Ventilator-Associated Events (VAE) and Hospital-acquired Pneumonia

Pathophysiology, Epidemiology, and Prevention

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DUKE INFECTIOUS DISEASES

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Overview

Ventilator associated events

- Surveillance
- Epidemiology
- Prevention

Hospital Acquired Pneumonia

- Epidemiology
- Pathophysiology and Microbiology
- Diagnosis
- Prevention

Acknowledgements: many slides adapted from prior version of this talk by Dr. David Weber

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

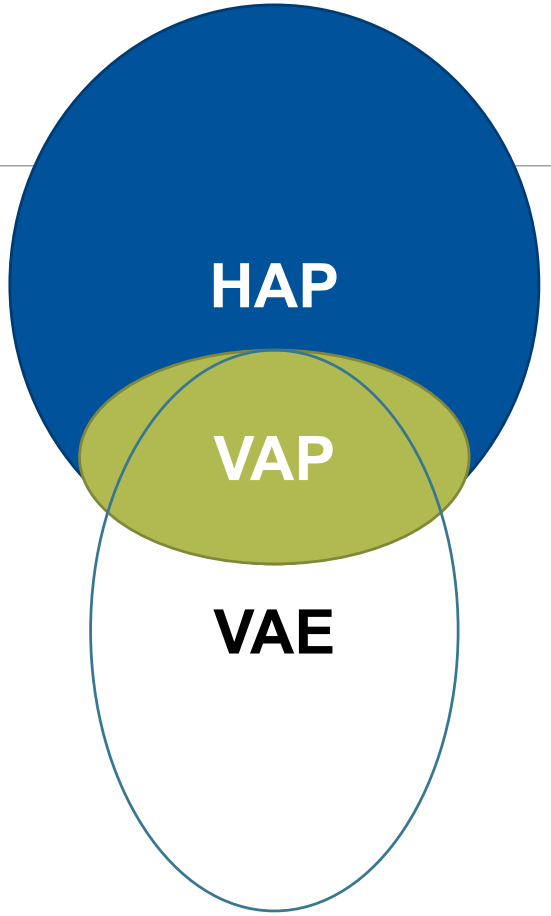
Magill SS, et al. New Engl J Med 2014;370:1198

Definitions

HAP: Hospital-acquired pneumonia

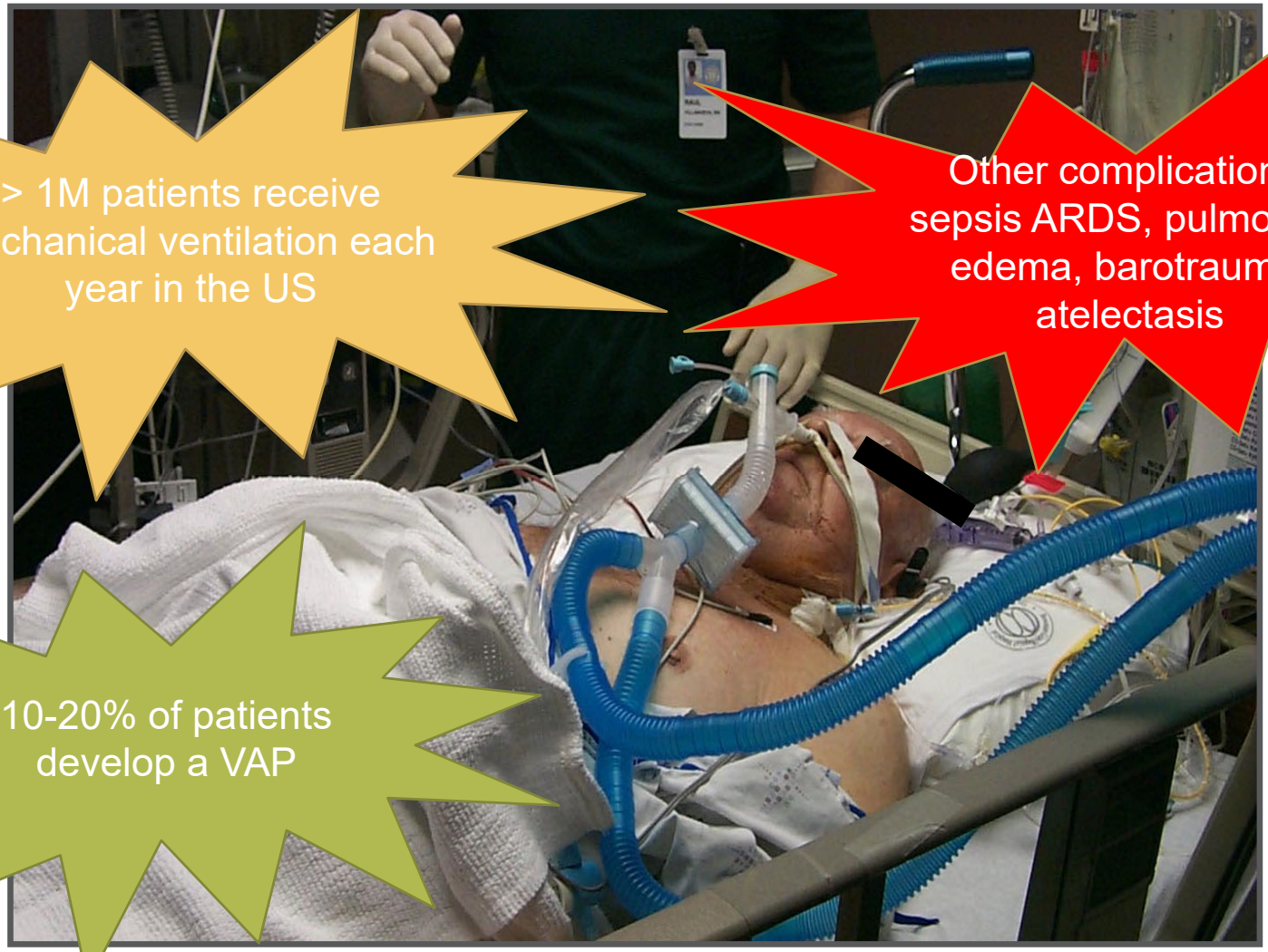
VAP: Ventilator-associated pneumonia

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



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

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%

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)

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

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

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

Challenges of surveillance

1) Balancing objectivity with clinical relevance

Ideally, a good target is something that:

