Ventilator-Associated Events (VAE) and Hospital-acquired Pneumonia:
Pathophysiology, Epidemiology, and Prevention

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Disclosures: Consultancy; Pfizer, GSK, Merck, PDI, BD, Germitec, GAMA
All devices/methods discussed consistent with FDA and EPA regulations

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Overview

- Ventilator associated events
  - Surveillance
  - Epidemiology
  - Prevention

Hospital Acquired Pneumonia
- Epidemiology
- Pathophysiology and Microbiology
- Diagnosis
- Prevention

Thanks to Sarah Lewis for slides

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ESTIMATES OF HAIs OCCURRING IN ACUTE CARE HOSPITALS, US, 2011

Major Site of Infection	Estimated Number (%)
Pneumonia	157,500 (21.8%)
Gastrointestinal illness	123,000 (17.0%)
Urinary tract infections	93,000 (12.9%)
Primary bloodstream infections	71,900 (10.0%)
Surgical site infections from any inpatient surgery	157,000 (21.7%)
Other types of infection	118,500 (16.3%)
Estimated total number of infections in hospitals	721,800

Magill SS, et al. New Engl J Med 2014;370:1198

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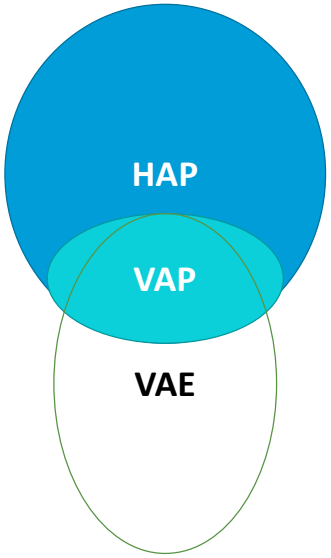
Definitions

- HAP: Hospital-acquired pneumonia
- VAP: Ventilator-associated pneumonia
- VAE: Ventilator-associated event



Disclaimers:
VAE is relatively 'new' and fewer data exist on its epidemiology, impact, and prevention relative to pneumonia

Few data in this talk include ventilator associated complications in the era of COVID-19

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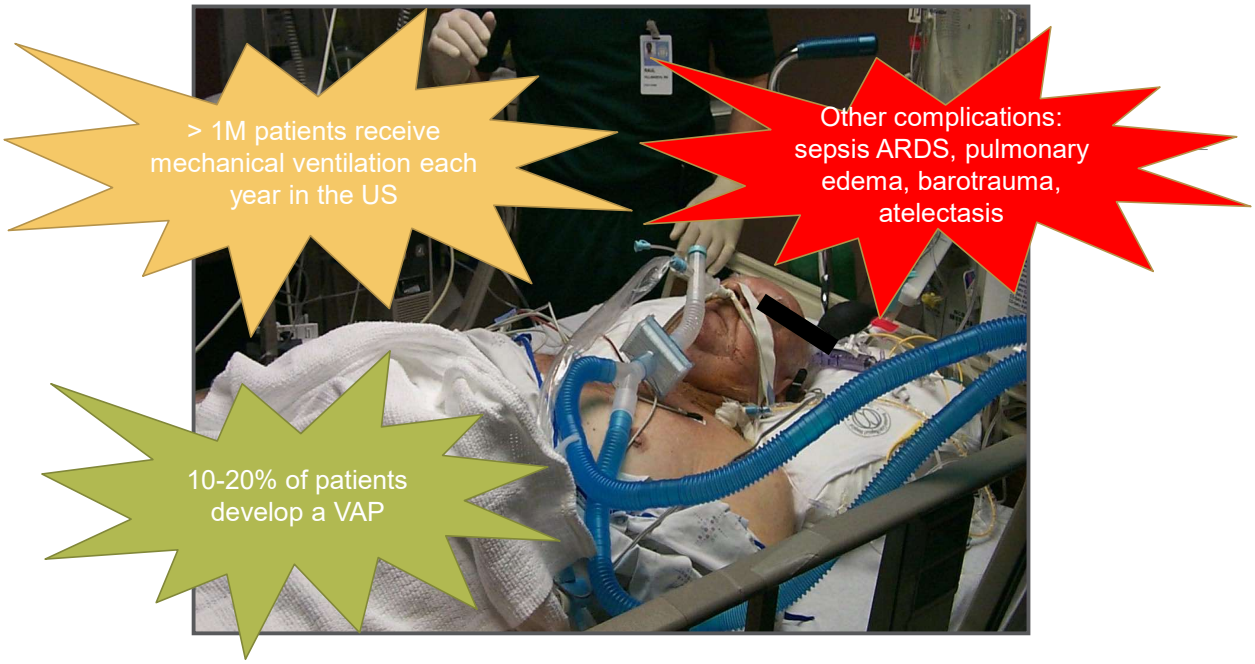

Rackley. Respiratory Care Jun 2020, 65 (6) 832-846 / https://www.cdc.gov/nhsn/pdfs/pscmanual/10-vae_final.pdf

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Overall Impact

- Potential complications of mechanical ventilation
  - Pneumonia, acute respiratory distress syndrome (ARDS), pulmonary embolism, barotrauma, pulmonary edema, and death
- Incidence
  - >300,000 patients receive mechanical ventilation each year in the US
    - 10% TO 20% develop VAP
  - 2011, an estimated 157,000 healthcare-associated pneumonias in US
    - 39% were ventilator-associated (VAP)
- Mortality (VAP)
  - Patients 15-19 years, 24%; patients ≥85 years of age, 60%
  - Attributable mortality ~10%

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Table 4. Estimated Numbers of Major Types of Health Care–Associated Infection in the United States in 2011.

Type of Infection	Infections Identified in Survey	Surveyed Patients with Type of Infection	Estimated Infections in the United States*
	no.	*% (95% CI)*	*no. (95% CI)*
All health care–associated infections			
Pneumonia	110	24.3 (20.6–28.5)	157,500 (50,800–281,400)
Surgical-site infection	110†	24.3 (20.6–28.5)	157,500 (50,800–281,400)
Gastrointestinal infection	86	19.0 (15.6–22.8)	123,100 (38,400–225,100)
Urinary tract infection	65	14.4 (11.4–17.9)	93,300 (28,100–176,700)
Primary bloodstream infection	50	11.1 (8.4–14.2)	71,900 (20,700–140,200)
Eye, ear, nose, throat, or mouth infection	28‡	6.2 (4.2–8.7)	40,200 (10,400–85,900)
Lower respiratory tract infection	20	4.4 (2.8–6.6)	28,500 (6900–65,200)
Skin and soft-tissue infection	16	3.5 (2.1–5.6)	22,700 (5200–55,300)
Cardiovascular system infection	6	1.3 (0.5–2.7)	8,400 (1200–26,700)
Bone and joint infection	5	1.1 (0.4–2.4)	7,100 (1000–23,700)
Central nervous system infection	4	0.9 (0.3–2.1)	5,800 (700–20,700)
Reproductive tract infection	3	0.7 (0.2–1.8)	4,500 (500–17,800)
Systemic infection	1	0.2 (0.01–1.1)	1,300 (0–10,900)
Total			721,800 (214,700–1,411,000)
Infections in non-neonatal intensive care units			
Catheter-associated urinary tract infection	25	5.5 (3.7–7.9)	35,600 (9100–78,000)
Central-catheter–associated primary bloodstream infection	11	2.4 (1.3–4.2)	15,600 (3200–41,500)
Ventilator-associated pneumonia	35	7.7 (5.5–10.5)	49,900 (13,600–103,700)
Surgical-site infections attributed to Surgical Care Improvement Project procedures§	46	10.2 (7.6–13.2)	66,100 (18,700–130,300)
Hospital-onset infections caused by specific pathogens			
Clostridium difficile infection¶	56	12.4 (9.6–15.7)	80,400 (23,700–155,000)
MRSA bacteremia‖	7	1.5 (0.7–3.0)	9,700 (1700–29,600)

