Ventilator-associated events: a patient safety opportunity

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Hosted by Paul Webber
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Disclosures

Honoraria from Premier Healthcare Alliance for lectures on
VAP surveillance

Outline

• VAE – how did we get here?
  • Limitations of VAP surveillance
  • VAE: morbidity and clinical correlates
  • Preventing VAEs
  • Can better surveillance drive better care?

States with mandatory reporting legislation for healthcare-associated infections

- Mandatory reporting enacted
- Study bill

Critical Care Medicine 2013;41:2467-2475

“Centers for Medicare and Medicaid Services (CMS)
announced its decision to cease paying hospitals for some of
the care made necessary by ‘preventable complications’”

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CDC’s old surveillance definition for VAP

<table>
<thead>
<tr>
<th>Patient must fulfill each of the three categories below:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chest Radiograph</strong></td>
</tr>
<tr>
<td>1. New, progressive, or persistent infiltrate</td>
</tr>
<tr>
<td>2. Consolidation</td>
</tr>
<tr>
<td>3. Cavitation</td>
</tr>
<tr>
<td><strong>Systemic Signs</strong></td>
</tr>
<tr>
<td>1. Temperature &gt;38°C</td>
</tr>
<tr>
<td>2. WBC &lt;4,000 or &gt;12,000 WBC/mm³</td>
</tr>
<tr>
<td>3. For adults 70 years old, altered mental status with no other recognized cause</td>
</tr>
<tr>
<td><strong>Pulmonary Signs</strong></td>
</tr>
<tr>
<td>1. New onset of purulent sputum, or change in character of sputum, increased respiratory secretion, or increased suctioning requirements</td>
</tr>
<tr>
<td>2. New onset or worsening cough, or dyspnea, or tachypnea</td>
</tr>
<tr>
<td>3. Rales or bronchial breath sounds</td>
</tr>
<tr>
<td>4. Worsening gas exchange, increased oxygen requirements, or increased ventilation demand</td>
</tr>
</tbody>
</table>

Complicated
Labor Intensive
Subjective
Non-Specific

“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
UTI
Drug fever

Pulmonary edema
Atelectasis
Consolidation
Fibrosis

Accuracy of clinical diagnosis of VAP
Relative to 253 autopsies

<table>
<thead>
<tr>
<th>Sensitivity / Positive Predictive Value</th>
<th>100%</th>
<th>80%</th>
<th>60%</th>
<th>40%</th>
<th>20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive Predictive Value</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Loose definition: Infiltrate and 2 of temp / wbc / purulence
Strict definition: Infiltrate and 3 of temp / wbc / purulence

Meduri, Chest 1994; 106:221-235
Petersen, Scand J Infect Dis 1995; 31:299-303
Tejerina et al., J Critical Care 2010;25:62

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Ven$lator	
  
  Associated	
  
  Events:	
  
  A	
  
  Patient	
  
  Safety	
  
  Opportunity

Prof.	
  
  Michael	
  
  Klompas,	
  
  Harvard	
  
  Medical	
  
  School

A	
  
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International VAP Rates

Increasing gap between clinical and surveillance VAP rates

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!

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

NATIONAL VAP Rates

Mean VAP Rate

Source: CDC Europe and CDC USA

Increasing gap between clinical and surveillance VAP rates

Surgical patients, Chattanooga, Tennessee
Med Surg patients, Barnes Jewish Hospital, Missouri

Hospitals

CDC

American Thoracic Society

Council of State and Territorial Epidemiologists

Leaders in Applied Public Health Epidemiology

VAC
Ventilator-Associated Condition

IVAC
Infection-related Ventilator-Associated Complication

Possible Pneumonia
Probable Pneumonia

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Ventilator-associated conditions (VAC)
Sustained rise in daily minimum PEEP or FiO2 after a period of stable or improving daily minimum PEEP or FiO2