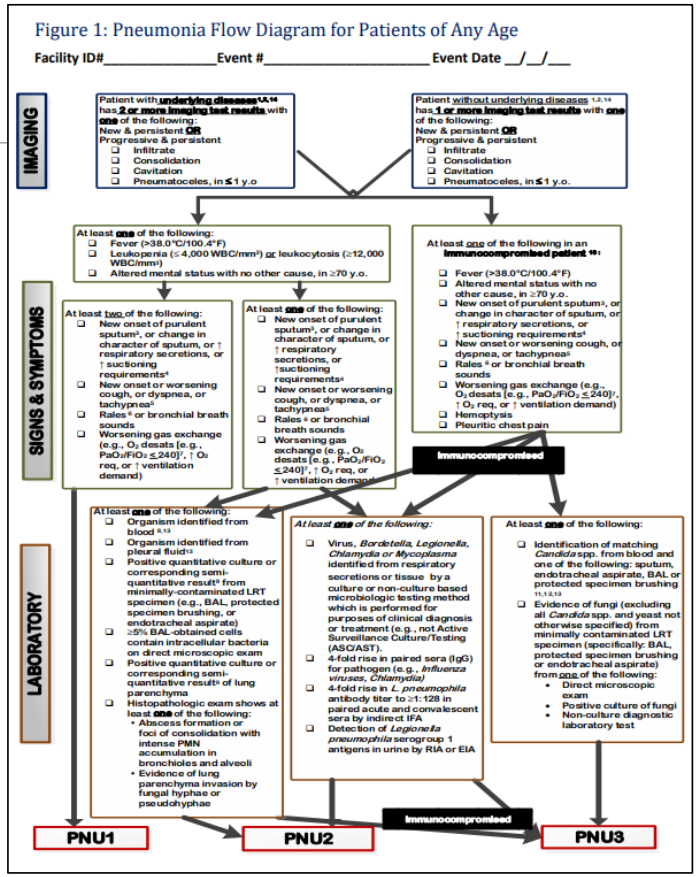
- Can be objectively defined
- Is relevant
- Can be modified

Surveillance definitions do not always equal clinical definitions

Challenges of surveillance

2) **Burden of data collection**

- Overly burdensome or complicated algorithms
- Problems with inter-rater reliability
- Quality of surveillance data may suffer

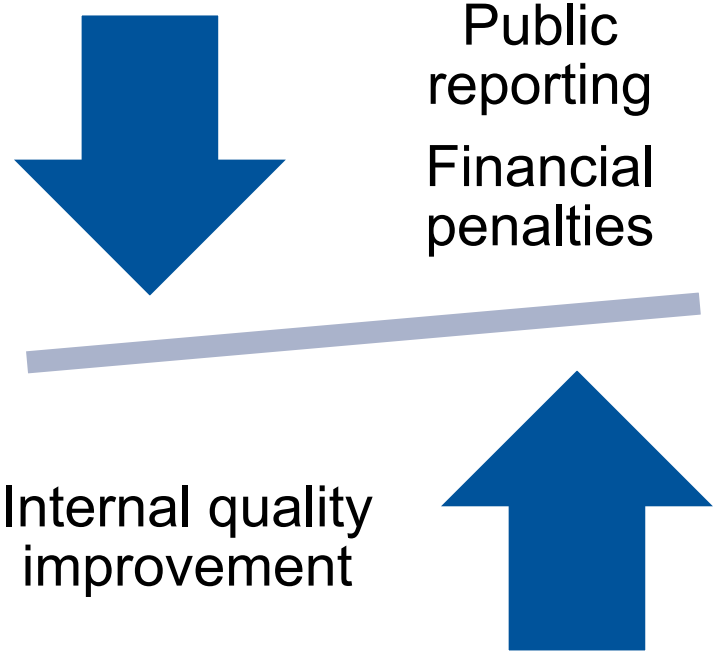


https://www.cdc.gov/nhsn/pdfs/pscmanual/6pscvapcurrent.pdf

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



Rationale for creation of VAE definition in 2014

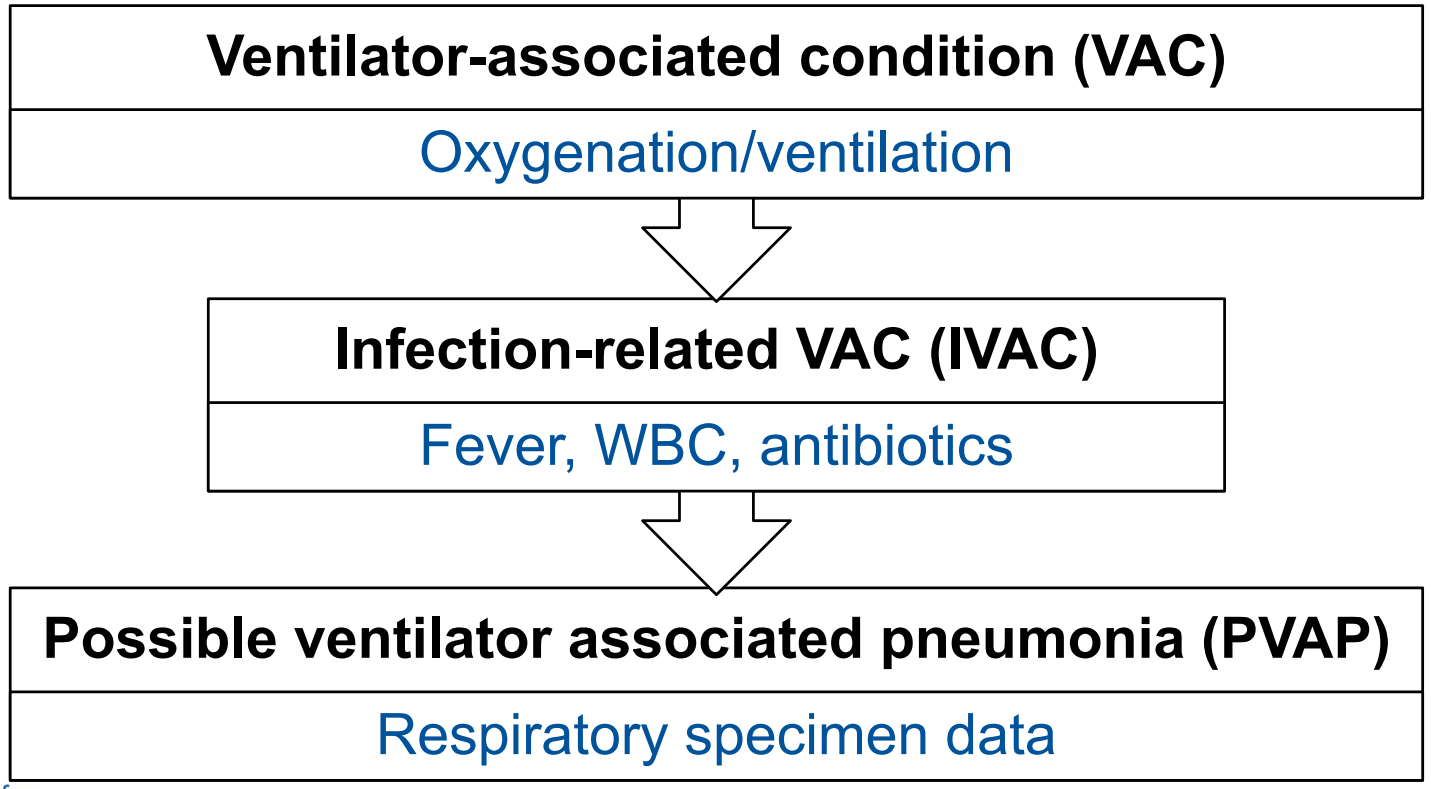
Old ventilator-associated pneumonia (VAP) surveillance definitions: *subjective and non-specific*