Magill SS, et al. New Engl J Med 2014;370:1198

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Surveillance: Quick Overview

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Why do we do surveillance?

- Identify **deviations from the norm**
- Devise/implement/test strategies for **quality improvement**
- Objective data for internal/external **comparisons**

Haley et al. Am J Epidemiol. 1980 ;111(5):472-85

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How do we do surveillance?

- CDC's **national surveillance network** for healthcare-associated infections (HAI)
  - Initially, participation voluntary but now facilitates mandatory reporting to states, CMS
- **Standardized case definitions** of HAIs
  - Goal is to allow 'fair' comparisons over time and between facilities

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Challenges of Surveillance

1) Balancing objectivity with clinical relevance

Ideally, a good target is something that:

- Can be objectively defined
- Is relevant
- Can be modified

Surveillance definitions do not always equal clinical definitions

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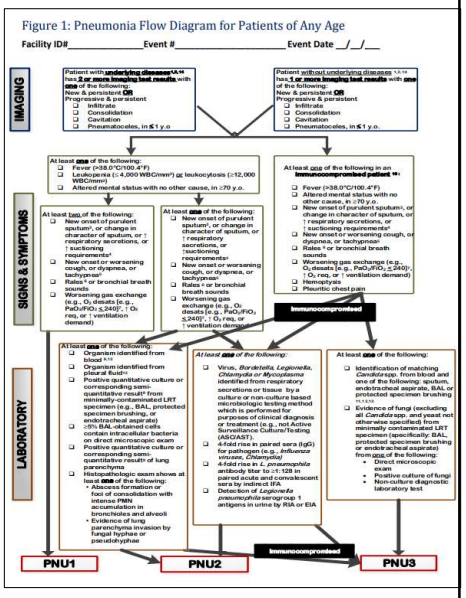
Challenges of Surveillance

2) **Burden of data collection**

Overly burdensome or complicated algorithms

- Problems with inter-rater reliability
- Quality of surveillance data may suffer



https://www.cdc.gov/nhsn/pdfs/pscmanual/6pscvapcurrent.pdf

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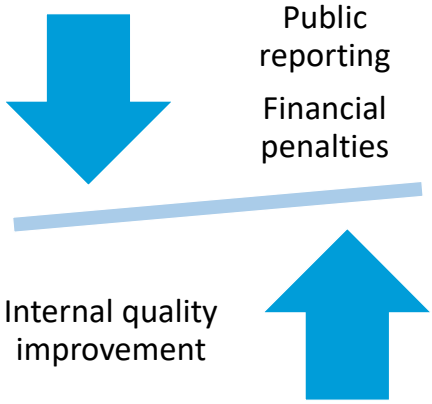
Challenges of Surveillance

- 3) **Risk adjustment**
  - Some patients will be more or less at risk for certain complications
  - Some hospitals may treat more high-risk patients than other hospitals



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Rationale for Creation of VAE Definition in 2014

Old ventilator-associated pneumonia (VAP) surveillance definitions: *subjective and non-specific*

Concerns about 'old' VAP definitions:

- Definitions prone to gaming/under-reporting
- Narrowly interpret radiographs
- Seek consensus between multiple IPs/providers
- Allow clinicians to veto surveillance determinations
- Losing sight of the value and mission of surveillance?
  - Many ICUs reporting 0 VAPs

Klompas Clin. Infect. Dis. 2010; 51:1123-26
Klompas Am J Infect Control 2012;40:408-10

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Ventilator Associated Events (VAE)

Ventilator-associated condition (VAC)

Oxygenation/ventilation

Infection-related VAC (IVAC)

Fever, WBC, antibiotics

Possible ventilator associated pneumonia (PVAP)

Respiratory specimen data

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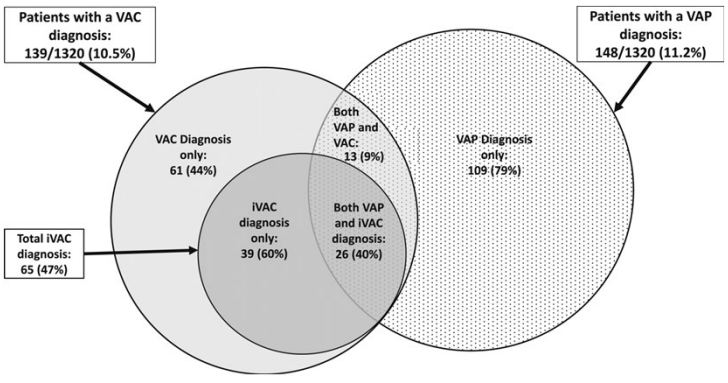
A Paradigm Shift: VAE ≠ VAP



Muscedere et al. Chest. 2013;144(5):1453-1460

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"Only **VAC and IVAC … are intended to be possible candidates for future use in public reporting, inter-facility comparisons, and pay-for-performance programs**. The VAC and IVAC definitions use criteria based on data anticipated to be available from most mechanically ventilated patients and less subject to manipulation or gaming. By contrast, the third definition tier, **possible and probable VAP, was developed to be used only in internal quality improvement**."

Magill et al. Clin Infect Dis 2013; 57(12):1742-46.

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What are VAE?

