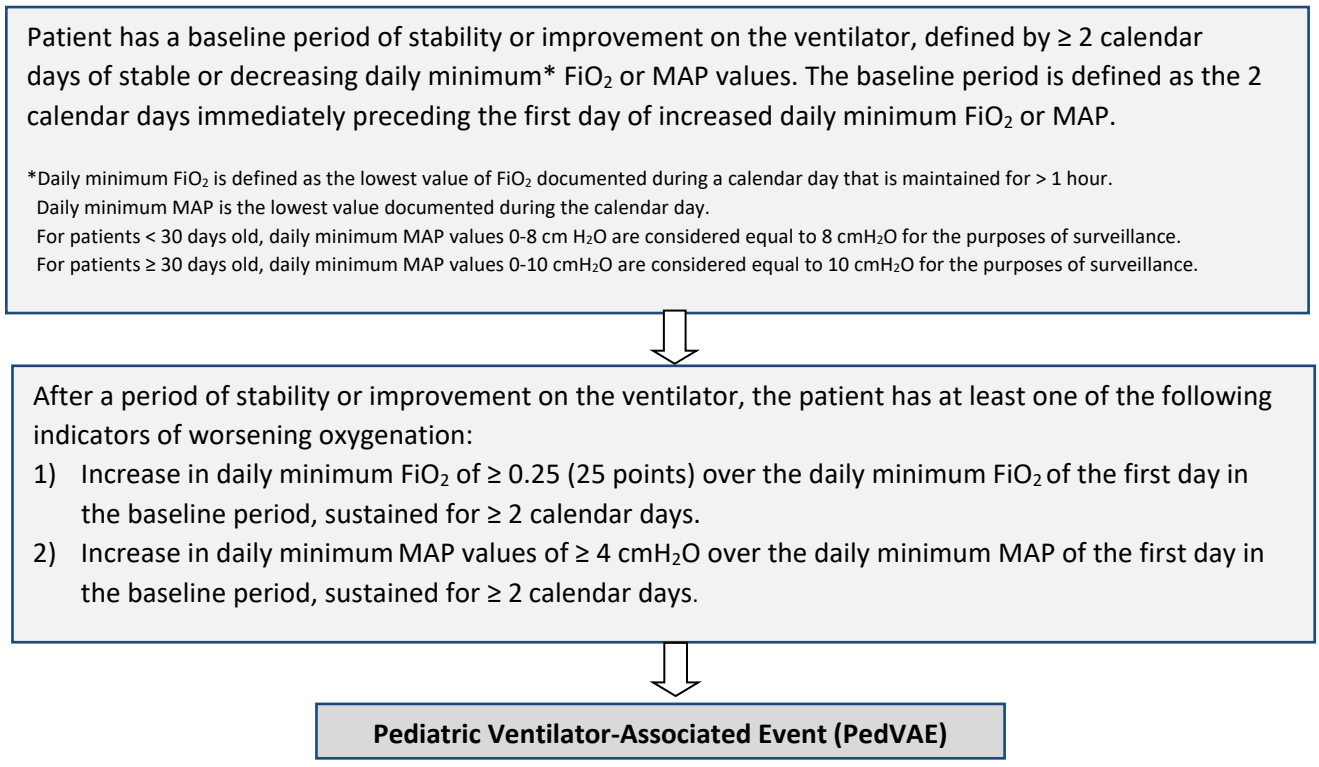
Day	Time	FiO_2
Tuesday	07:30	0.75
Tuesday	15:30	0.70
Tuesday	23:30	0.70
Wednesday	07:30	0.95
Wednesday	15:30	0.95
Wednesday	23:30	0.95

Baseline Period: The baseline period of stability or improvement on the ventilator is defined as the 2 calendar days immediately preceding the first day of increased daily minimum MAP or FiO_2, and must be characterized by ≥ 2 calendar days of stable or decreasing daily minimum MAP or FiO_2 values (specifically, the daily minimum MAP or FiO_2 on the second day of the baseline period of stability or improvement must be equal to or less than the daily minimum MAP or FiO_2 on the first day of the baseline period of stability

or improvement). Note that the daily minimum MAP is the lowest value documented during a calendar day, and the daily minimum FiO_2 is the lowest value documented during a calendar day that was maintained for > 1 hour (see daily minimum FiO_2 definition for exception to the > 1 hour requirement).