Concerns about 'old' VAP definitions:

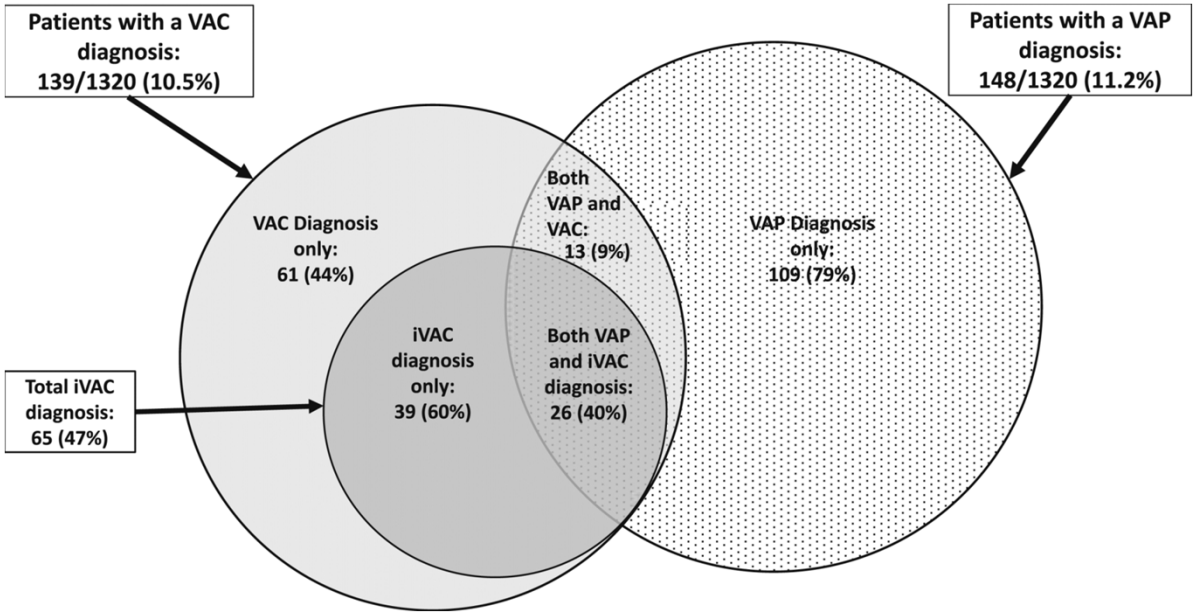
- Definitions prone to gaming/under-reporting
- Narrowly interpret radiographs
- Seek consensus between multiple IPs/providers
- Allow clinicians to veto surveillance determinations
- Losing sight of the value and mission of surveillance?
  - Many ICUs reporting 0 VAPs

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

Ventilator associated events (VAE)



A paradigm shift: VAE ≠ VAP



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

"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.

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

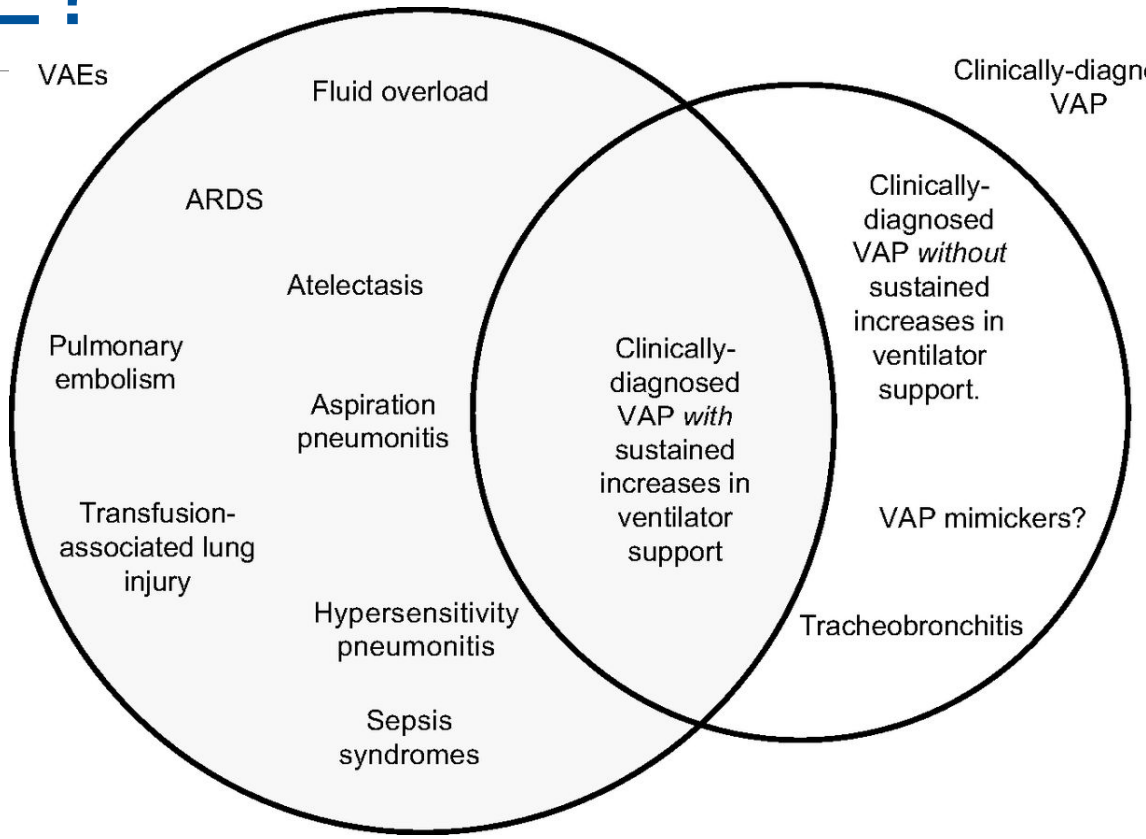
Variables[a]	Ventilator-Associated Condition (n = 2,331)	Infection-Related Ventilator-Associated Complication (n = 869)
Number of etiologies per patient		
0	818 (35.1)	189 (21.78)
1	726 (31.2)	260 (29.9)
2	445 (19.1)	213 (24.5)
3	214 (9.2)	124 (14.3)
≥ 4	128 (5.5)	83 (9.6)
Nosocomial infections	637 (27.3)	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

What are VAE?



