Ventilator-Associated Events: A Patient Safety Opportunity

Healthcare Association of New York State

June 10, 2015

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Brigham and Women’s Hospital, Boston, USA
Disclosures

Grant funding from the US Centers for Disease Control and Prevention
Ventilator-associated pneumonia

Affects ~5-10% of ventilated patients
Increases ICU length of stay by ~4-7 days
Increases hospital length of stay by ~14 days
Crude mortality rate 30-50%
Attributable mortality 8-12%
Adds ~$10-50,000 to cost of hospital stay

CMS 1533-P, 2007
Safdar et al, Crit Care Med 2005; 33:2184
Tejerina et al, J Crit Care 2006; 21:56
Muscedere et al, J Crit Care 2008; 23:5-10
Eber et al, Arch Intern Med 2010; 170:347-353
Beyersmann et al, Infect Control Hosp Epidemiol 2006; 27:493
VAP?

NOT ON MY WATCH.
States with mandatory reporting legislation for healthcare-associated infections

- Mandatory reporting enacted
- Study bill

Association for Professionals in Infection Control and Epidemiology 2012
2016 National Patient Safety Goal (proposed)

Prevent ventilator-associated pneumonia
“Centers for Medicare and Medicaid Services (CMS) announced its decision to cease paying hospitals for some of the care made necessary by ‘preventable complications’”
These initiatives all presume we can accurately identify and track who does and does not have VAP....

...but VAP is a difficult diagnosis.
## Diagnostic Criteria for VAP

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<th>High Temp</th>
<th>Low Temp</th>
<th>High WBC</th>
<th>Low WBC</th>
<th>Low P:F Ratio</th>
<th>Increased vent settings</th>
<th>Purulent secretions</th>
<th>Gram stain neutrophils</th>
<th>New Antibiotic Start</th>
<th>Infiltrate</th>
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Ego et al. *Chest* 2015;147:347-355
Impact of Diagnostic Criteria on VAP Prevalence

Prospective surveillance, 1,824 patients, Tertiary Med-Surg Unit, Belgium

The challenge of VAP diagnosis

Many complications of critical care present with subjective clinical signs that mimic VAP:

- Radiographic opacities
- Fever
- Abnormal white blood cell count
- Impaired oxygenation
- Increased pulmonary secretions
Accuracy of clinical signs for VAP
Relative to autopsy, systematic review, 14 studies, 655 pts

Fever
Abnormal WBC
Purulent sputum
Crepitations
Hypoxemia
New infiltrate

Negative Likelihood Ratio
Positive Likelihood Ratio

95% confidence interval

Klompas, JAMA 2007; 297:1583
“Diffuse patchy airspace disease right greater than left with obliteration of both hemi-diaphragms. Opacities possibly slightly increased since yesterday accounting for changes in patient position and inspiration. This could represent atelectasis, pneumonia, or effusion.”
Sources of fever and infiltrates

ARDS
Diffuse alveolar damage
Thromboembolic disease
Hemorrhage
Infarction
Fibrosis
Carcinoma
Lymphoma
Contusion

Tracheobronchitis
CLABSI
UTI
Drug fever

PLUS

Pulmonary edema
Atelectasis
Contusion
Fibrosis

Meduri, Chest 1994; 106:221-235
Petersen, Scand J Infect Dis 1999; 31:299-303
Accuracy of clinical diagnosis of VAP
Relative to 253 autopsies

- Sensitivity:
  - Loose definition: Infiltrate and 2 of temp / wbc / purulence (60%)
  - Strict definition: Infiltrate and 3 of temp / wbc / purulence (40%)

- Positive Predictive Value:
  - Loose definition: Infiltrate and 2 of temp / wbc / purulence (100%)
  - Strict definition: Infiltrate and 3 of temp / wbc / purulence (80%)

Tejerina et al., J Critical Care 2010;25:62
Accuracy of quantitative BAL cultures Relative to histology

Kirtland, Chest 1997;112:445
Fabregas, Thorax 1999;54:867
Chastre, Am Rev Respir Dis 1984;130:924
Torres, Am J Resp Crit Care Med 1994;149:324
Implications for surveillance
**CDC’s old surveillance definition for VAP**

Patient must fulfill each of the three categories below:

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<thead>
<tr>
<th>Chest Radiograph</th>
<th>Any one of the following:</th>
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<td>1. New, progressive, or persistent infiltrate</td>
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<td>2. Consolidation</td>
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<td>3. Cavitation</td>
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<th>Systemic Signs</th>
<th>Any one of the following:</th>
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<td>1. Temperature $&gt;38^\circ$C</td>
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<td>2. WBC $&lt;4,000$ or $&gt;12,000$ WBC/mm$^3$</td>
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<td>3. For adults 70 years old, altered mental status with no other recognized cause</td>
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<th>Pulmonary Signs</th>
<th>Any two of the following:</th>
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<td>1. New onset of purulent sputum, or change in character of sputum, or increased respiratory secretions, or increased suctioning requirements</td>
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<td>2. New onset or worsening cough, or dyspnea, or tachypnea</td>
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<td>3. Rales or bronchial breath sounds</td>
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<td>4. Worsening gas exchange, increased oxygen requirements, or increased ventilation demand</td>
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Complicated
Labor Intensive
Subjective
Non-Specific
Interobserver agreement in VAP surveillance

50 ventilated patients with respiratory deterioration

Kappa = 0.40

Klompas, AJIC 2010:38:237
6 Case Vignettes Presented to 43 Surveyors
Ways to lower VAP rates

Without meaningfully changing patient care

1. Narrowly interpret subjective clinical signs
2. Narrowly interpret radiographs
3. Seek consensus between multiple surveyors
4. Allow clinicians to veto surveillance determinations
5. Increase use of quantitative BAL for diagnosis

Klompas, Clin Infect Dis 2010:51:1123-26
Klompas, Am J Infect Control 2012;40:408-10
U.S. National VAP rates
United States, 2004-2012

Source: CDC NNIS and NHSN
International VAP Rates

Source: CDC Europe and CDC USA
Increasing gap between clinical and surveillance VAP rates

Thomas et al. Am Surgeon 2011;77:998
Vincent et al. JAMA 2009;302:2323
Where does this leave hospitals?

We need to publicly report VAP rates to catalyze improved quality of care and save lives!

But the definition of VAP is ambiguous, hard to implement, and open to be gamed!
Developing a New, National Approach to Surveillance for Ventilator-Associated Events*

Shelley S. Magill, MD, PhD1; Michael Klompas, MD, MPH2,3,4; Robert Balk, MD5,6; Suzanne M. Burns, RN, ACNP, MSN, RRT6,7; Clifford S. Deutschman, MS, MD6,8; Daniel Diekema, MD9,10; Scott Fridkin, MD1; Linda Greene, RN, MPS11,12; Alice Guh, MD, MPH1; David Guterman, MD6,13; Beth Hammer, RN, MSN, ANP-BC6,14; David Henderson, MD15; Dean Hess, PhD, RRT16,17,18; Nicholas S. Hill, MD6,19; Teresa Horan, MPH1; Marin Kollef, MD6,20; Mitchell Levy, MD6,21; Edward Septimus, MD22,23; Carole VanAntwerpen, RN, BSN24,25; Don Wright, MD, MPH26; Pamela Lipsett, MD, MHPE6,27
An alternative approach to surveillance

Broaden the focus from pneumonia alone to the syndrome of ventilator complications in general

- More accurate description of what can be reliably determined using surveillance definitions
- Emphasizes the importance of preventing all complications of mechanical ventilation, not just pneumonia

Streamline the definition using quantitative criteria

- Reduce ambiguity
- Improve reproducibility
- Enable electronic collection of all variables
Ventilator-associated conditions (VAC)

Sustained rise in daily minimum PEEP ≥3cm or FiO2 ≥20 points after a period of stable or improving daily minimum PEEP or FiO2

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VAC
VAC
Ventilator-Associated Condition

IVAC
Infection-related
Ventilator-Associated Complication

Possible
Pneumonia
Infection-related ventilator-associated complications (IVAC)

VAC with concurrent abnormal temp or WBC count
AND ≥4 days of new antibiotics

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**Ventilator-associated pneumonia**

*IVAC with concurrent purulent sputum (Gram stain neutrophils) and/or positive pulmonary cultures*

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Electronic Implementation of a Novel Surveillance Paradigm for Ventilator-associated Events
Feasibility and Validation

Peter M. C. Klein Klouwenberg¹,²,³*, Maaike S. M. van Mourik¹*, David S. Y. Ong¹,²,³, Janneke Horn⁴, Marcus J. Schultz⁴, Olaf L. Cremer³, and Marc J. M. Bonten¹,³; on behalf of the MARS Consortium

Automated Surveillance for Ventilator-Associated Events

Jennifer P. Stevens, MD; George Silva; Jean Gillis, RN, MPH; Victor Novack, MD, PhD; Daniel Talmor, MD, MPH; Michael Klompas, MD, MPH; and Michael D. Howell, MD, MPH

http://www.cdc.gov/nhsn/VAE-calculator
Canadian Critical Care Trials Group ABATE Study
11 ICUs, 1330 patients, VAE vs VAP Surveillance

VAE
9.9 events per 1000 vent days

VAP
10.6 events per 1000 vent days

Muscedere et al. Chest 2013;144:1453
Qualitative analysis of 153 VAEs
Royal Brisbane & Women’s Hospital, Queensland, Australia