Period of Worsening Oxygenation: The period of worsening oxygenation is defined as an increase in the daily minimum MAP values of at least 4 cmH_2O over the daily minimum MAP of the first day in the baseline period or an increase in the daily minimum FiO_2 of at least 0.25 (25 points) over the daily minimum FiO_2 of the first day in the baseline period, that immediately follows the baseline period and is sustained for at least 2 or more calendar days.

Figure 1: Pediatric Ventilator-Associated Events (PedVAE) Surveillance Algorithm



Meeting PedVAE Surveillance Algorithm

EXAMPLE: In the example below, in a patient < 30 days old, the baseline period is mechanical ventilation (MV) days 1 through 4 (shaded in light gray), and the period of worsening oxygenation is MV days 5 and 6 (shaded in darker gray), where the daily minimum MAP is ≥ 4 cmH_2O greater than the daily minimum MAP during the baseline period (keeping in mind that daily minimum MAP values 0-8 cmH_2O in a patient < 30 days should be considered to be equal to 8 cmH_2O for the purposes of surveillance, and an increase in the daily minimum MAP to at least 12 cmH_2O, sustained for at least 2 calendar days, would be needed to meet the PedVAE definition).

MV Day	Daily minimum MAP (cmH_2O)	Daily minimum FiO_2 (oxygen concentration, %)	PedVAE
1	7 (8)	1.00 (100%)	
2	7 (8)	0.50 (50%)	
3	**8**	0.50 (50%)	
4	**8**	0.50 (50%)	
5	**12**	0.50 (50%)	✓
6	**12**	0.50 (50%)	

EXAMPLE: In the example below, the baseline period is mechanical ventilation (MV) days 3 and 4 (shaded in light gray), and the period of worsening oxygenation is MV days 5 and 6 (shaded in darker gray), where the daily minimum FiO_2 is ≥ 0.25 (25 points) over the daily minimum FiO_2 during the baseline period.

MV Day	Daily minimum MAP (cmH_2O)	Daily minimum FiO_2 (oxygen concentration, %)	PedVAE
1	12	1.00 (100%)	
2	11	0.50 (50%)	
3	9	**0.40 (40%)**	
4	9	**0.40 (40%)**	
5	11	**0.70 (70%)**	✓
6	11	**0.70 (70%)**	

EXAMPLE: In the example below, there is no PedVAE because the FiO_2 on MV day 4 is higher than the FiO_2 on MV day 3 (and therefore not stable or decreasing) – even though the FiO_2 on MV days 5 and 6 meets the 25-point threshold when compared with the daily minimum FiO_2 on MV days 3 and 4.

MV Day	Daily minimum MAP (cmH_2O)	Daily minimum FiO_2 (oxygen concentration, %)	PedVAE
1	12	1.00 (100%)	
2	11	0.50 (50%)	
3	9	0.35 (35%)	
4	9	0.40 (40%)	
5	11	0.70 (70%)	No event
6	11	0.70 (70%)	

Additional Definitions

Date of Event: The date of onset of worsening oxygenation. This is defined as the first calendar day in which the daily minimum MAP or FiO_2 increases above the thresholds outlined in the PedVAE definition algorithm (specifically, day 1 of the required ≥ 2-day period of worsening oxygenation following a ≥ 2-day period of stability or improvement on the ventilator).

The earliest date of event for PedVAE is day 3 of mechanical ventilation (where the day of intubation and initiation of mechanical ventilation is day 1).

The "date of event" is NOT the date on which all PedVAE criteria have been met. It is the first day (of a ≥ 2-day period) on which either of the worsening oxygenation thresholds (for MAP or FiO_2) is met.