- Retrospective study- 3028 patients 1996-2012 on mechanical ventilation >= 5 days
  - VAE are COMMON
    - 77% of patients with at least 1 VAC
    - 29% of patients with at least 1 IVAC
  - There are many etiologies of VAE
    - Infectious complications (not just pneumonia) common
    - Non-infectious complications not directly related to mechanical ventilation also play role

Variables[a]	Ventilator-Associated Condition (n = 2,331)	Infection-Related Ventilator-Associated Complication (n = 869)
Number of etiologies per patient		
0	818 (35.1)	189 (21.78)
1	726 (31.2)	260 (29.9)
2	445 (19.1)	213 (24.5)
3	214 (9.2)	124 (14.3)
≥ 4	128 (5.5)	83 (9.6)
Nosocomial infections	637 (27.3)	381 (43.8)
Ventilator-associated pneumonia	339 (14.5)	240 (27.6)
Tracheobronchitis	23 (1)	12 (1.4)
Bloodstream infection	173 (7.4)	95 (10.9)
Catheter-related infection	81 (3.5)	44 (5.1)
Urinary infection	102 (4.4)	42 (4.8)
Sinusitis	5 (0.2)	4 (0.5)
Viral infection	10 (0.4)	8 (0.9)
Surgical site infections	41 (1.8)	30 (3.5)
Iatrogenic adverse events	322 (13.8)	137 (15.8)
Pneumothorax	37 (1.6)	23 (2.6)
Failure of planned extubation	11 (0.5)	1 (0.1)
Accidental extubation	21 (0.9)	9 (1)
Self-extubation	71 (3)	19 (2.2)
Venous puncture accident	14 (0.6)	9 (1)
Atelectasis	52 (2.2)	20 (2.3)
Peripheral thrombosis	36 (1.5)	18 (2.1)
Pulmonary embolism	9 (0.4)	1 (0.1)
Myocardial infarction	10 (0.4)	4 (0.5)
Cardiac arrest	43 (1.8)	24 (2.8)
Cardioversion	29 (1.2)	17 (2)
Gastrointestinal bleeding	26 (1.1)	11 (1.3)
Acute mesenteric infarction	5 (0.2)	4 (0.5)
Intestinal pseudo-obstruction	2 (0.1)	0
Transport	387 (16.6)	186 (21.4)
Fluid resuscitation	123 (5.3)	58 (6.7)

[a]Expressed as number (%).

CRITICAL CARE MEDICINE

Critical Care Medicine43(9):1798-1806, September 2015

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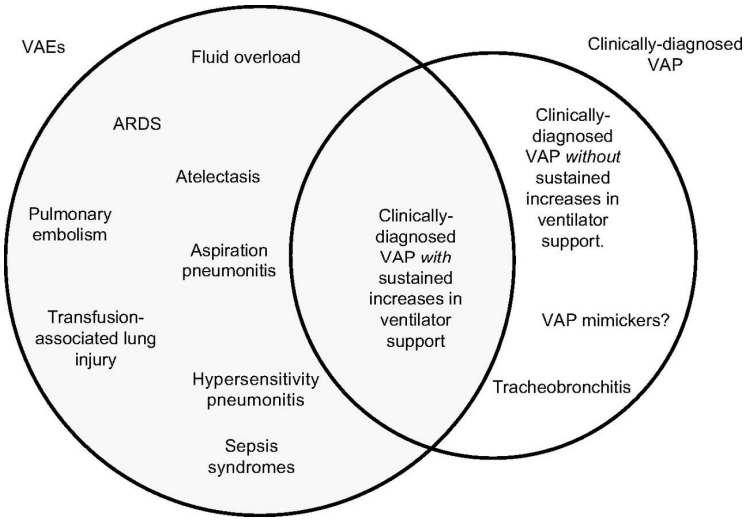
What are VAE?



Klompas Respir Care 2019;64:953-961

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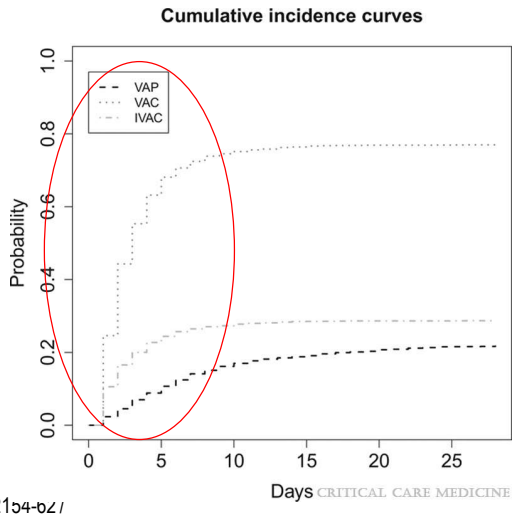
Incidence of VAC/IVAC/VAP

- Approximately 5-10% of mechanically ventilated patients develop VAEs
- Probability increases with duration of mechanical ventilation
  - Most occur within the first week of ventilation
  - Approaches 80% at 30 days
- Incidence varies widely among reporting hospitals and by unit type
  - Higher among neuro, surgery, and trauma units, academic-affiliated medical centers



Critical Care Medicine 2015; 43(9):1798-1806 / Magill Crit Care Med 2016; 44(12): 2154-62 / Klompas. Infect Control Hosp Epidemiol *43*(6), 687-713

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Relevance of VAE

- Mortality:
  - In-hospital mortality 38-50%
  - OR 2.0 (1.3-3.2) vs. non-VAE
- ICU LOS:
  - 22 days IVAC v. 9 days non-IVAC
- Antibiotic usage:
  - 17.8 days IVAC v. 9.3 days non-IVAC

Good correlation of VAE with other quality outcomes

Klompas 2011. PLoS One. 6(3), e18062
Muscedere et al. Chest. 2013;144(5):1453-1460

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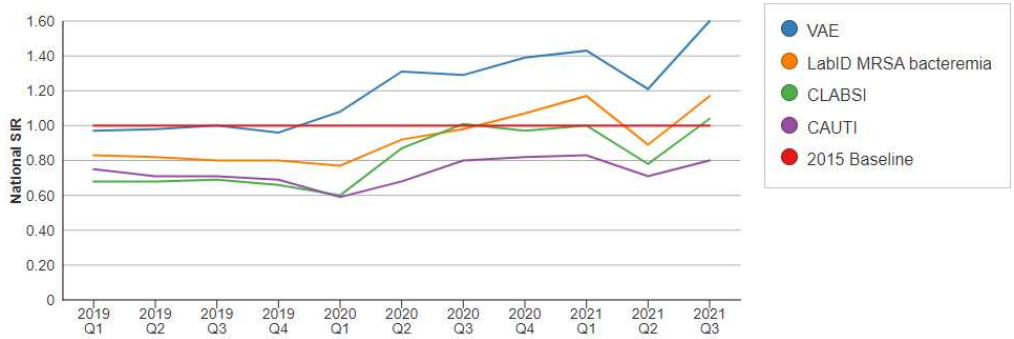
Impact of COVID-19 Pandemic on VAEs

