

Ventilator-Associated Events

**Symposium on Prevention of Healthcare-associated Infections
in Hospitals and Community Institutions**

Infection Control Branch, Centre for Health Protection, Department of Health, Hong Kong

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Disclosures

- **Grant funding**
 - Centers for Disease Control and Prevention
 - Massachusetts Department of Public Health
- **Royalties**
 - UpToDate

Objectives

- **Why did CDC replace VAP with VAE?**
 - Limitations of VAP diagnosis
 - Implications for prevention
 - Implications for surveillance
 - **How can we optimize surveillance for VAEs?**
 - CDC' s online VAE calculator
 - Automated implementations
 - **How can we best prevent VAEs?**
 - Early extubation
 - Target the specific diseases that typically cause VAEs
-

**Why did CDC replace
VAP with VAE?**

The Challenge of VAP Diagnosis

- Many complications of critical care present with the same clinical signs as VAP
 - Radiographic opacities
 - Fever
 - Abnormal white blood cell count
 - Impaired oxygenation
 - Increased pulmonary secretions
-



“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
- Thromboembolic disease
- Hemorrhage
- Infarction
- Fibrosis
- Carcinoma
- Lymphoma
- Contusion

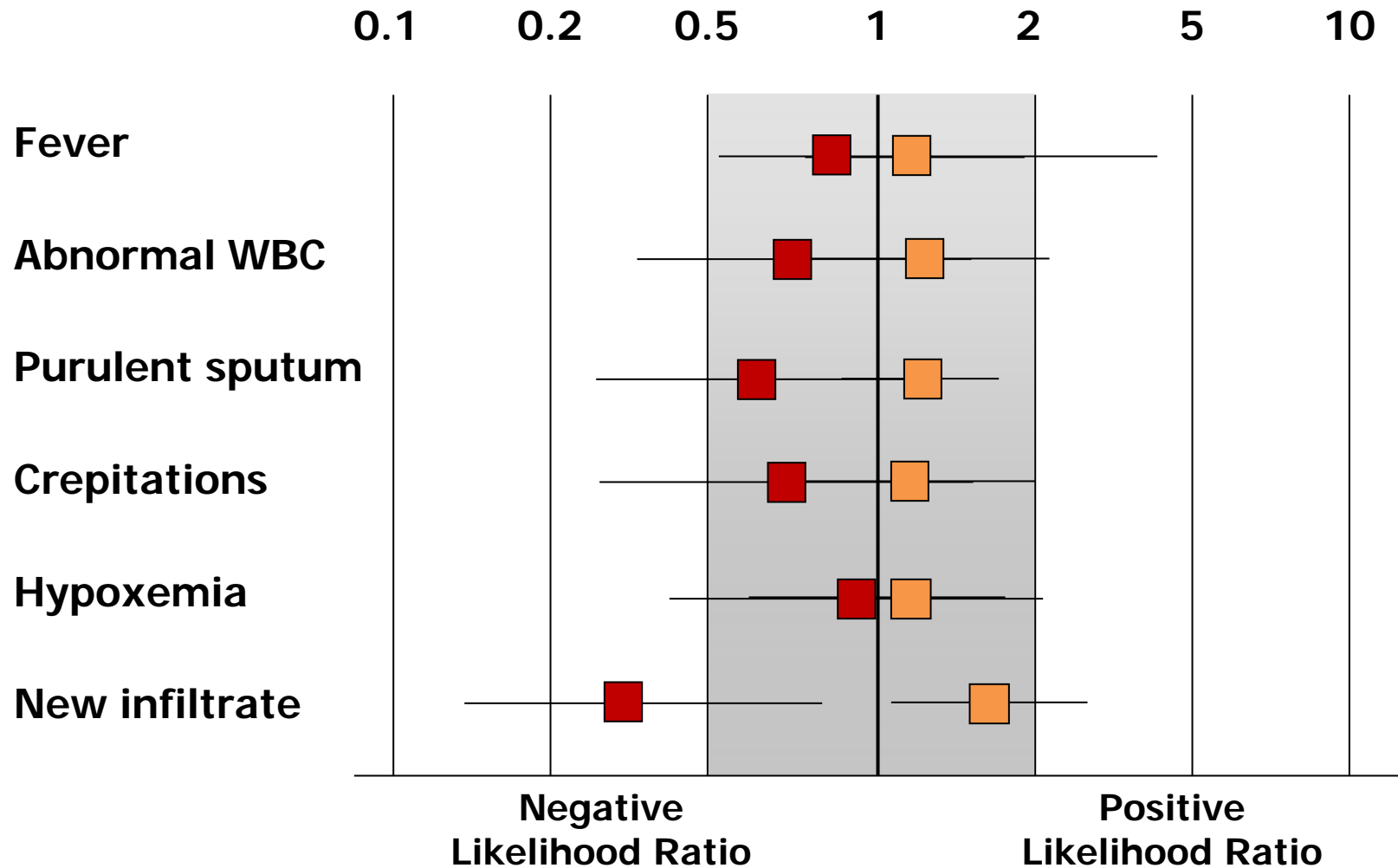
Tracheobronchitis
CLABSI
UTI
Drug fever

PLUS

Pulmonary edema
Atelectasis
Contusion
Fibrosis

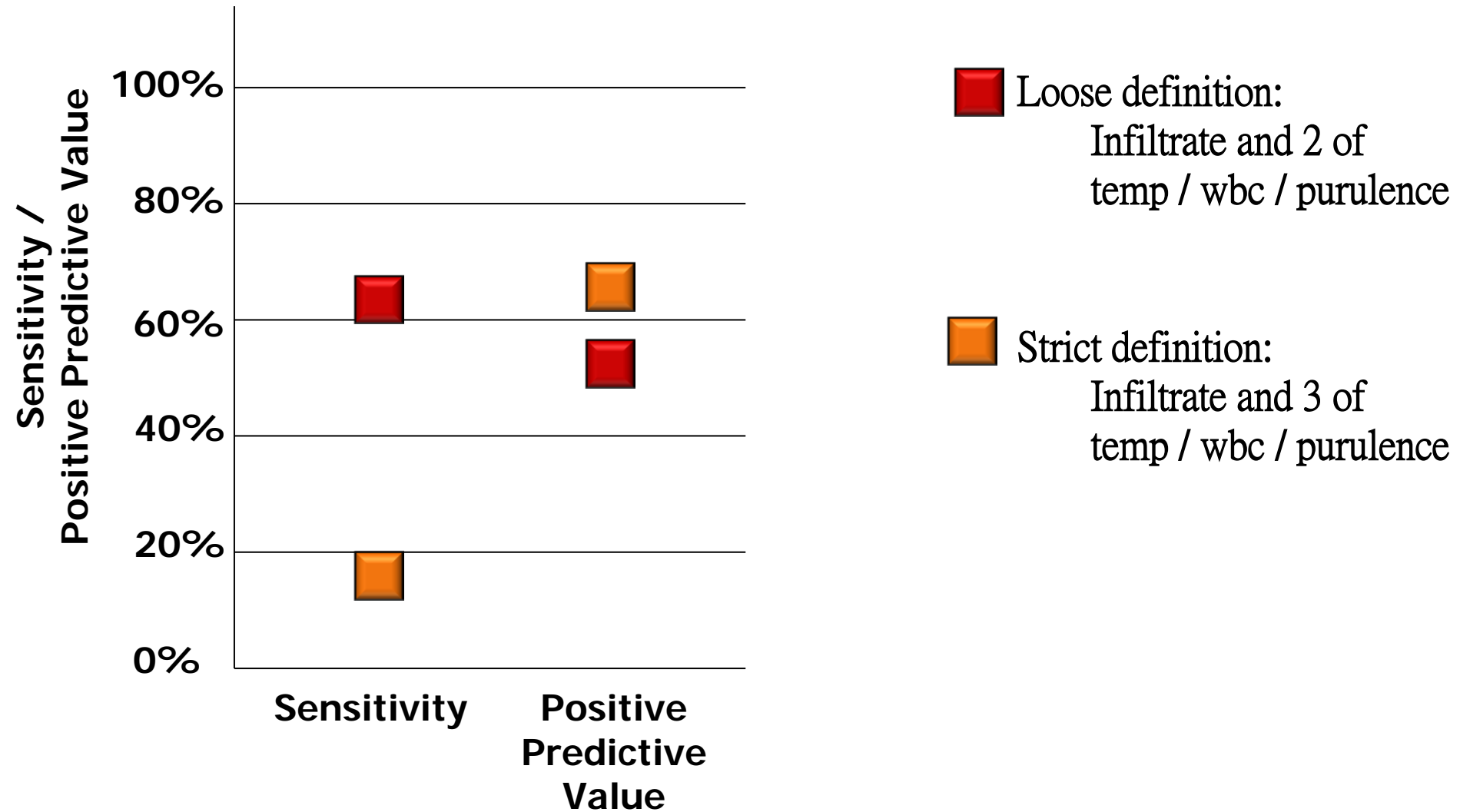
Accuracy of clinical signs for VAP

Relative to autopsy, systematic review, 14 studies, 655 patients



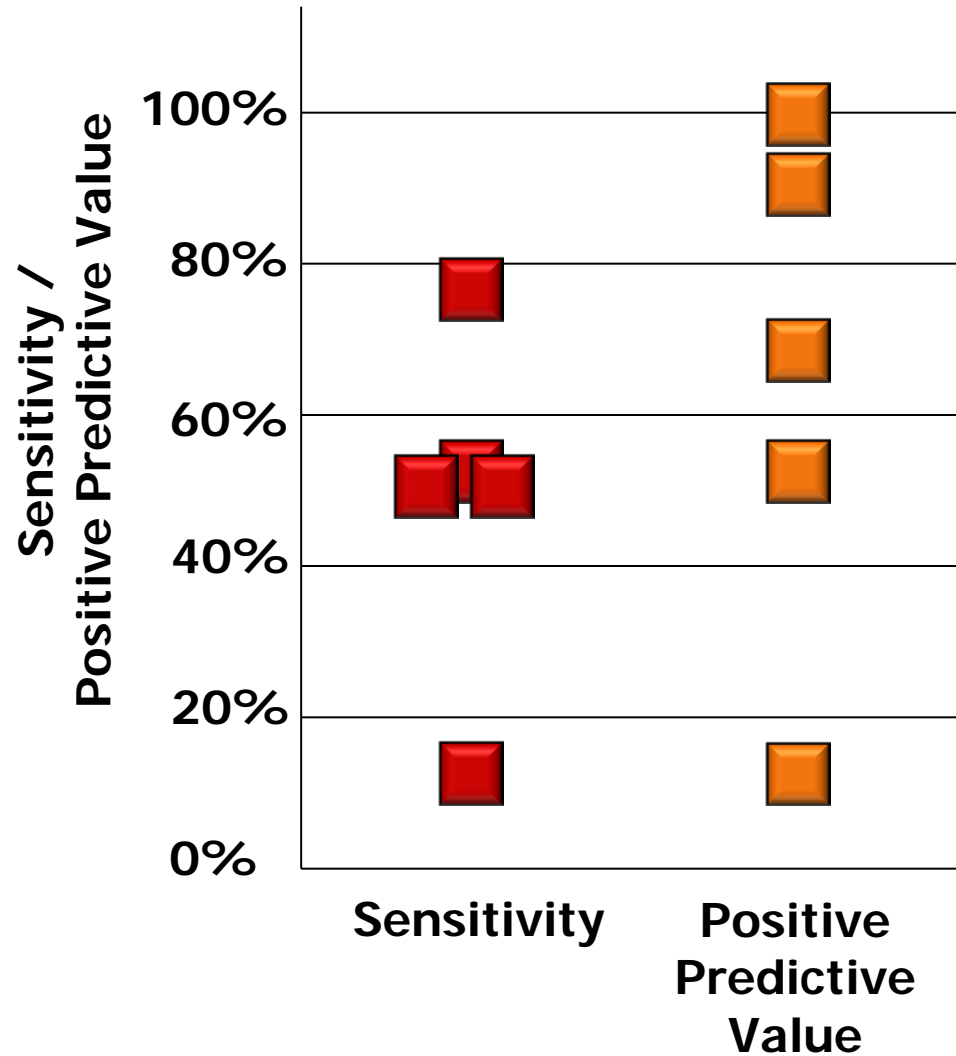
Accuracy of Clinical Diagnosis of VAP

Relative to 253 autopsies



Accuracy of 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
Marquette, *Am J Resp Crit Care Med* 1995;151:1878
Papazian, *Am J Resp Crit Care Med* 1995;152:1982