EXAMPLE: A patient is intubated in the Emergency Room for severe community-acquired pneumonia and admitted to the PICU (day 1). The patient stabilizes and improves on days 2-5, with a daily minimum FiO_2 of 0.35 (35%) on days 4 and 5. On day 6, the patient experiences respiratory deterioration and requires a minimum FiO_2 of 0.60 (60%) on days 6 and 7, meeting the criteria for a PedVAE. The date of the PedVAE event is day 6.

14-day Event Period: PedVAEs are defined by a 14-day period, starting on the day of onset of worsening oxygenation (the date of event, day 1). While patients may have multiple PedVAEs during a single hospitalization, a new PedVAE cannot be identified or reported until this 14-day period has elapsed. The 14-day event period is event date to event date, so a new baseline period of stability or improvement can occur during the previous event period.

EXAMPLE: A patient is intubated and mechanical ventilation (MV) is initiated in the PICU (MV day 1). The patient is stable during the 6 following calendar days (MV days 2-7). On MV days 8 and 9, the patient's minimum daily MAP is increased more than 4 cmH_2O over the first day in the baseline period, therefore meeting the PedVAE MAP threshold. The PedVAE is defined by the period encompassing MV days 8 through 21 (14 days, starting on day 1 of worsening oxygenation, which in this case is MV day 8). If the patient were to experience a period of stability or improvement on the ventilator on MV days 20 and 21, followed by another 2-day period of worsening on MV days 22 and 23, a new PedVAE would be reported, since the second period of worsening oxygenation occurred more than 14 days after the start of initial period of worsening oxygenation.

Episode of Mechanical Ventilation: Defined as 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/or reinitiation of mechanical ventilation during the same hospitalization, defines a new episode of mechanical ventilation.

EXAMPLE: A patient is intubated and mechanical ventilation is initiated at 23:00 on hospital day 1. The patient remains intubated and mechanically ventilated from hospital days 2-10. The patient is extubated at 09:00 on hospital day 11 and remains extubated on hospital day 12. The patient is reintubated and mechanical ventilation is reinitiated on hospital day 13. The patient remains

intubated and mechanically ventilated from hospital day 14-18. This patient has had two episodes of mechanical ventilation (days 1-11 and days 13-18), separated by at least one full calendar day off of mechanical ventilation.

Location of Attribution: The inpatient location where the patient was assigned on the PedVAE date of event, which is further defined as the date of onset of worsening oxygenation.

EXAMPLE: Patient is intubated and ventilated in the Operating Room on hospital day 1 and then is admitted post-operatively to the NICU on hospital day 1, still on the ventilator. On hospital day 3, the patient experiences the onset of worsening oxygenation, manifested by an increase in the daily minimum FiO_2 of ≥ 0.25 (25 points). On day 4 (also the 4th day of mechanical ventilation) the patient meets criteria for a PedVAE. This is reported as a PedVAE for the NICU.

EXCEPTION: ***Transfer Rule***: If the PedVAE date of event is 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. This is called the Transfer Rule. If the patient was in multiple locations within the transfer rule time frame, attribute the PedVAE to the **first** location in which the patient was housed **the day before** the PedVAE date of event. See Transfer Rule examples below.

EXAMPLE: On hospital day 6, the patient is extubated in the PICU and transferred to the stepdown unit. The next day, while in the stepdown unit (day 7), the patient experiences worsening oxygenation and is reintubated and transferred back to the PICU. Criteria for PedVAE are met the next day (hospital day 8). In this case, the day prior to extubation and the day of extubation (hospital days 5 and 6) count as the required 2-day period of stability or improvement. The day of reintubation (hospital day 7) and the following day (hospital day 8) count as the required 2-day period of worsening oxygenation. Because the date of event occurred on the day following transfer out of the PICU, the event is reported as a PedVAE for the PICU.