Figure 1. Quarterly National SIRs for Select HAI Types, 2019-Q1 - 2021-Q3



https://www.cdc.gov/hai/data/portal/covid-impact-hai.html

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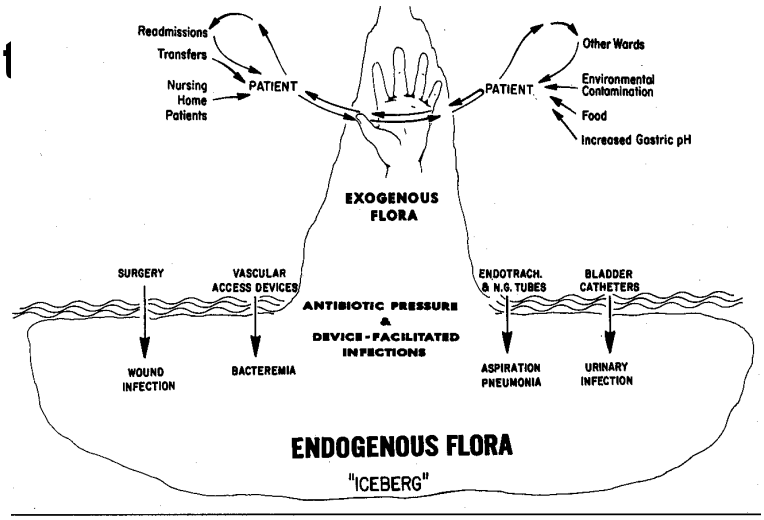
Approach to prevent

- Understanding the hazards of the ICU



Weinstein RA. Am J Med 1991;91(suppl 3B):180S

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Approach to Prevention

Decrease duration of mechanical ventilation	⟷	Decrease risk of complication during mechanical ventilation

- Understand that these 2 aspects of prevention are intimately related
- Look for opportunities to standardize and improve process measures that are likely to benefit many patients

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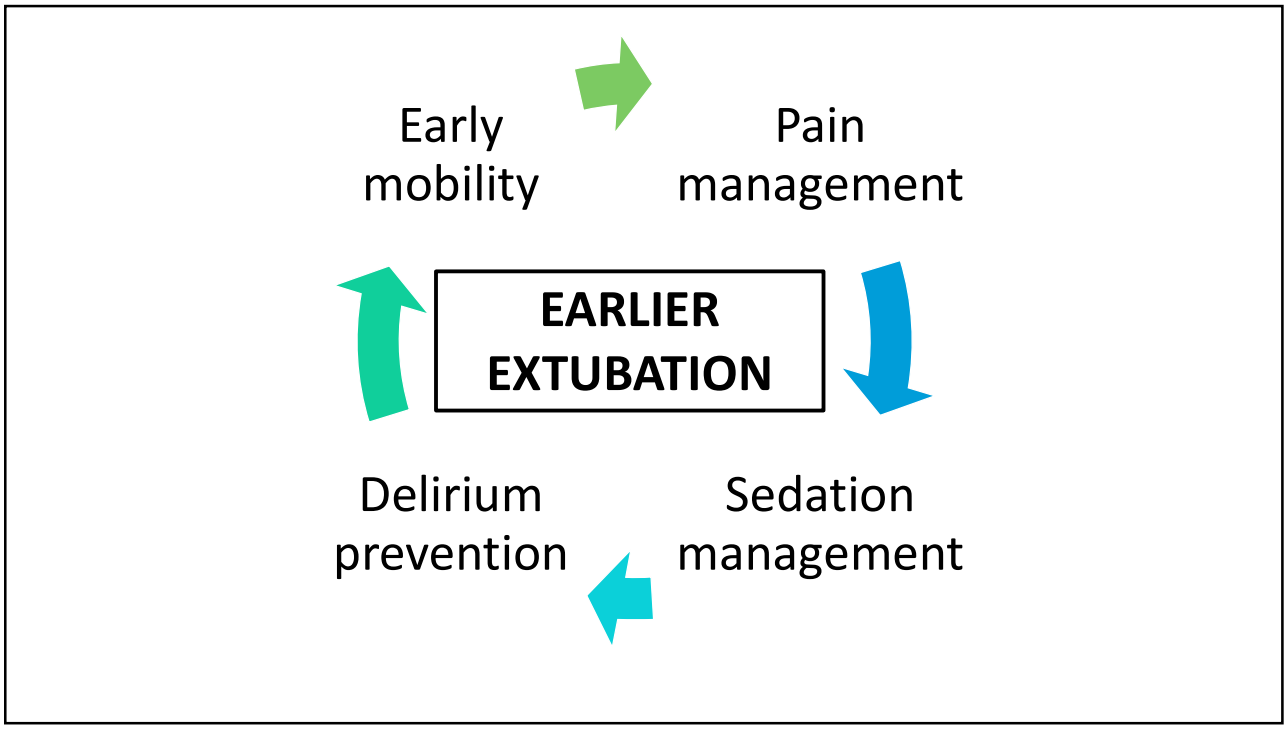

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Evidence-based Prevention Approaches

⇩ **Possible** (evidence from observational studies alone and/or inconsistent evidence from randomized controlled trials) ↓ **Probable** (evidence from randomized controlled trials and/or meta-analyses)	Duration of Ventilation	Pneumonia	Atelectasis	ARDS	Fluid Overload
Minimize sedation	↓	⇩	⇩		
Paired SATs and SBTs	↓	⇩		⇩	
Early mobility	↓	⇩	⇩		
Low tidal volume ventilation	⇩	↓	↓	↓	
Conservative fluid management	↓	⇩		⇩	↓
Conservative transfusion thresholds	⇩	↓		↓	↓

Am J Respir Crit Care Med, 2015. PMID 26398835

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Sedation Management

- Sedatives and analgesics are mandatory in most mechanically ventilated patients
- Overuse of analgesics/sedating medications may impair ventilator weaning, resulting in prolonged intubation, mechanical ventilation, and ICU stay

- **Recommendation:**
- Nurse-driven assessments and protocols to target sedation to a monitored sedation goal
- Daily spontaneous awakening trials in appropriate patients*

DeGrado et al. J Pain Res. 2011;4:127-134

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Goal-directed Analgesia/Sedation Management

1) Measure and document pain and sedation level using validated, objective criteria
   - Pain: Behavioral Pain Scale (BPS)
   - Sedation: Richmond-Agitation Sedation Scale (RASS)
2) Implement nurse-driven protocols to target adequate analgesia and light sedation
3) Screen for and treat delirium

DeGrado et al. J Pain Res. 2011;4:127-134 / Am J Health-Syst Pharm. 2013;70:53-8.