Implications for Prevention

The Classic Ventilator Bundle



Elevate the head of the bed

Daily sedative interruptions

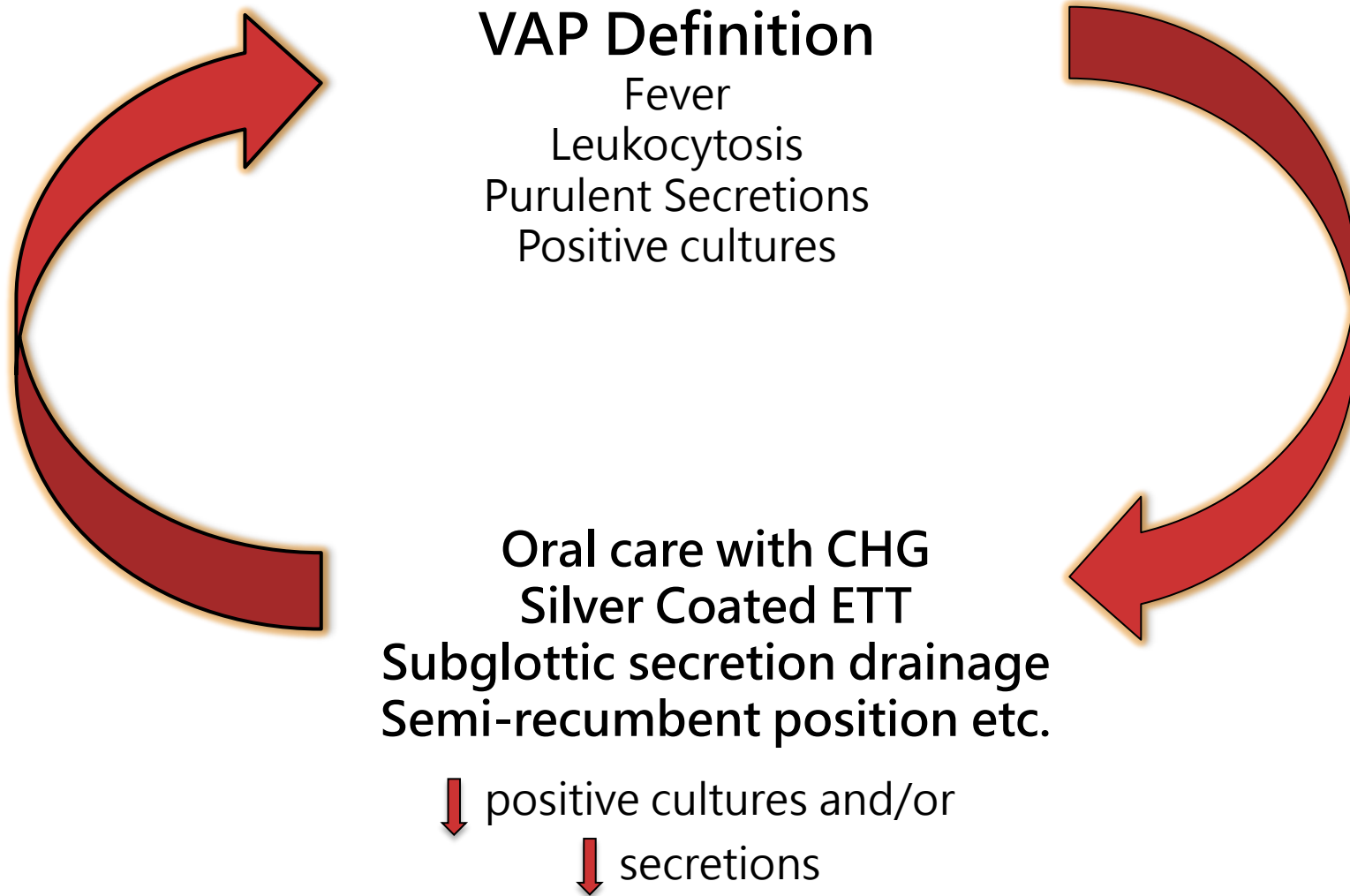
Spontaneous breathing trials

Stress ulcer prophylaxis

DVT prophylaxis

Oral care with chlorhexidine

Circularity Between VAP Prevention Practices and the VAP Definition



Oral Care with Chlorhexidine: Significantly *Lower* VAP Rates

Chlorhexidine

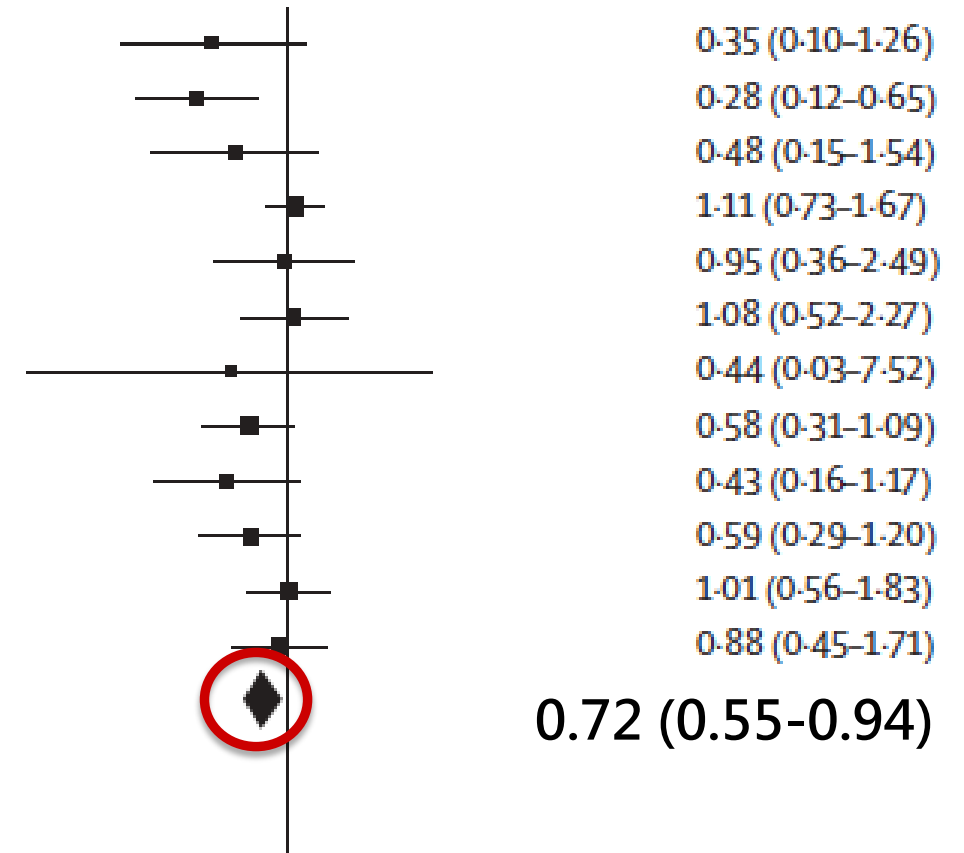
De Riso et al (1996) ¹⁸	3	173	9	180	3.8%
Fourrier et al (2000) ¹³	5	30	18	30	7.0%
Houston et al (2002) ²⁰	4	270	9	291	4.4%
MacNaughton et al (2004) ²²	32	91	28	88	14.1%
Grap et al (2004) ¹⁴	4	7	3	5	5.9%
Fourrier et al (2005) ¹⁹	13	114	12	114	8.3%
Bopp et al (2006) ¹⁷	0	2	1	3	0.9%
Koeman et al (2006) ²¹	13	127	23	130	9.9%
Tantipong et al (2008) ²³	5	102	12	105	5.5%
Scannapieco et al (2009) ²⁶	14	116	12	59	8.8%
Bellisimo-Rodriguez et al (2009) ²⁴	16	64	17	69	10.6%
Panchabhai et al (2009) ²⁵	14	88	15	83	9.4%
Subtotal (95% CI)		1184		1157	88.5%