- Pneumonia 38%
- Edema 26%
- Atelectasis 15%
- ARDS 6%
- Abx + Furosemide 6%
- Other 8%

VAE = VAP + CHF + ARDS + Atelectasis + Others
Attributable Mortality of VAE versus VAP

- **USA – 3 centers**
  *PLoS ONE* 2011;6:e18062

- **USA – 8 centers**
  *Crit Care Med* 2012;40:3154

- **Canada – 11 centers**
  *Chest* 2013;144:1453

- **Netherlands – 2 centers**
  *Am J Resp Crit Care Med* 2014;189:947

- **USA – 2 centers**
  *Crit Care Med* 2014;ePub

- **USA – 1 center**
  *Infect Control Hosp Epidemiol* 2014;5:502
Criticisms of VAE

1. Most VAEs are not pneumonias

2. VAE surveillance misses many pneumonias

3. VAE surveillance can be gamed

4. Scant evidence that VAEs are preventable
Sensitivity & Positive Predictive Value of VAC relative to VAP

Klompas, PLoS ONE 2011;e18191
Muscedere, Chest 2013;144:1453
Klein Klouwenberg, AJRCCM 2014;189:947
Lilly, Crit Care Med 2014;42:2019
Deep vs superficial surgical site infections

Severe sepsis vs SIRS

VAE vs VAP

- Surveillance metrics often prioritize objectivity and reproducibility over sensitivity.

- Focus surveillance on the most severe cases in order to enhance objectivity, clinical significance, and the opportunity to identify patients most likely to benefit from interventions.

- Interventions chosen to prevent the most severe events will likely also prevent less severe events too.
# Ventilator-associated conditions (VAC)

## Opportunities for Gaming

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### Ventilator-associated conditions (VAC)

**Opportunities for Gaming**

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**No VAC**
Prospective survey: 1,209 patients vented ≥2 days, Barnes-Jewish Hospital

Identified precipitants for each case and evaluated whether preventable

Identified 67 VACs. Most common causes were:
- Pneumonia (31%)
- ARDS (16%)
- Pulmonary edema (15%)
- Atelectasis (9%)

Adjudicated 37% of VACs as potentially preventable
Fewer VAEs

How do we get there?
Strategies for preventing VAEs

- Decrease duration of mechanical ventilation
- Target the primary conditions associated with VAEs
Strategies for preventing VAEs

- Minimize sedation
- Paired SATs and SBTs
- Early mobility
- Low tidal volume ventilation
- Conservative fluid management
- Minimize blood transfusions
- Decrease duration of mechanical ventilation
- Target the primary conditions associated with VAEs
Canadian Critical Care Trials Group ABATE Study
Enhanced care for vented patients, 11 ICUs, 1330 patients

Sinuff et al. Crit Care Med 2013;41:15-23
Canadian Critical Care Trials Group ABATE Study
Enhanced care for vented patients, 11 ICUs, 1330 patients

Muscedere et al. Chest 2013;144:1453-1460
Depletable Fluid Management

- Randomized controlled trial of ventilator weaning

- 304 patients randomized to daily BNP levels versus usual care

- Patients randomized to daily BNP levels
  - More diuretics
  - More negative fluid balance
  - Less time to extubation
  - 50% fewer VAEs

Mekontso Dessap et al. *Chest* 2014;146:58-65
CDC Prevention Epicenters’
Wake Up and Breathe Collaborative

Prospective quality improvement collaborative

Goal: prevent VAEs through less sedation and earlier liberation from mechanical ventilation

Mechanism: increase performance of paired daily spontaneous awakening trials and breathing trials (SATs and SBTs)

12 ICUs affiliated with 7 hospitals

Klompas et al., Am J Resp Crit Care Med 2015;191:292-301
SATs and SBTs

- SATs: 100% increase
- SBTs: 40% increase
SBTs Done with Sedatives Off
Ventilator-Associated Events

CDC Prevention Epicenters Wake Up and Breathe Collaborative

VAEs: 37% decrease

IVAC: 65% decrease
Ventilator Days and ICU Days

Percent of Days with SATs

ICU Days: -3 days

Vent Days: -2.4 days

Nov-11  Jan-12  Mar-12  May-12  Jul-12  Sep-12  Nov-12  Jan-13  Mar-13  May-13
Ventilator-associated events
A patient safety opportunity

Broaden Awareness
• VAE surveillance provides hospitals with a fuller picture of serious complications in mechanically ventilated patients

Catalyze Prevention
• A significant portion of VAEs are likely preventable

Reflect and Inform Progress
• VAE surveillance provides an efficient and objective yardstick to track one’s progress relative to oneself and to peers

NEJM 2013;368:1472
Thank You!

Michael Klompas (mklompas@partners.org)