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Preventing VAEs: Wake up and Breathe

- Quality improvement collaborative
- 12 ICUs participated in initiative: nurse-led daily SAT and SBT for all eligible patients

Klompas et al. AJRCCM. 2015;191(3):292-301

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Criteria for Spontaneous Awakening Trial

Safety Screen

- No active seizures
- No alcohol withdrawal
- No agitation
- No paralytics
- No myocardial ischemia
- Normal intracranial pressure

SAT Failure

- Anxiety, agitation, pain
- Respiratory rate > 35/min
- Oxygen saturation < 88%
- Respiratory distress
- Acute cardiac arrhythmia

www.icudelirium.org

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Criteria for Spontaneous Breathing Trial

Safety Screen

- No agitation
- Oxygen saturation >=88%
- FiO2 <=50%
- PEEP <= 7.5 cm H2O
- No myocardial ischemia
- No vasopressor use
- Inspiratory efforts

SBT Failure

- Respiratory rate > 35/min
- Respiratory rate < 8/min
- Oxygen saturation < 88%
- Respiratory distress
- Mental status change
- Acute cardiac arrhythmia

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Preventing VAEs: Wake up and Breathe

Participating units

- Improved performance of daily SAT when indicated (14 to 77%)
- Improved performance of SBTs when indicated (49 to 75%)
- Improved proportion of SBTs performed with sedatives off (6 to 87%)

- Decreased mean duration of mechanical ventilation by 2.4 (95% CI 1.7-3.1) days
- Decreased ICU LOS by 3.0 (95% CI 1.6-4.3) days

Klompas Am J Respir Crit Care Med 2015; 191(3): 292-301

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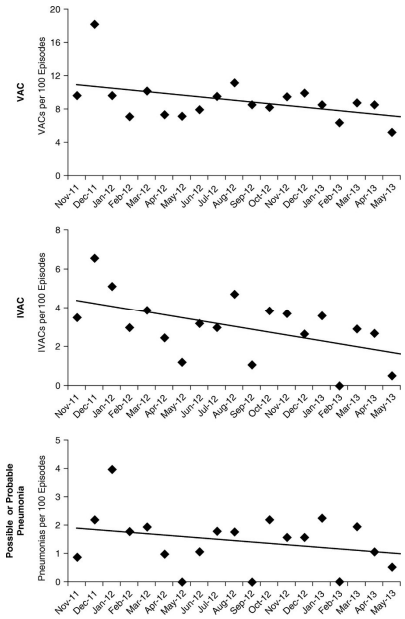

Am J Respir Crit Care Med, 2015; http://www.atsjournals.org/doi/abs/10.1164/rccm.201407-1394OC

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ABCDEF Bundle

www.icudelirium.org

A: Assess, Prevent, Manage Pain

B: Both Spontaneous Awakening Trials and Spontaneous Breathing Trials

C: Choice of Analgesia and Sedation

D: Delirium: Assess, Prevent, and Manage

E: Early Mobility and Exercise

F: Family Engagement and Empowerment

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What VAEs Are and Are Not

	What They Are	What They Aren't
Intent	Surveillance concept	Clinical diagnosis
Surveillance	Objective and reproducible	Sensitive/specific for VAP
Etiology	Many potential causes including non-infectious ones	Proxy for pneumonia
Morbidity	Highly morbid	Not benign
Prevention strategy	Re-think prevention bundles: • Minimize sedation • Early mobility • Low tidal volume ventilation • Conservative fluid management	Not fully preventable by traditional bundles

Michael Klompas Respir Care 2019;64:953-961

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Tips for Establishing a VAE Surveillance and Prevention Program

- Establish a multidisciplinary collaboration with intensivists, respiratory therapists, infection prevention
  - Review the surveillance definitions and goals of the surveillance
  - Frame VAE as an objective measure of 'harm' in ventilated patients with many etiologies, and not solely an infection-related outcome
  - Agree on best practices to prevent ventilator harm and track performance of these processes (SBT/SAT, delirium assessment, pain management)

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Pneumonia

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Pneumonia and VAE Surveillance: Current State for Many IP programs

	PNEU	VAE
Surveillance	• Selectively performed on cases of BSI in patients with central venous catheters to determine if criteria met for secondary attribution (all programs)	• Performed on all patients on mechanical ventilation > 4 days
Clinical relevance	• Poor correlation between clinical and surveillance definitions of pneumonia	• Not specific for an individual clinical presentation – represents a large group of conditions
Prevention	• Hand hygiene, avoid ventilation when possible, early mobility, pain/sedation management, elevate head of bed, minimize unnecessary devices, antibiotic stewardship	

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Non-ventilator- associated HAP (NVHAP): Recent call to action

Clinical Relevance

- 1% of all hospitalized patients develop NVHAP
- Crude mortality 15-30%
- Extends LOS up to 15 days
- Increases antibiotic utilization
- Increases risk for readmissions

Munro, S., Baker, D., Giuliano, K., Sullivan, S. Haber, J., Jones, B., Klompas, M. (2021). Nonventilator hospital-acquired pneumonia: A call to action: Recommendations from the National Organization to Prevent Hospital-Acquired Pneumonia (NOHAP) among nonventilated patients. *Infection Control & Hospital Epidemiology, 42*(8), 991-996

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Non-ventilator-associated HAP (NVHAP): Recent call to action

Quick Safety

Issue 61 | September 2021

Preventing non-ventilator hospital-acquired pneumonia

Issue:
It's estimated that one in every 100 hospitalized patients will be affected by non-ventilator hospital-acquired pneumonia (NVHAP). While NVHAP is a significant patient safety and quality of care concern, it is not currently recognized as one of the National Database of Nursing Quality indicators for which hospitals are held accountable; nor is it one of the conditions that the Centers for Medicare & Medicaid Services (CMS) requires hospitals to report to the Centers for Disease Control & Prevention (CDC) National Healthcare Safety Network; and it is not integrated into the CMS current pay-for-reporting or performance programs.[1] As a result, this leaves NVHAP a health care-acquired condition without national tracking or accountability, and, most likely, is unaddressed by health care organizations.

Quick Safety Alert: Preventing non-ventilator hospital-acquired pneumonia. The Joint Commission. 2021: 61. https://www.jointcommission.org/resources/news-and-multimedia/news/2021/09/new-quick-safety-on-preventing-nvhap/

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Non-ventilator- associated HAP (NVHAP): Recent call to action

Current Gaps
- **No current surveillance definition or methodology**

Big questions
- How can we improve the reproducibility, relevance, and efficiency of surveillance for HAP?
- Do we fully understand the mechanism of NVHAP to inform prevention strategies?
- What are the best-performing interventions to prevent NVHAP?

In absence of data
- Promote early mobility
- Screen for and manage dysphagia to reduce risk of aspiration
- Decrease risk of hospital transmission of respiratory viruses
- Perform regular oral care

Munro, S., Baker, D., Giuliano, K., Sullivan, S., Haber, J., Jones, B., . . . Klompas, M. (2021). Nonventilator hospital-acquired pneumonia: A call to action: Recommendations from the National Organization to Prevent Hospital-Acquired Pneumonia (NOHAP) among nonventilated patients. *Infection Control & Hospital Epidemiology, 42*(8), 991-996