Hospital Day	MV Day	Daily minimum FiO_2 (oxygen concentration, %)	PedVAE DOE	Location	Location of Attribution
5	5	0.30 (30%)		PICU	
6	6	0.30 (30%) (extubated at 09:00)		PICU -> Stepdown (transferred at 18:00)	
7	7	0.60 (60%) (reintubated at 10:00)	✓	Stepdown -> PICU (transferred at 10:15)	PICU
8	8	0.60 (60%)		PICU	

EXAMPLE: Patient intubated and mechanically ventilated for 8 days in the NICU of Hospital A. The patient was stable on the ventilator in Hospital A from days 3-6. In the evening on day 7 the patient began to have episodes of desaturation and on day 8 the patient was transferred to Hospital B (day 1 in Hospital B). The day after transfer (day 2 in Hospital B), the patient meets criteria for PedVAE. The date of the event, the first day of the period of worsening oxygenation meeting PedVAE MAP or FiO_2 thresholds, is day 1 in Hospital B. The infection preventionist (IP) from Hospital B calls the IP at Hospital A to report that this patient was admitted to Hospital B with a PedVAE. This PedVAE should be reported by Hospital A and attributed to the Hospital A NICU. No additional ventilator days are reported by Hospital A.

Hospital Day for Hospital A	Hospital Day for Hospital B	Daily minimum FiO_2 (oxygen concentration, %)	PedVAE DOE	Location	Location of Attribution
6		0.30 (30%)		Hospital A	
7		0.30 (30%)		Hospital A	
8	1	0.60 (60%)	✓	Hospital A -> Hospital B	Hospital A
	2	0.60 (60%)		Hospital B	

Reporting Instructions

1. Conducting in-plan PedVAE surveillance means monitoring patients for the presence of events meeting the PedVAE definition.
2. If the date of event (date of onset of worsening oxygenation) is on or after the date of documentation of evidence of consent AND the patient is being supported for organ donation purposes, the event should not be reported as a PedVAE.
3. Secondary BSIs are not reported or attributable to a PedVAE.
4. Clinical findings associated with a PedVAE may assist in better understanding the etiology and focusing efforts to prevent PedVAEs [23-25]. Should a facility choose to provide the following information, the PedVAE form includes optional data fields to report:
    a. Clinical diagnoses or events that were associated with the PedVAE. Note that multiple events may be reported for a single PedVAE.
    b. Antimicrobial agents listed in the Appendix that are administered on the date of event or within the 2 days before or 2 days after the event. The name of the specific antimicrobial agent and the administration initiation date may also be reported.
    c. Pathogens detected by culture or non-culture based microbiological testing of upper or lower respiratory specimens with a specimen collection date on the date of event or within the 2 days before or 2 days after the date of event or in blood with a specimen collection date within the 2 days before the date of event and up to 13 days after the date of event.

        NOTE: Because organisms belonging to the following genera are typically causes of community-associated respiratory infections and are rarely or are not known to be causes of healthcare-associated infections, they are excluded and cannot be reported.
        - **Fungi:** *Blastomyces, Histoplasma, Coccidioides, Paracoccidioides, Cryptococcus, Pneumocystis*
        - **Vector-borne bacteria:** *Anaplasma spp., Ehrlichia spp., Borrelia spp, Rickettsia spp.*

    d. *Legionella* or *Streptococcus pneumoniae* detected by urine antigen testing with a date of specimen collection on the date of event or within the 2 days before or 2 days after the event.

Numerator and Denominator Data

Numerator Data: The *Pediatric Ventilator-Associated Event (PedVAE)* form (CDC 57.113) is used to collect and report each PedVAE that is identified during the month selected for surveillance. The *Instructions for Completion of Pediatric Ventilator-Associated Event PedVAE Form* includes brief instructions for collection and entry of each data element on the form. The PedVAE form includes patient demographic information and information on the start date and location of initiation of mechanical ventilation. Additional data include the specific criteria met for identifying PedVAE, information about whether the patient was on antimicrobial drugs or had pathogens detected in culture or non-culture based microbiological testing, whether the patient died, and, where applicable, the organisms detected and their antimicrobial susceptibilities.