Klompas Respir Care 2019;64:953-961

Incidence of VAC/IVAC/VAP

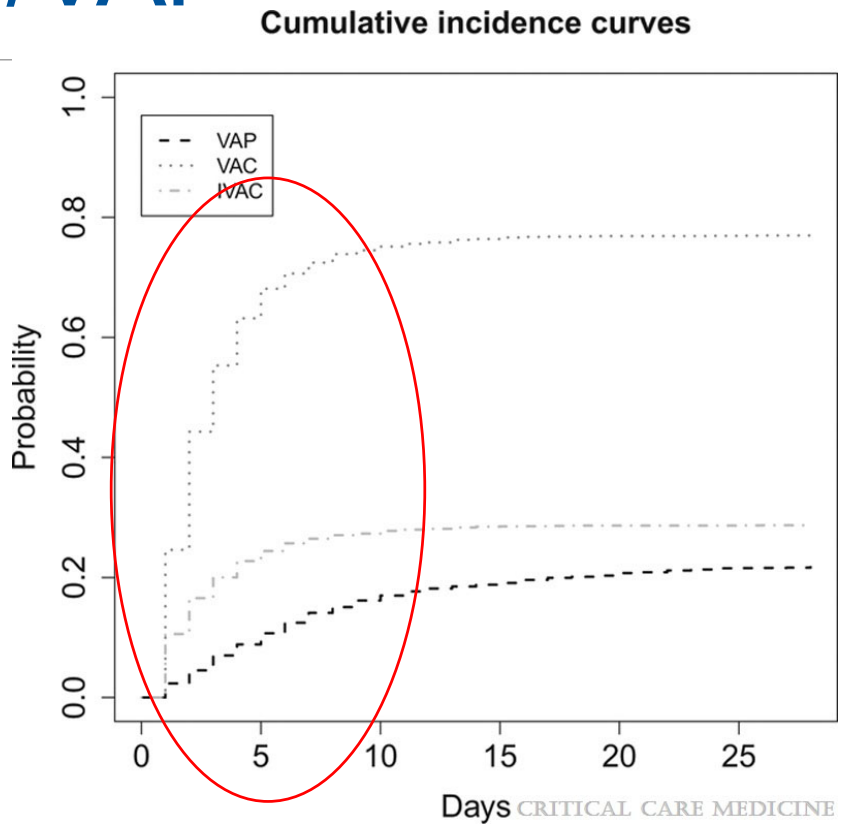
Approximately 5-10% of mechanically ventilated patients develop VAEs

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

Relevance of VAE

Mortality:

- In-hospital mortality 38-50%
- OR 2.0 (1.3-3.2) vs. non-VAE

ICU LOS:

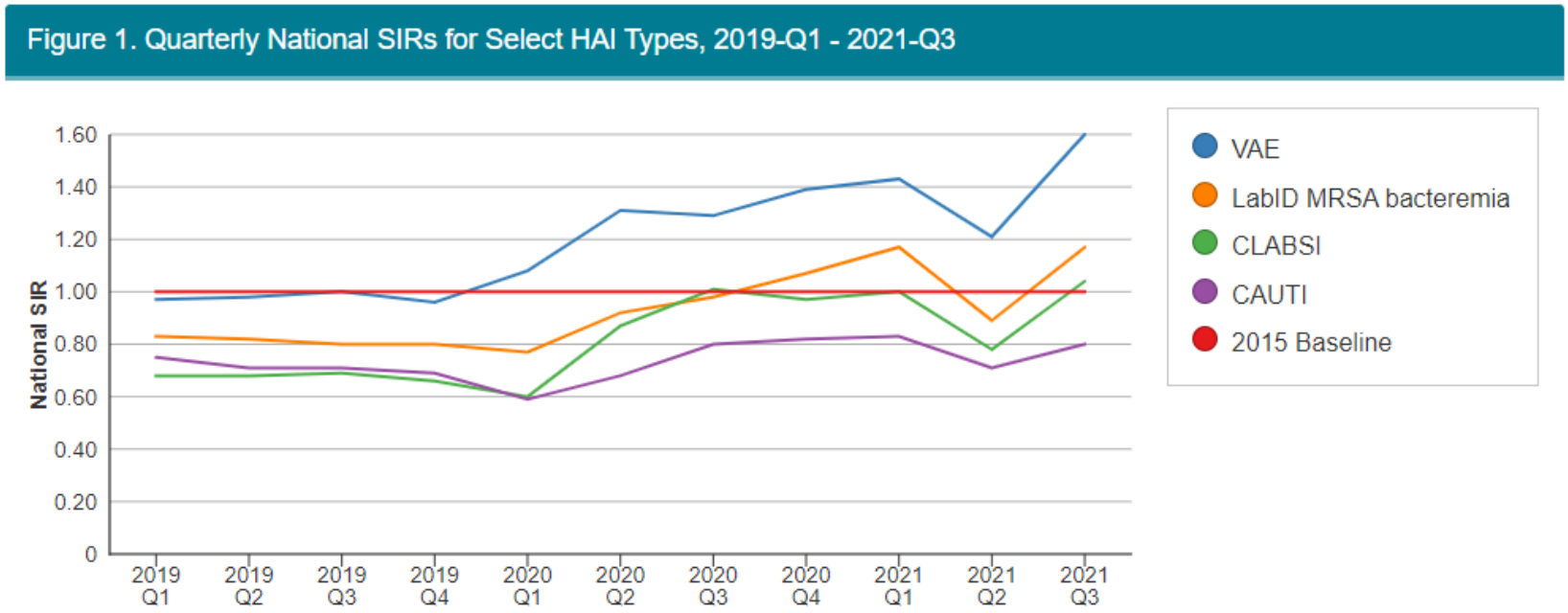
- 22 days IVAC v. 9 days non-IVAC

Antibiotic usage:

- 17.8 days IVAC v. 9.3 days non-IVAC

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

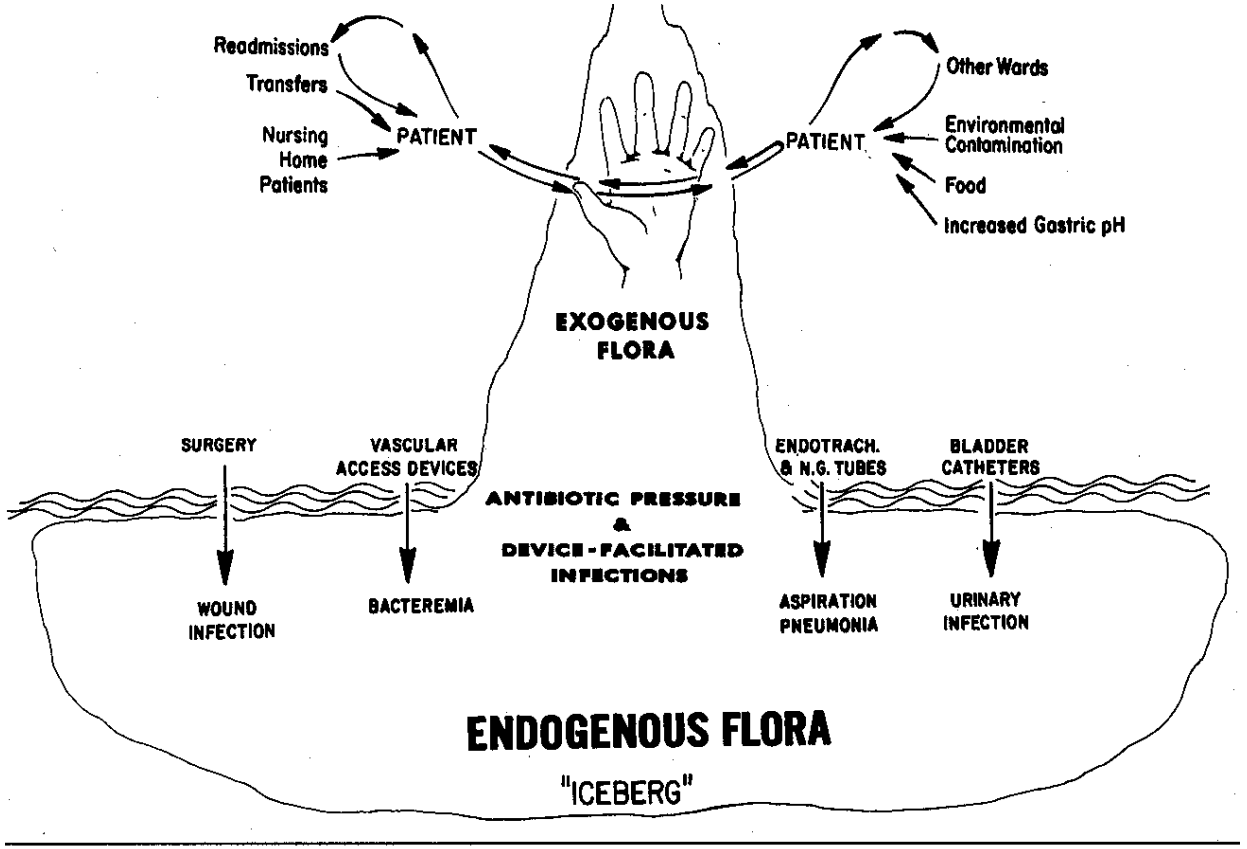
Impact of COVID-19 Pandemic on VAEs



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

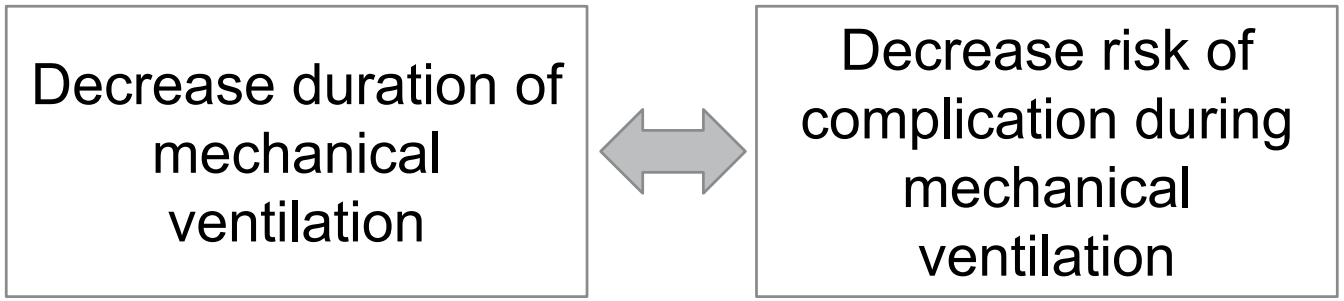
Approach to prevention

Understanding the hazards of the ICU

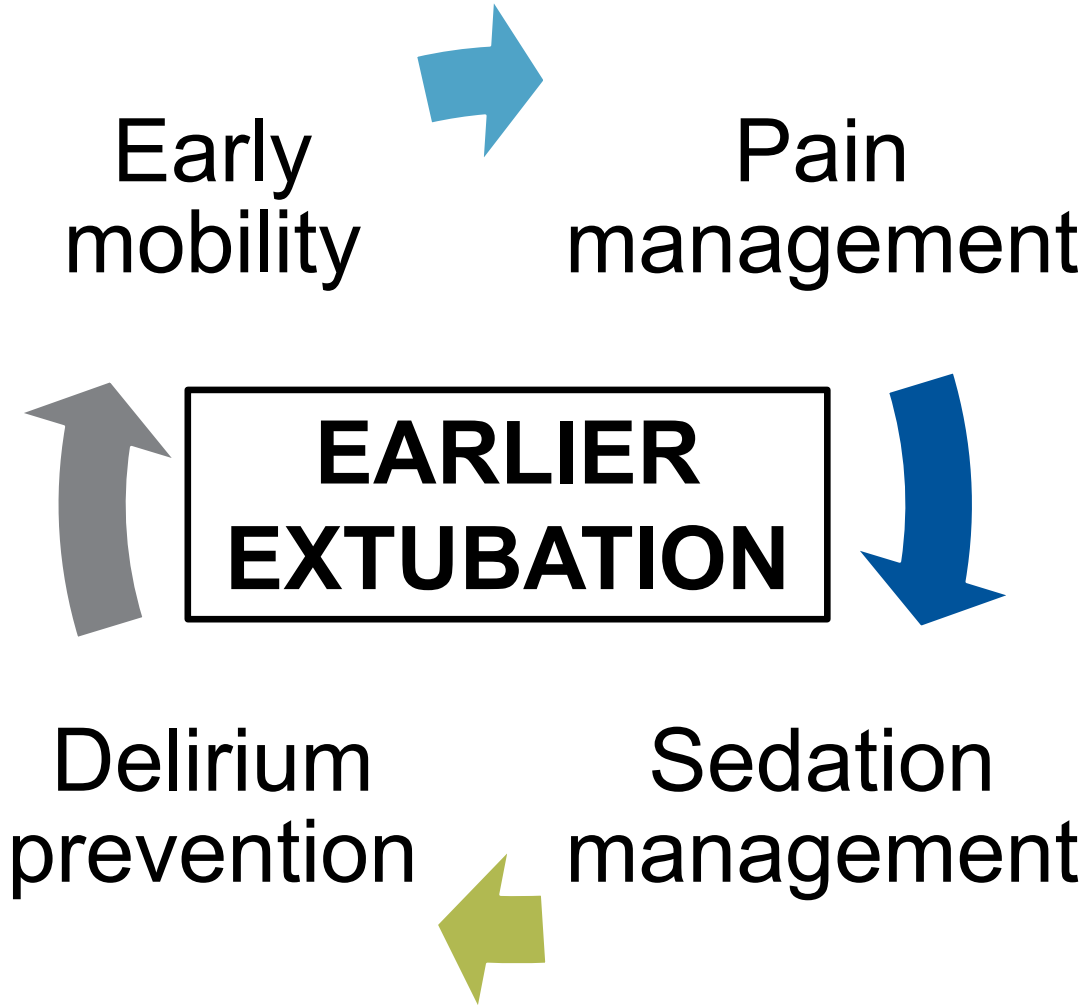


Weinstein RA. Am J Med 1991;91(suppl 3B):180S

Approach to prevention



- 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


Early mobility
Pain management
EARLIER EXTUBATION
Delirium prevention
Sedation management

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

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

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.

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

Criteria for Spontaneous Awakening Trial

SAFETY SCREEN	SAT FAILURE
No active seizures	Anxiety, agitation, pain