Total events 123 159

Heterogeneity: $\tau^2=0.06$, $\chi^2=15.54$, $df=11$ ($p=0.16$); $I^2=29\%$

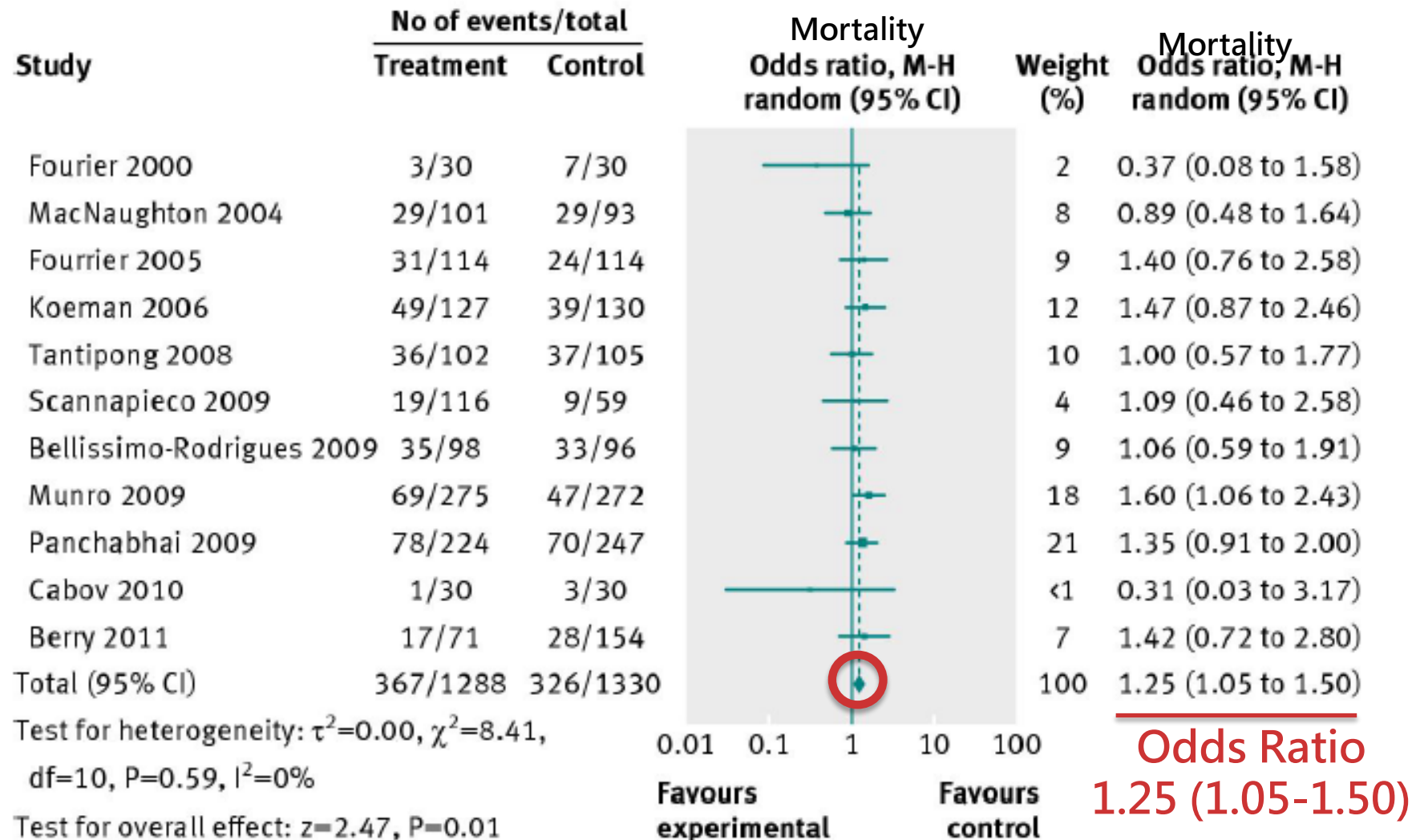
Test for overall effect: $Z=2.40$ ($p=0.02$)