Reporting Instruction: If no PedVAEs are identified during the month of surveillance, the "*Report No Events*" box must be checked on the appropriate denominator summary screen, for example, Denominators for Intensive Care Unit (ICU)/Other Locations (Not NICU or SCA), etc.

Denominator Data: Device days and patient days are used for denominators (see Chapter 16 *General Key Terms*). Ventilator days, which are the number of patients managed with ventilatory devices, are collected daily, at the same time each day, according to the chosen location using the appropriate form (CDC 57.116 [NICU] or CDC 57.117 [Specialty Care Areas] or CDC 57.118 [ICU/Other Locations]). These daily counts are summed and only the total for the month is reported. Ventilator and patient days are collected for each of the locations monitored.

All ventilator days are counted, including ventilator days for patients on mechanical ventilation for < 3 days, and ventilator days for patients on extracorporeal life support or paracorporeal membrane oxygenation who are excluded from PedVAE surveillance. Patients with tracheostomies who are undergoing weaning from mechanical ventilation using tracheostomy collar trials are included in ventilator day counts if they are on mechanical ventilation at the time when the daily ventilator day count is performed. Patients who are not receiving mechanical ventilation via an artificial airway at the time of the daily ventilator count are not included.

When denominator data are available from electronic sources, these sources may be used as long as the counts are within +/- 5% of manually collected counts, validated for a minimum of 3 consecutive months. Validation of electronic counts should be performed separately for each location conducting PedVAE surveillance.

When converting from one electronic counting system to another electronic counting system, the new electronic system should be validated against manual counts as above. If electronic counts for the new electronic system are not within 5% of manual counts, resume manual counting and continue working with IT staff to improve design of electronic denominator data extraction (while reporting manual counts) until concurrent counts are within 5% for 3 consecutive months.

This guideline is important because validating a new electronic counting system against an existing electronic system can magnify errors and result in inaccurate denominator counts.

Collection of an additional denominator, episodes of mechanical ventilation (EMV), is optionally available for PedVAE surveillance. The EMV denominator represents the sum of the number of episodes

of mechanical ventilation that occurred in that location during the month. A single episode of mechanical ventilation for each patient is to be counted only once per month. Do note, it is possible for a patient to have more than one episode of ventilation occur during a month (for example, discontinuation of mechanical ventilation for greater than 1 calendar day followed by reinitiation of mechanical ventilation).

The EMV denominator is determined by counting all patients in the location who are on mechanical ventilation on the first day of the month regardless of eligibility for inclusion in PedVAE surveillance. Then, on each subsequent day of the month, count each additional patient that is started on mechanical ventilation. This would include those that are admitted to the location already on mechanical ventilation, those that are newly ventilated, and any previously ventilated patients who have new episodes of mechanical ventilation occurring during the same month. The sum of the count for the first day and each subsequent day of the month is reported.

EXAMPLE: On January 1, there are 5 patients on mechanical ventilation in the PICU (2 patients were started on mechanical ventilation on December 24, 2 patients on December 31, and 1 patient on January 1). During the rest of the month, the following are noted: 1 patient is started on mechanical ventilation on January 8; 2 patients are transferred to the PICU on mechanical ventilation on January 15; and 1 patient who was previously ventilated (from January 1 through January 12) goes back on mechanical ventilation on January 20. No other patients are on mechanical ventilation during the month of January. The number of EMV for January is nine. This is calculated as follows: 5 patients (on mechanical ventilation on the first day of the month) + 4 patients who were either started on mechanical ventilation, transferred into the PICU on mechanical ventilation, or reinitiated on mechanical ventilation after being off of the ventilator for at least 1 calendar day = 9 EMV.

Data Analyses

All PedVAE data entered into NHSN can be analyzed at event (specifically, PedVAE event) or summary level (for example, location or facility level). You can visualize both with descriptive reports, such as line lists, frequency tables, bar/pie charts, rate tables, and run charts.