No alcohol withdrawal	Respiratory rate > 35/min
No agitation	Oxygen saturation < 88%
No paralytics	Respiratory distress
No myocardial ischemia	Acute cardiac arrhythmia
Normal intracranial pressure	

Criteria for Spontaneous Breathing Trial

SAFETY SCREEN	SBT FAILURE
No agitation	Respiratory rate > 35/min
Oxygen saturation >=88%	Respiratory rate < 8/min
FiO2 <=50%	Oxygen saturation < 88%
PEEP <= 7.5 cm H2O	Respiratory distress
No myocardial ischemia	Mental status change
No vasopressor use	Acute cardiac arrhythmia
Inspiratory efforts	

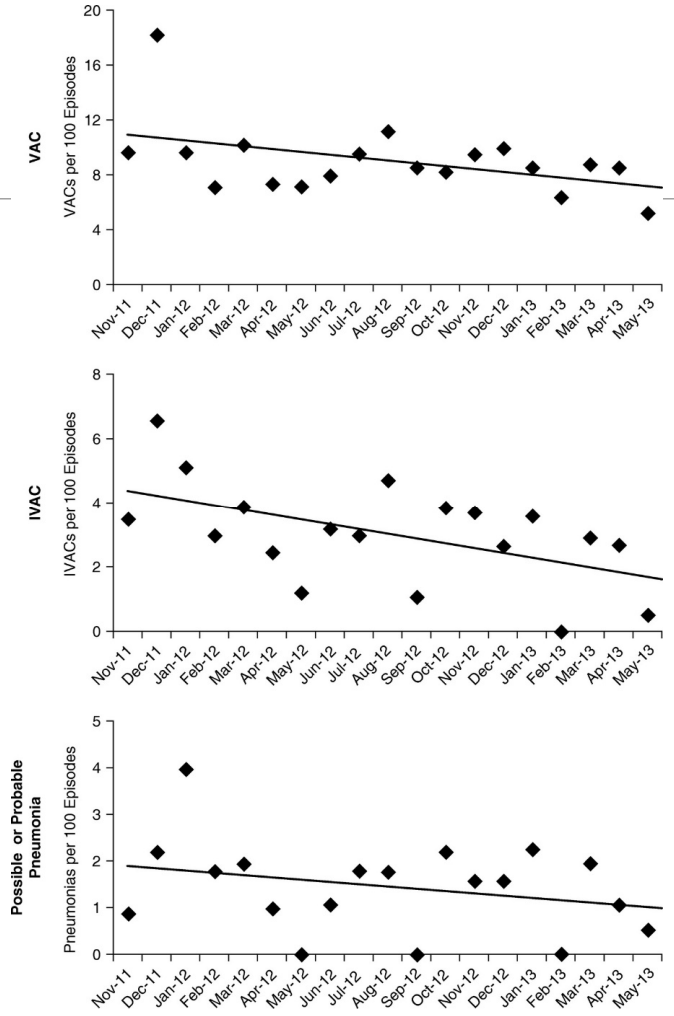
Preventing VAEs: Wake up and Breathe

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



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

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

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

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)