Ventilator-Associated Pneumonia



Significantly lower VAP rates!

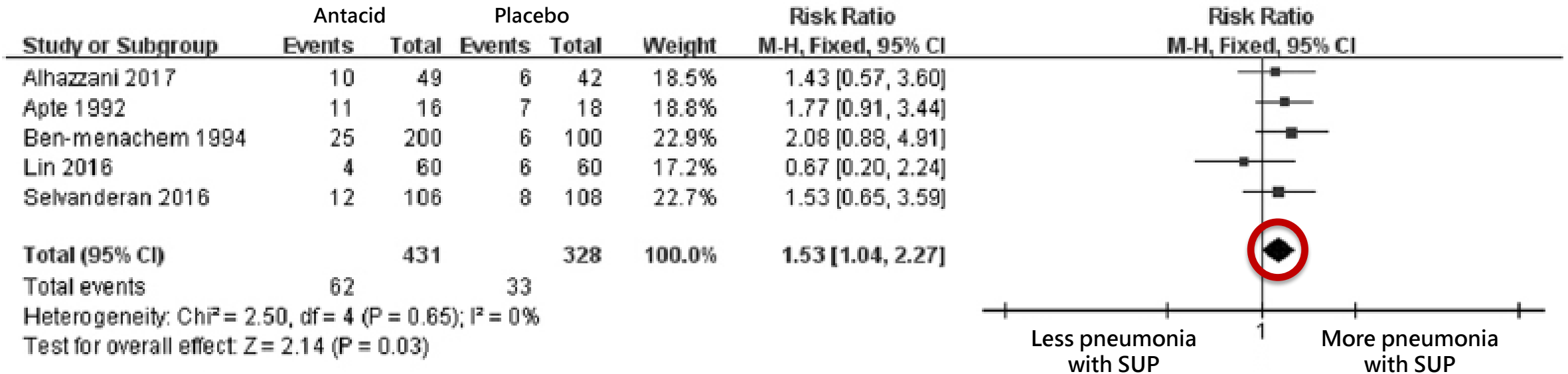
Oral Care with Chlorhexidine: Significantly *Higher* Mortality Rates



Stress Ulcer Prophylaxis

Randomized controlled trials of ulcer prophylaxis vs placebo in patients getting enteral nutrition

Ventilator-associated pneumonia



Significantly higher risk for VAP!

VAP

Atelectasis

ARDS

Pneumothorax

Sepsis

**Pulmonary
Emboli**

**Pulmonary
Edema**

Implications for surveillance

CDC's VAP Surveillance Definition

2008

Patient must fulfill each of the three categories below:

Chest Radiograph	<i>Any one of the following:</i> <ol style="list-style-type: none">1. New, progressive, or persistent infiltrate2. Consolidation3. Cavitation
Systemic Signs	<i>Any one of the following:</i> <ol style="list-style-type: none">1. Temperature >38°C2. WBC <4,000 or >12,000 WBC/mm³3. For adults 70 years old, altered mental status with no other recognized cause
Pulmonary Signs	<i>Any two of the following:</i> <ol style="list-style-type: none">1. New onset of purulent sputum, or change in character of sputum, or increased respiratory secretions, or increased suctioning requirements2. New onset or worsening cough, or dyspnea, or tachypnea3. Rales or bronchial breath sounds4. Worsening gas exchange, increased oxygen requirements, or increased ventilation demand