Before running reports in NHSN, generate data sets. This process freezes your NHSN data at a point in time and copies those data into defined data sets. When you want updates reflected in NHSN reports, regenerate data sets.

Types of PedVAE Analysis Reports

Standardized Infection Ratio (SIR)

The Standardized Infection Ratio (SIR) is a summary metric used to track HAI incidence over time at a national, state, or local level. The SIR adjusts for various facility and/or patient-level factors that contribute to HAI risk within each facility. In HAI data analysis, the SIR compares the observed (numerator) number of HAIs to the number predicted (denominator), given the standard population (specifically, the NHSN baseline), adjusting for several risk factors that have been found to be significantly associated with differences in infection incidence. The number of predicted PedVAE events is calculated using negative binomial regression (2022 NHSN baseline) to estimate expected counts from facility denominator (specifically, ventilator days) and risk-factor data.

For more information on the SIR, exclusion factors, and the VAE parameter estimates, refer to the SIR guide:

- 2022 Baseline: https://www.cdc.gov/nhsn/2022rebaseline/sir-guide.pdf

The SIR is calculated by dividing the number of observed infections by the number of predicted infections.

$$\text{SIR*} = \frac{Observed\ (O) HAIs}{\text{Pr}\ edicted\ (P) HAIs}$$

*PedVAE SIR is only available under the 2022 baseline.

PedVAE Rate

The PedVAE rate per 1000 ventilator days is calculated by dividing the number of PedVAEs by the number of ventilator days and multiplying the result by 1000 (ventilator days).

$$\text{PedVAE Rate per 1000 ventilator days} = \frac{No.\ of\ PedVAEs}{No.\ of\ Ventilator\ Days} \cdot\ 1000$$

The PedVAE rate per 100 episodes of mechanical ventilation (EMV) is calculated by dividing the number of PedVAEs by the number of episodes of mechanical ventilation and multiplying the result by 100 (episodes of mechanical ventilation).

$$\text{PedVAE Rate per 100 EMV} = \frac{No.\ of\ PedVAEs}{No.\ of\ EMV} \cdot\ 100$$

Device Utilization Ratio (DUR)

The Ventilator or Device Utilization Ratio (DUR) is calculated by dividing the number of ventilator days by the number of patient days. These calculations will be performed separately for the different types of ICUs, SCAs, and other locations in the institution.

$$\text{DUR} = \frac{No.\ of\ Ventilator\ Days}{No.\ of\ Patient\ Days}$$

Descriptive Analysis Output Options

Descriptive analysis output options of numerator and denominator data, such as line listings, frequency tables, and bar and pie charts are also available in the NHSN application. Guides on using NHSN analysis features are available at: www.cdc.gov/nhsn/PS-Analysis-resources/reference-guides.html.

- Line List: https://www.cdc.gov/nhsn/pdfs/ps-analysis-resources/linelists.pdf
- Frequency Table: https://www.cdc.gov/nhsn/pdfs/ps-analysis-resources/frequencytables.pdf
- Bar Chart: https://www.cdc.gov/nhsn/pdfs/ps-analysis-resources/BarCharts.pdf
- Pie Chart: https://www.cdc.gov/nhsn/pdfs/ps-analysis-resources/PieChart.pdf
- Rate Table: https://www.cdc.gov/nhsn/pdfs/ps-analysis-resources/ratetables.pdf

Analysis Resources Links

- Analysis Resources Website: https://www.cdc.gov/nhsn/ps-analysis-resources/index.html
- Analysis Quick Reference Guides: http://www.cdc.gov/nhsn/PS-Analysis-resources/reference-guides.html
- Reporting of VAE and PedVAE: https://www.cdc.gov/nhsn/pdfs/ps-analysis-resources/setup-vae-pedvae-508.pdf
- PedVAE Analysis Training: https://www.cdc.gov/nhsn/training/patient-safety-component/pedvae.html