<table>
<thead>
<tr>
<th>Date</th>
<th>PEEP (min)</th>
<th>FiO2 (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan 1</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>Jan 2</td>
<td>5</td>
<td>50</td>
</tr>
<tr>
<td>Jan 3</td>
<td>5</td>
<td>40</td>
</tr>
<tr>
<td>Jan 4</td>
<td>5</td>
<td>40</td>
</tr>
<tr>
<td>Jan 5</td>
<td>5</td>
<td>40</td>
</tr>
<tr>
<td>Jan 6</td>
<td>5</td>
<td>40</td>
</tr>
<tr>
<td>Jan 7</td>
<td>5</td>
<td>40</td>
</tr>
<tr>
<td>Jan 8</td>
<td>5</td>
<td>40</td>
</tr>
<tr>
<td>Jan 9</td>
<td>5</td>
<td>40</td>
</tr>
</tbody>
</table>

Infection-related ventilator-associated complications (IVAC)
VAC with concurrent abnormal temp or WBC count AND ≥4 days of new antibiotics

<table>
<thead>
<tr>
<th>Date</th>
<th>PEEP (min)</th>
<th>FiO2 (min)</th>
<th>T min</th>
<th>T max</th>
<th>WBC min</th>
<th>WBC max</th>
<th>Antibiotic</th>
<th>Antibiotic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan 1</td>
<td>10</td>
<td>100</td>
<td>99.1</td>
<td>99.9</td>
<td>8.4</td>
<td>10.1</td>
<td>Linezolid</td>
<td>Cefepime</td>
</tr>
<tr>
<td>Jan 2</td>
<td>5</td>
<td>50</td>
<td>99.9</td>
<td>101.9</td>
<td>9.9</td>
<td>11.2</td>
<td>Linezolid</td>
<td>Cefepime</td>
</tr>
<tr>
<td>Jan 3</td>
<td>5</td>
<td>40</td>
<td>86.8</td>
<td>100.5</td>
<td>12.1</td>
<td>17.4</td>
<td>Linezolid</td>
<td>Cefepime</td>
</tr>
<tr>
<td>Jan 4</td>
<td>8</td>
<td>60</td>
<td>99.8</td>
<td>99.1</td>
<td>15.0</td>
<td>16.1</td>
<td>Cefepime</td>
<td></td>
</tr>
<tr>
<td>Jan 5</td>
<td>8</td>
<td>50</td>
<td>96.8</td>
<td>100.5</td>
<td>14.1</td>
<td>17.4</td>
<td>Cefepime</td>
<td></td>
</tr>
<tr>
<td>Jan 6</td>
<td>8</td>
<td>50</td>
<td>96.8</td>
<td>99.1</td>
<td>15.0</td>
<td>16.1</td>
<td>Cefepime</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Date</th>
<th>PEEP (min)</th>
<th>FiO2 (min)</th>
<th>Gram Stain Polys</th>
<th>Gram Stain Epis</th>
<th>Culture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan 1</td>
<td>10</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Jan 2</td>
<td>5</td>
<td>50</td>
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<td></td>
</tr>
<tr>
<td>Jan 3</td>
<td>5</td>
<td>40</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Jan 4</td>
<td>5</td>
<td>40</td>
<td>3+</td>
<td>0</td>
<td>Klebsella pneumoniae</td>
</tr>
<tr>
<td>Jan 5</td>
<td>5</td>
<td>60</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Jan 6</td>
<td>8</td>
<td>50</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Jan 7</td>
<td>8</td>
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<td>Jan 8</td>
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<td></td>
</tr>
<tr>
<td>Jan 9</td>
<td>8</td>
<td>40</td>
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<td>-</td>
<td></td>
</tr>
</tbody>
</table>

Intriguing! But many questions
1. How does VAC compare to VAP?
2. What are the clinical correlates of VAC
3. Are these clinically meaningful complications?
4. Are these things preventable?

Canadian Critical Care Trials Group ABATE Study
11 ICUs, 1330 patients, VAC vs VAP Surveillance

VAC
9.9 events per 1000 vent days

VAP
10.6 events per 1000 vent days

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Qualitative analysis of 147 VACs
Royal Brisbane & Women’s Hospital, Queensland, Australia

VAC = VAP + CHF + ARDS + Atelectasis + Others

Attributable mortality and morbidity

Attributable Mortality of VAC vs VAP

Controlled for time to VAE, age, sex, unit, comorbidities, severity of illness. All comparisons are to patients without VAE (control).