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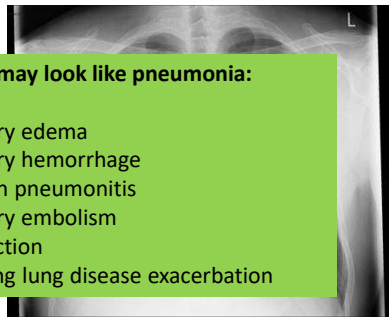
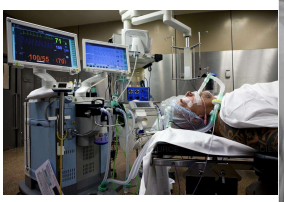
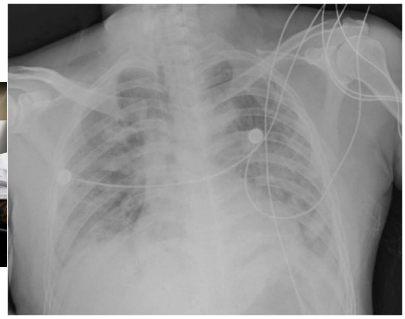
Pneumonia Clinical Definition

- Combination of the following:
  - Fever
  - Leukocytosis
  - Purulent sputum
  - Radiographic infiltrates
  - Change in oxygenation
  - + / - Positive microbiologic culture from respiratory tract
  - **Clinical judgment**



Things that may look like pneumonia:
- ARDS
- Pulmonary edema
- Pulmonary hemorrhage
- Aspiration pneumonitis
- Pulmonary embolism
- Drug reaction
- Underlying lung disease exacerbation





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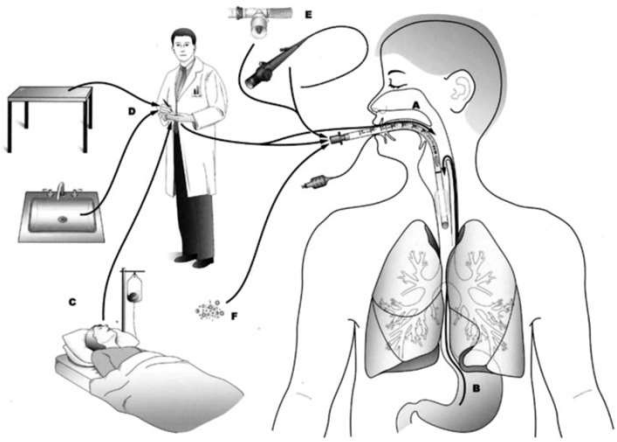
Healthcare-Associated Pneumonia (HAP) Pathogenesis



Aerodigestive tract colonization

- Colonization of the aerodigestive tract may occur **endogenously** (A and B) or **exogenously** (C through F)
- **Exogenous** colonization may result in primary colonization of the oropharynx or may be the result of direct inoculation into the lower respiratory tract during manipulations of respiratory equipment (D), during using of respiratory devices (E), or from contaminated aerosols (F).

Safdar et al. Respir Care 2005;50(6):725-739

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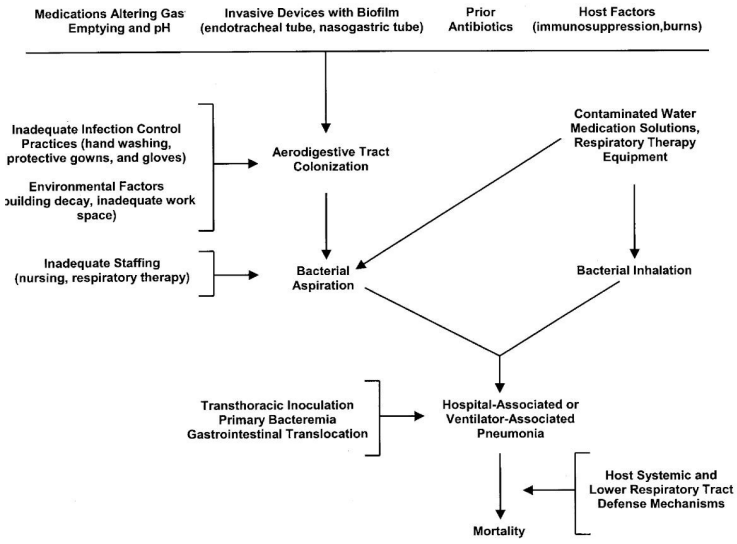
Pathogenesis of Pneumonia in Hospitalized Patients

- **Aspiration** of secretions from upper airway
- **Inhalation** of pathogens (e.g., Legionella, Aspergillus)
- **Instillation** of pathogens (e.g atypical mycobacteria, environmental Gram-negative rods)



Kollef MH, et al. Chest 2004;32:1396

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VAP: RISK FACTORS

Host-related risk factors	Intervention-related risk factors
Medical history and underlying illness	Peri-operative transfusion of blood products
Male gender	Duration of the mechanical ventilation
Extreme age	Reintubation
Prior central nervous system disorder	Supine head position in patients receiving enteral nutrition
Immunocompromised	Antibiotic therapy[a]
Acute underlying diseases	Enteral nutrition
Emergent surgery	Absence of subglottic secretion drainage[b]
Neurosurgery	Intra-hospital transports
Thoracic surgery	Continuous sedation, use of paralytic agents
Cardiac surgery	Nasogastric tubes
Burns	Tracheostomy
Re-intervention	Frequent ventilator circuit changes
Acute severity factors	Intracuff pressure of less than 20 cm H_2O
Organ system failure index of at least 3	
Acute renal failure	
Acute respiratory distress syndrome	
ECMO, intra-aortic support	
Ulcer disease	

Adapted from 2,35–38. [a]Antibiotic therapy protects from early-onset pneumonia due to susceptible bacteria but is a risk factor for late-onset pneumonia due to more resistant organisms. [b]Protective impact of subglottic secretion drainage is mainly demonstrated for cardiac surgery patients. ECMO, extra-corporeal membrane oxygenation.

Timsit J-F, et al. F10000Research 2017, 6

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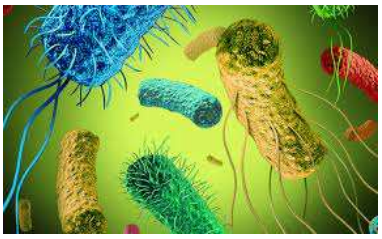
HAP/VAP pathogens

- Determinants of pathogens
  - Setting
  - Prior antibiotic use
  - Duration of hospitalization
    - Early (<5 days): *S. pneumoniae*, *H. influenzae*, MSSA
    - Late (≥5 days): *P. aeruginosa*, MRSA, Gram (-) bacilli
  - ICU stay
  - Colonization



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MICROBIOLOGY

Community acquired aspiration	Hospital acquired aspiration	Inhalational	Hematogenous
• Haemophilus influenzae • Streptococcus pneumoniae • Oropharyngeal streptococci and anaerobes	• Oropharyngeal streptococci and anaerobes • Enterobacteriaceae • Pseudomonas	• Fungi • Legionella • Viruses • Mycobacteria	• Staph aureus (common) • Enterobacteriaceae (uncommon)

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Methods to Confirm a Microbiologic Diagnosis

- **Note: microbiologic diagnosis is not required clinically**
- Blood cultures
- Pleural fluid analysis & cultures (if parapneumonic effusion present)
- Tissue diagnosis (rare)
- Non-bronchoscopic
  - Endotracheal aspiration (common)
- Bronchoscopic techniques (pursued when treatment failure, concern for atypical pathogen such as fungus, immunocompromised, or non-infectious etiology)
  - Protected specimen brush (PSB)
  - Bronchoalveolar lavage (BAL)