Data Quality Resources Links

- Data Quality Website: https://www.cdc.gov/nhsn/ps-analysis-resources/data-quality/index.html
- Data Quality Manual: https://www.cdc.gov/nhsn/pdfs/pscmanual/Instructions_DQ.pdf
- Data Quality Training: https://www.cdc.gov/nhsn/training/analysis/index.html

Table 1: PedVAE Measures Available in NHSN

Measure	Calculation	Application
PedVAE Rates (Ventilator Days)*	$\frac{No}{\quad} \cdot 1000$	Location specific measure only
PedVAE Rates (EMV)*	$\frac{No}{\quad} \cdot 1000$	Location specific measure only
DUR	$\frac{No.\ of\ Ventilator\ Days}{No.\ of\ Patient\ Days}$	Location specific measure only

*Rates do not adjust for differences in risk factors across locations/facilities; use caution when comparing rates.

NHSN Group Analysis

NHSN Group Users can perform the same analysis as facility level users in NHSN. A few helpful tools in NHSN for groups are listed in the resources below. These tools are guides on how to start and join a Group; how to create a template to request data from facilities; how to determine the level of access granted by the facility following the previous steps; and how to analyze the facilities data.

Group Analysis Resources

- NHSN Group Users Page: https://www.cdc.gov/nhsn/group-users/index.html
- Group User's Guide to the Membership Rights Report: https://www.cdc.gov/nhsn/pdfs/ps-analysis-resources/membership-rights-508.pdf
- Group User's Guide to the Line Listing - Participation Alerts: https://www.cdc.gov/nhsn/pdfs/ps-analysis-resources/group-alerts.pdf

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Appendix. List of Eligible Antimicrobial Agents

Antimicrobial Agent
AMIKACIN
AMPHOTERICIN B
AMPHOTERICIN B LIPOSOMAL
AMPICILLIN
AMPICILLIN/SULBACTAM
ANIDULAFUNGIN
AZITHROMYCIN
AZTREONAM
AZTREONAM/AVIBACTAM
BALOXAVIR MARBOXIL
CASPOFUNGIN
CEFAZOLIN
CEFEPIME
CEFEPIME/ENMETAZOBACTAM
CEFIDEROCOL
CEFOTAXIME
CEFOTETAN
CEFOXITIN
CEFTAROLINE
CEFTAZIDIME
CEFTAZIDIME/AVIBACTAM
CEFTOBIPROLE MEDOCARIL
CEFTOLOZANE/TAZOBACTAM
CEFTRIAXONE
CEFUROXIME
CIPROFLOXACIN
CLARITHROMYCIN
CLESROVIMAB
CLINDAMYCIN
COLISTIMETHATE
DALBAVANCIN
DELAFLOXACIN
DOXYCYCLINE
ERAVACYCLINE
ERTAPENEM
FLUCONAZOLE
FOSFOMYCIN
GENTAMICIN
IMIPENEM/CILASTATIN

IMIPENEM/CILASTATIN/RELABACTAM
ISAVUCONAZONIUM
ITRACONAZOLE
LEFAMULIN
LEVOFLOXACIN
LINEZOLID
MEROPENEM
MEROPENEM/VABORBACTAM
METRONIDAZOLE
MICAFUNGIN
MINOCYCLINE
MOLNUPIRAVIR
MOXIFLOXACIN
NAFCILLIN
NIRMATRELVIR (includes NIRMATRELVIR/RITONAVIR)
OMADACYCLINE
ORITAVANCIN
OSELTAMIVIR
OXACILLIN
PENICILLIN G
PERAMIVIR
PIPERACILLIN/TAZOBACTAM
PLAZOMICIN
POLYMYXIN B
POSACONAZOLE
REMDESIVIR
REZAFUNGIN
RIFAMPIN
SULBACTAM/DURLOBACTAM
SULFAMETHOXAZOLE/TRIMETHOPRIM
TEDIZOLID
TELAVANCIN
TETRACYCLINE
TIGECYCLINE
TOBRAMYCIN
VANCOMYCIN, intravenous only
VORICONAZOLE
ZANAMIVIR