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Preventability

Canadian Critical Care Trials Group ABATE Study
Enhanced care for vented patients, 11 ICUs, 1330 patients

VAC Rate (trend P=.05)

Risk factors for VAC and IVAC

Canadian Critical Care Trials Group
Multivariate analysis of risk factors for VAC

Variable | Odds Ratio (95% CI) | P-value
---|---|---
APACHE II score | 0.92 (0.82, 1.04) | 0.17
Hospital days to ICU admission | 1.09 (0.99, 1.20) | 0.09
% ventilator days with SBTs | 0.97 (0.94, 1.01) | 0.10
% ventilator days with SATs | 0.93 (0.99, 1.04) | 0.05
% ventilator days with CHG oral care | 1.02 (0.99, 1.04) | 0.16

Canadian Critical Care Trials Group ABATE Study
Enhanced care for vented patients, 11 ICUs, 1330 patients

VACs per 100 patients

Baseline 6 months 15 months 24 months

Concordance (% of patients)

Muscedere et al., Chest 2013;144:1453-1460

Muscedere et al., Chest 2013;144:1453-1460

Risk factors for VAC and IVAC

Case control study to identify potentially modifiable risk factors for VAC and IVAC

Patient with VAC matched to patients without VAC
- Matched on age, sex, unit type, Charlson score, and time to VAC
- 110 cases, 110 controls
- 38 of the 110 VAC patients met IVAC criteria

Evaluated vent bundle adherence, sedatives, analgesics, paralytics, nutrition, blood products, fluid balance, vent modes, tidal volumes...

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Multivariate Analysis

<table>
<thead>
<tr>
<th>Risk factors for VAC</th>
<th>Odds Ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandatory ventilator mode (AC, PC, VC)</td>
<td>3.4</td>
<td>1.6-8.0</td>
</tr>
<tr>
<td>3-day net fluid balance (per liter)</td>
<td>1.2</td>
<td>1.0-1.4</td>
</tr>
<tr>
<td>Propofol</td>
<td>0.5</td>
<td>0.2-1.1</td>
</tr>
<tr>
<td>History of congestive heart failure</td>
<td>0.4</td>
<td>0.2-1.0</td>
</tr>
</tbody>
</table>

Risk factors for IVAC

<table>
<thead>
<tr>
<th>Risk factors</th>
<th>Odds Ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzodiazepines</td>
<td>5.0</td>
<td>1.3-29</td>
</tr>
<tr>
<td>Total opioids</td>
<td>3.3</td>
<td>0.9-16</td>
</tr>
<tr>
<td>Paralytics</td>
<td>2.3</td>
<td>0.8-8.0</td>
</tr>
</tbody>
</table>

Strategies for preventing VAEs

- Decrease duration of mechanical ventilation
- Target the primary conditions associated with VAC

Strategies for preventing VAEs

- Minimize sedation
- Early mobility
- ETT with subglottic suction
- Low tidal volume ventilation
- Conservative fluid management
- Minimize blood transfusions

Enhanced prevention of VAEs

- Strong evidence from RCTs and/or meta-analyses
- Probable but not proven

Conservative fluid management

- About a third of VACs are due to pulmonary edema
- Elevated central venous pressures associated with increased mortality rates
- Randomized controlled trial showing conservative fluid management associated with more ventilator-free days compared to liberal fluid management

BNP Driven 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 VACs

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Time for a new ventilator bundle?
Endotracheal tubes with subglottic secretion drainage
Paired daily spontaneous awakening & breathing trials
Early mobility
Conservative fluid management strategy
Conservative blood transfusion strategy
Low tidal volume lung ventilation

Summary
- VAC intentionally seeks all complications of mechanical ventilation severe enough to require sustained increases in ventilator support
- VAC ≠ VAP. Most cases are attributable to:
  - Pneumonia
  - Pulmonary edema
  - ARDS
  - Atelectasis
- Powerful predictor of adverse outcomes (increased ventilator days, hospital days, and mortality)
- Emerging evidence of preventability but we probably need a new ventilator bundle that specifically targets the fuller array of conditions associated with VAC

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