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Preventing HAP/VAP: An Important Target for Antimicrobial Stewardship

Pathogen	Incidence and resistance trends
MRSA	Rate in VAP: 12–42%[a] Rate of methicillin resistance is decreasing: 1.4–82%[b]
Pseudomonas aeruginosa	Rate in VAP: 21–61% especially for the second episode of VAP[a] MDR/XDR rates as high as 38–46% with 8–20% susceptible only to colistin [12–14] Meropenem with >10% increase in resistance in North America with susceptibility across all classes of antimicrobials at 60–71% [10]
Enterobacteriaceae	Rate in VAP: 5–19.1% with rising rates of resistance to all classes of antimicrobials[a] [9,10,13] Rates of ESBL of 40% in Asia [9]
Acinetobacter spp.	Rate in VAP: 4.8–36.5% (highest in Latin America and Asia) [9,10,13] MDR rate as high as 80% and XDR 50% with 30% susceptible only to colistin [9,10,13] Meropenem and doripenem with >10% increase in resistance [10], colistin-resistant cases reported [15]

Abbreviations: ESBL, extended spectrum β-lactamases; MDR/XDR, multidrug resistant/extremely drug resistant; MRSA, methicillin-resistant *Staphylococcus aureus*; SA, *Staphylococcus aureus*; VAP, ventilator-associated pneumonia.

Guillamet CV, Kollef MH. Curr Opin Crit Care 2015;21:430-8

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SHEA/ IDSA/ APIC 2022 Prevention of VAE and Pneumonia Guidelines

Klompas. Infect Control Hosp Epidemiol 2022 *43*(6), 687-713

Category	Rationale	Intervention	Quality of Evidence
Essential practices	Good evidence that the intervention decreases the average duration of mechanical ventilation, length of stay, mortality, and /or costs. Benefits likely outweigh risks.	Avoid intubation and prevent reintubation • Use high-flow nasal oxygen or noninvasive positive pressure ventilation (NIPPV) as appropriate whenever safe and feasible[91–93,96,99]	HIGH
		Minimize sedation[105,106] • Avoid benzodiazepines in favor of other agents[106] • Use a protocol to minimize sedation[110] • Implement a ventilator liberation protocol[113]	MODERATE
		Maintain and improve physical conditioning[113,120–123]	MODERATE
		Elevate the head of the bed to 30–45°[125,386–390]	LOW[a]
		Provide oral care with toothbrushing but *without* chlorhexidine[126,127]	MODERATE
		Provide early enteral vs. parenteral nutrition[131]	HIGH
		Change the ventilator circuit only if visibly soiled or malfunctioning (or per manufacturers' instructions)[391–394]	HIGH
Additional approaches	Good evidence that the intervention improves outcomes in some populations, but may confer some risk in others.	Use selective oral or digestive decontamination in countries and ICUs with low prevalence of antibiotic-resistant organisms[128,134,135]	HIGH[a]
	May lower VAP rates but insufficient data to determine impact on duration of mechanical ventilation, length of stay, or mortality.	Utilize endotracheal tubes with subglottic secretion drainage ports for patients expected to require >48–72 hours of mechanical ventilation[395]	MODERATE
		Consider early tracheostomy[144]	MODERATE
		Consider postpyloric rather than gastric feeding for patients with gastric intolerance or at high risk for aspiration[131,147]	MODERATE
Generally not recommended	Inconsistently associated with lower VAP rates and no impact or negative impact on duration of mechanical ventilation, length of stay, or mortality.	Oral care with chlorhexidine[126–130,150]	MODERATE
		Probiotics[162–165]	MODERATE
		Ultrathin polyurethane endotracheal tube cuffs[165–167]	MODERATE
		Tapered endotracheal tube cuffs[169]	MODERATE
		Automated control of endotracheal tube cuff pressure[170,171,174,175]	MODERATE
		Frequent cuff-pressure monitoring[176]	MODERATE
		Silver-coated endotracheal tubes[178]	MODERATE
		Kinetic beds[180]	MODERATE
		Prone positioning[181,183,a]	MODERATE
		Chlorhexidine bathing[184–186,a]	MODERATE
	No impact on VAP rates, average duration of mechanical ventilation, length of stay, or mortality.[a]	Stress-ulcer prophylaxis[190,191,193]	MODERATE
		Monitoring residual gastric volumes[194]	MODERATE
		Early parenteral nutrition[195]	MODERATE
No recommendation	No impact on VAP rates or other patient outcomes, unclear impact on costs.	Closed endotracheal suctioning systems[197–199]	MODERATE

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Table 3. Summary of Recommendations to Prevent VAP and/or VAE in Preterm Neonates

Category	Rationale	Intervention	Quality of Evidence
Essential practices	May lower VAP and/or PedVAE rates and have minimal risks of harm. Benefits likely outweigh potential risks.	Use non-invasive positive pressure ventilation in selected populations[62,205,206]	HIGH
		Minimize the duration of mechanical ventilation	HIGH
		Use caffeine therapy to facilitate extubation[396,397]	HIGH
		Assess readiness to extubate daily	LOW
		Manage patients without sedation whenever possible[209,210]	LOW
		Avoid unplanned extubations and reintubations[212]	LOW
		Avoid reintubation by using nasal CPAP, non-invasive positive pressure ventilation (NIPPV), of high flow nasal cannula in the post-extubation period[396]	HIGH
		Provide regular oral care with sterile water	LOW
		Change the ventilator circuit only if visibly soiled or malfunctioning[259] (or per manufacturer's instructions)	LOW
Additional approaches	Unknown impact on VAP and VAE rates but risk of harm likely minimal. Reasonable to consider implementing if rates remain elevated despite essential practices.	Lateral recumbent positioning[215]	LOW
		Reverse Trendelenberg positioning	LOW
		Closed/in-line suctioning systems[216,217]	LOW
		Oral care with maternal colostrum[218]	MODERATE
Generally not recommended	Unknown impact on VAP rates and inadequate data on risks.	Regular oral care with an antiseptic or Biotene[219]	LOW
	May be harmful. Risk-benefit balance does not favor intervention, unless specifically indicated for reasons other than VAP prevention	Histamine-2 receptor antagonists[220,221]	MODERATE
		Prophylactic broad-spectrum antibiotics[222-225]	MODERATE
		Daily spontaneous breathing trials[398,399]	LOW
		Daily sedative interruptions	LOW
		Prophylactic probiotics or synbiotics[228,229]	LOW
	Not recommended because appropriate products are not available or approved for use in this population.	Endotracheal tubes with subglottic secretion drainage ports	NA
		Silver-coated endotracheal tubes	NA

Note. CPAP, continuous positive airway pressure; VAP, ventilator-associated pneumonia.