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	

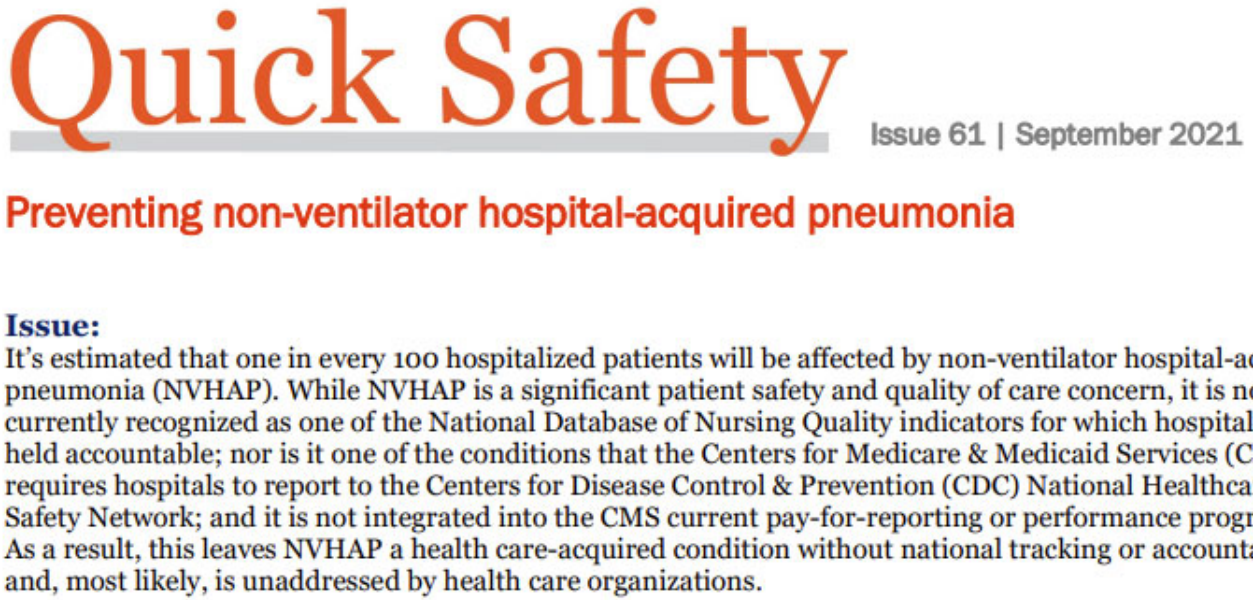
Non-ventilator- associated HAP (NVHAP): Recent call to action

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

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/

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

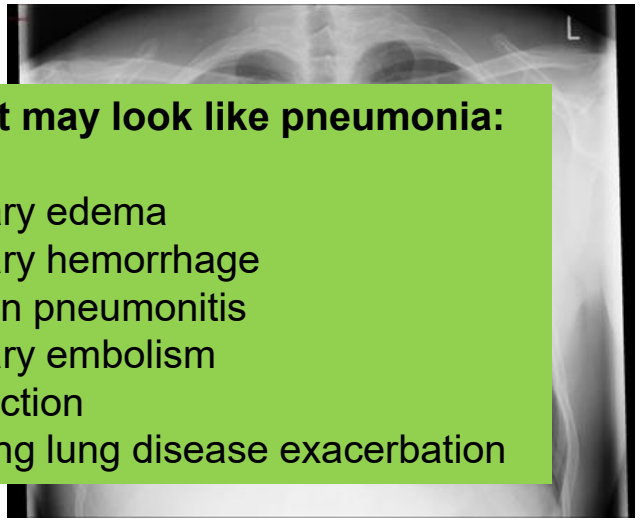
Munro, S., Baker, D., Giuliano, K., Sullivan, S., Haber, J., Jones, B., . . . Klompas, M. (2021). Nonventilator hospital-acquired pneumonia: A call to action: Recommendations from the National Organization to Prevent Hospital-Acquired Pneumonia (NOHAP) among nonventilated patients. *Infection Control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

Pneumonia
Clinical definition

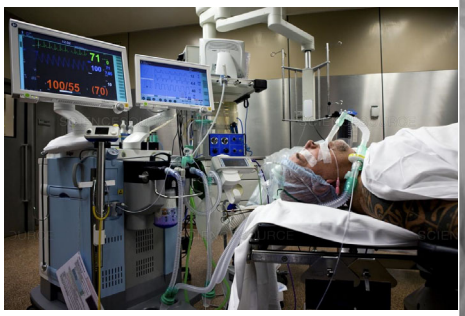
Combination of the following:

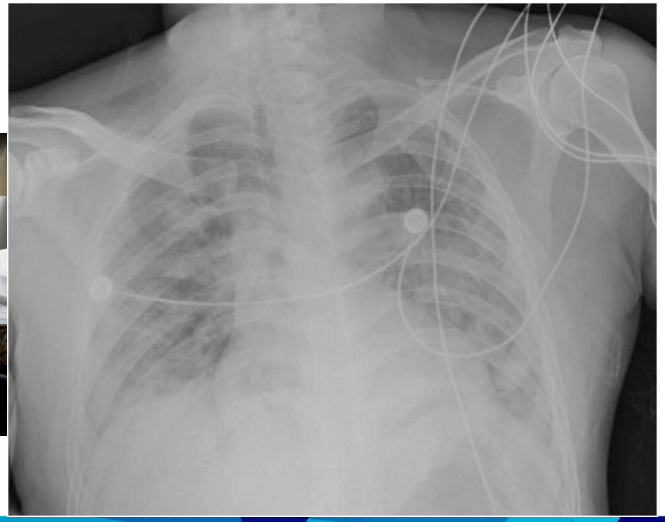
- Fever
- Leukocytosis
- Purulent sputum
- Radiographic infiltrates
- Change in oxygenation
- + / - Positive microbiologic culture from respiratory tract

- **Clinical judgment**

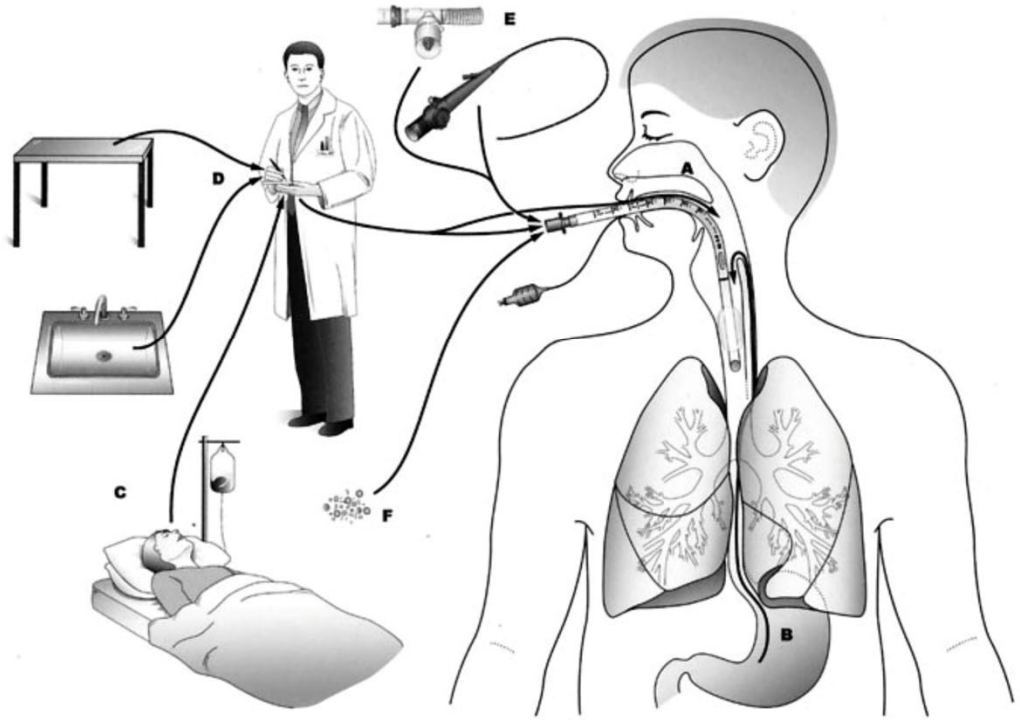


Things that may look like pneumonia:
- ARDS
- Pulmonary edema
- Pulmonary hemorrhage
- Aspiration pneumonitis
- Pulmonary embolism
- Drug reaction
- Underlying lung disease exacerbation