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Table 4. Summary of Recommendations to Prevent VAP and/or PedVAE in Pediatric Patients

Category	Rationale	Intervention	Quality of Evidence
Essential practices	Interventions with minimal risk of harm and some data that they may lower VAP rates, PedVAE rates, and/or duration of mechanical ventilation.	Avoid intubation if possible. Use non-invasive positive pressure ventilation for selected populations[240-242]	MODERATE
		Assess readiness to extubate daily in patients without contraindications[244-248]	MODERATE
		Take steps to minimize unplanned extubations and reintubations[249]	LOW
		Avoid fluid overload[251,253,254]	MODERATE
		Provide regular oral care (i.e., toothbrushing or gauze if no teeth)[234,256,257]	LOW
		Elevate the head of the bed unless medically contraindicated[234]	LOW
		Change ventilator circuits only if visibly soiled or malfunctioning[259] (or per manufacturer's instructions)	MODERATE
		Prevent condensate from reaching the patient[234,266]	LOW
		Use cuffed endotracheal tubes[262-264]	LOW
		Maintain cuff pressure and volume at the minimal occlusive settings	LOW
		Suction oral secretions before each position change	LOW
Additional approaches	Risk of harm likely minimal with some evidence of benefit in adult patients, but data in pediatric populations are limited. Reasonable to consider implementing if rates remain elevated despite essential practices.	Interrupt sedation daily[267]	MODERATE
		Utilize endotracheal tubes with subglottic secretion drainage ports for older pediatric patients expected to require >48 or 72 hours of mechanical ventilation[395]	LOW
		Consider early tracheostomy[268-270]	LOW
Generally not recommended	Unknown impact on VAP rates and inadequate data on risks.	Prolonged systemic antimicrobial therapy for ventilator-associated tracheitis[272]	LOW
		Selective oropharyngeal or digestive decontamination[274]	LOW
		Prophylactic probiotics[163]	LOW
	No impact on VAP rates.[a]	Oral care with antiseptics such as chlorhexidine[280,284,285]	MODERATE
		Stress-ulcer prophylaxis[286-288]	LOW
	Lowers VAP rates in adults but no impact on duration of mechanical ventilation, length of stay, or mortality.	Silver-coated endotracheal tubes	LOW
No recommendation	Limited data on pediatric patients, no impact on VAP rates or outcomes in adults, unclear impact on costs	Closed or in-line suctioning[293]	LOW

Note.VAP, ventilator-associated pneumonia
[a]May be indicated for reasons other than VAP prevention.

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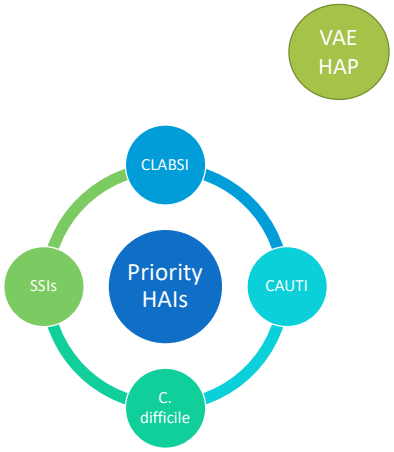
Where does VAE/VAP/HAP prevention fit in?



- Importance of VAE prevention
  - **Correlates with important outcomes of mortality, length of stay**
  - **Key prevention strategies provide many layers of benefit for patients**
  - **Strong correlation with antimicrobial utilization**
    - Prevent MDROs
    - Decrease *C. difficile* rates

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Summary

- VAE definitions are based on objective criteria
- Infectious and non-infectious conditions will be identified as VAEs
- Many VAE are believed to be preventable complications
  - Optimize pain management, sedation, delirium, early mobilization
- VAE and HAP are common and highly correlated with healthcare utilization, morbidity, and antimicrobial utilization
- Growing interest in NVHAP as a target for prevention – stay tuned

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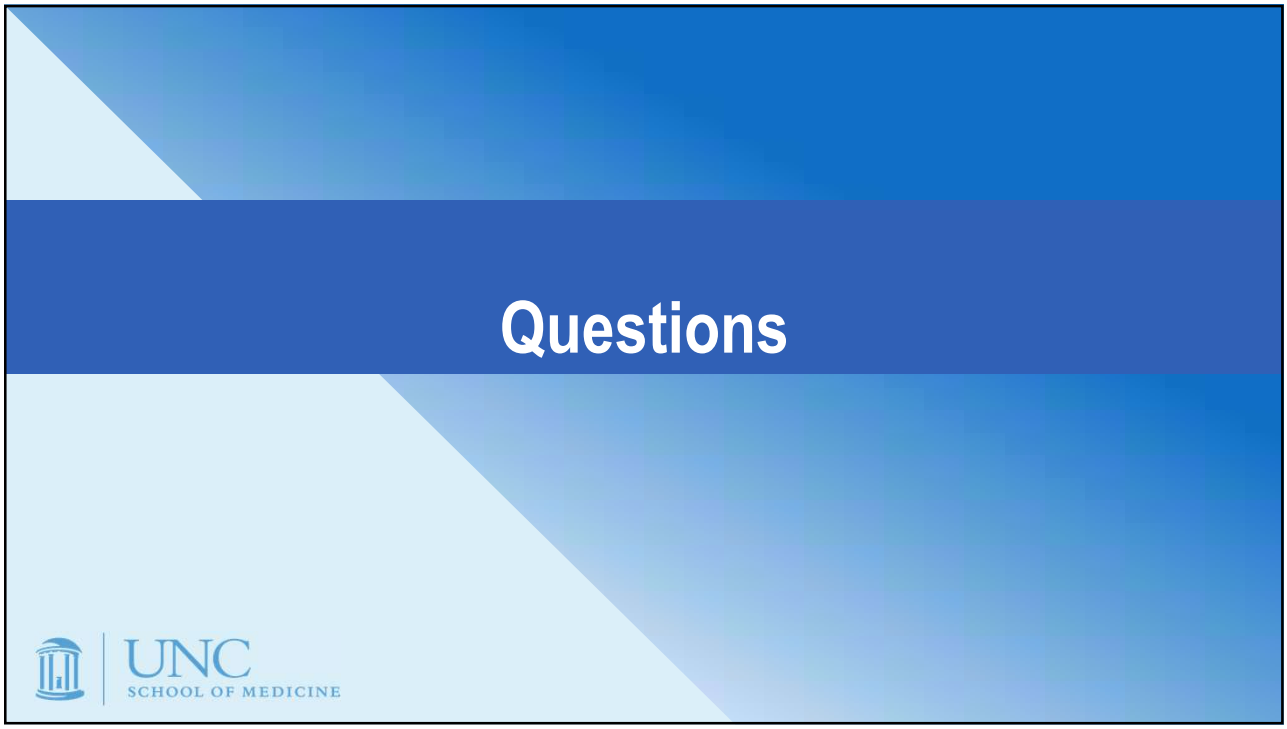

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