Healthcare-Associated Pneumonia (HAP) Pathogenesis



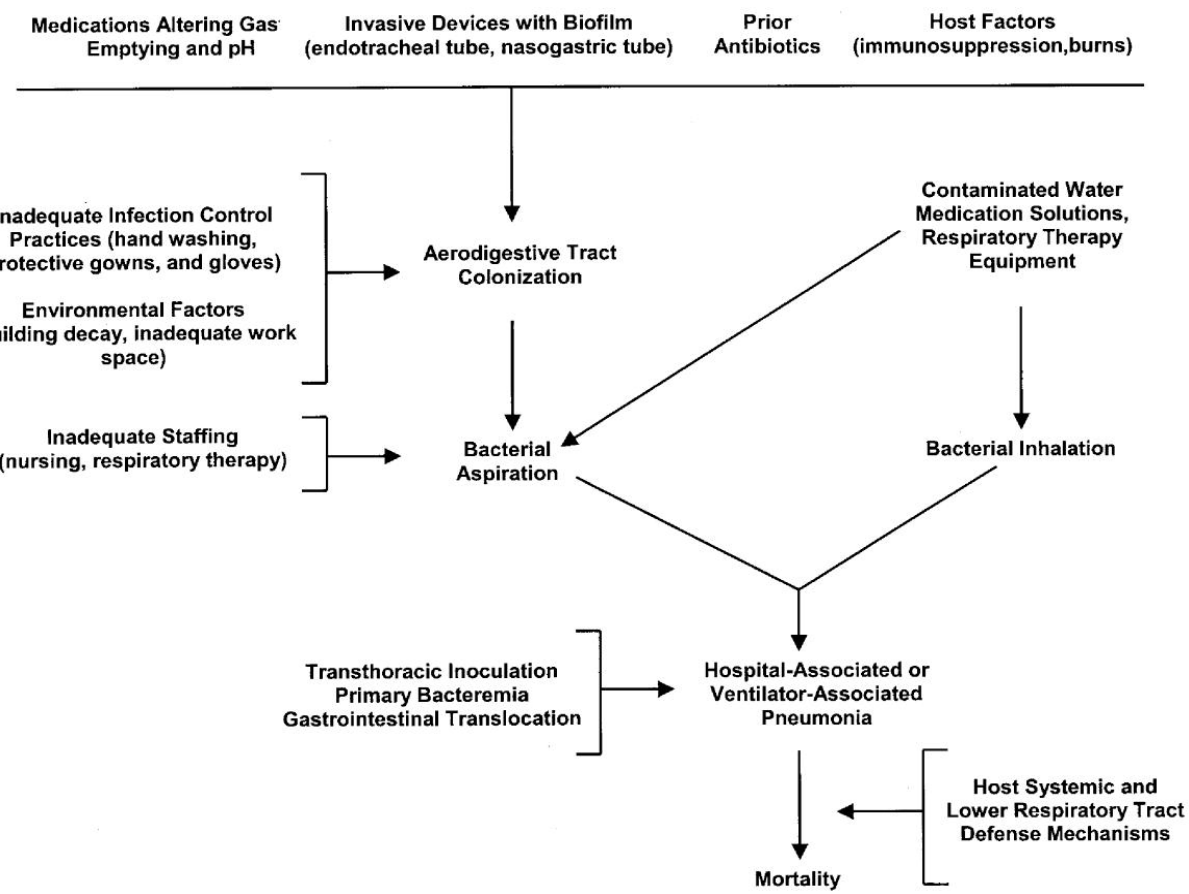
Aerodigestive tract colonization

- 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

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

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

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

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)

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)

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

Duke Center for
Antimicrobial Stewardship
and Infection Prevention

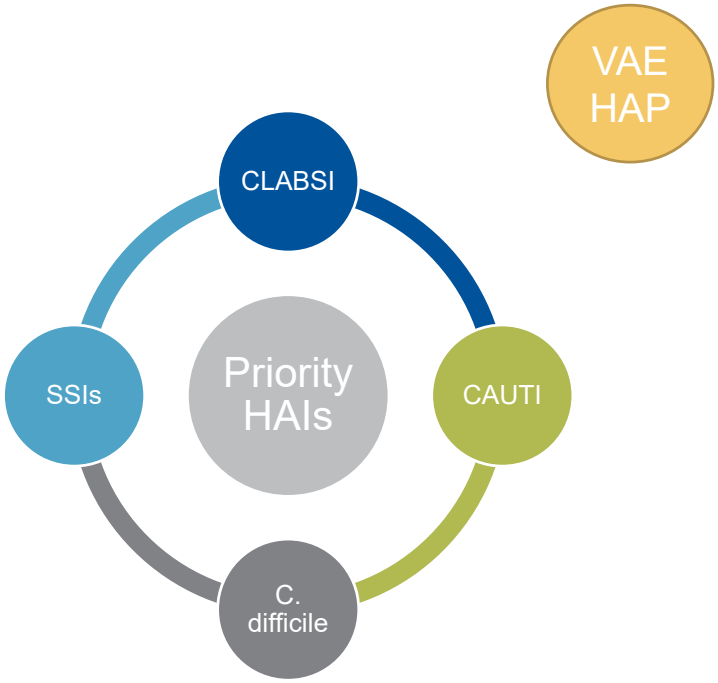
SHEA/ IDSA/ APIC 2022 Prevention of VAE and Pneumonia Guidelines

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

Duke Center for Antimicrobial Stewardship and Infection Prevention

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°[125,388–390]	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[75,128–130,150]	MODERATE
		Probiotics[152–156]	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

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

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

QUESTIONS

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