Complicated

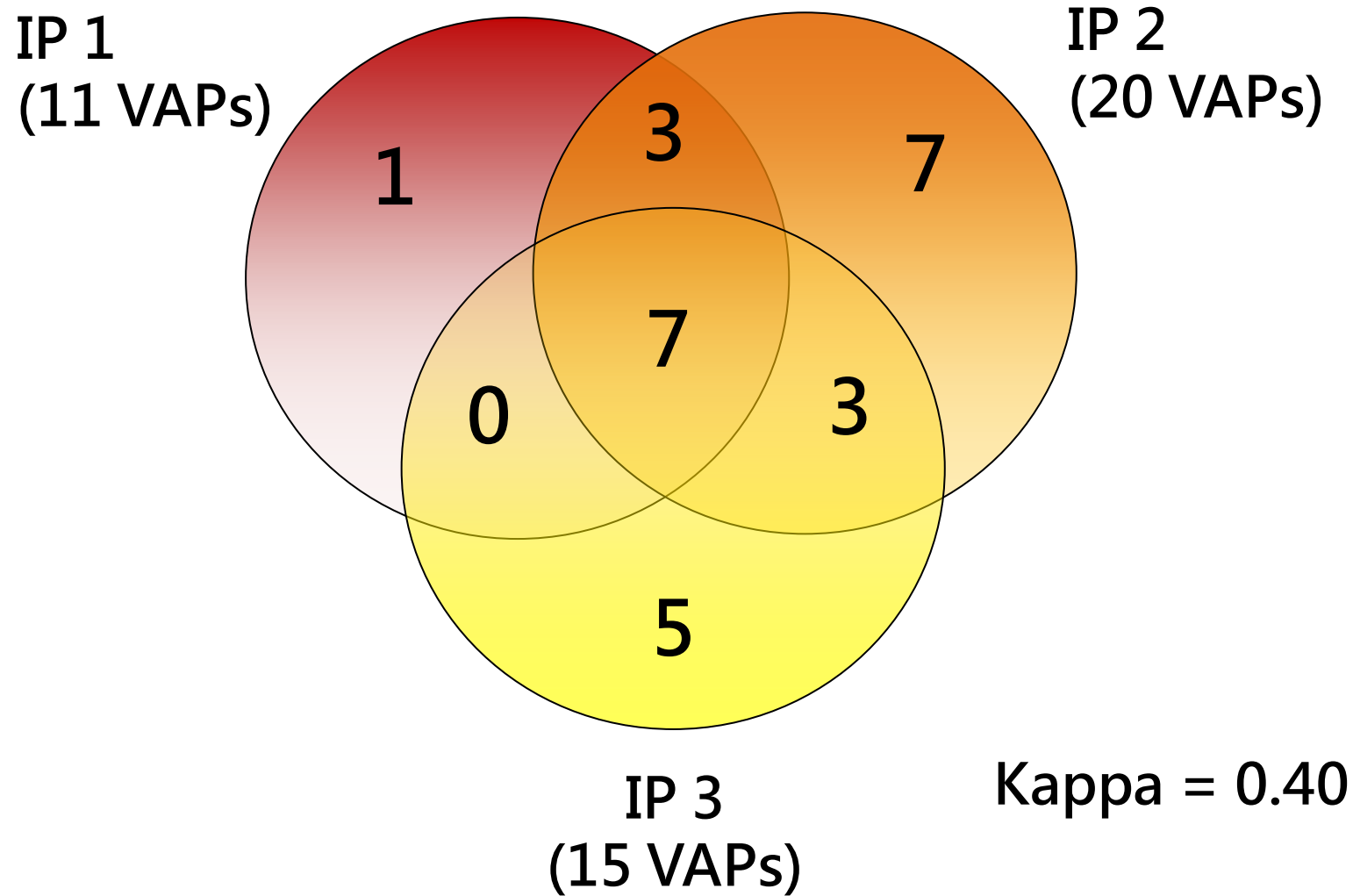
Labor Intensive

Subjective

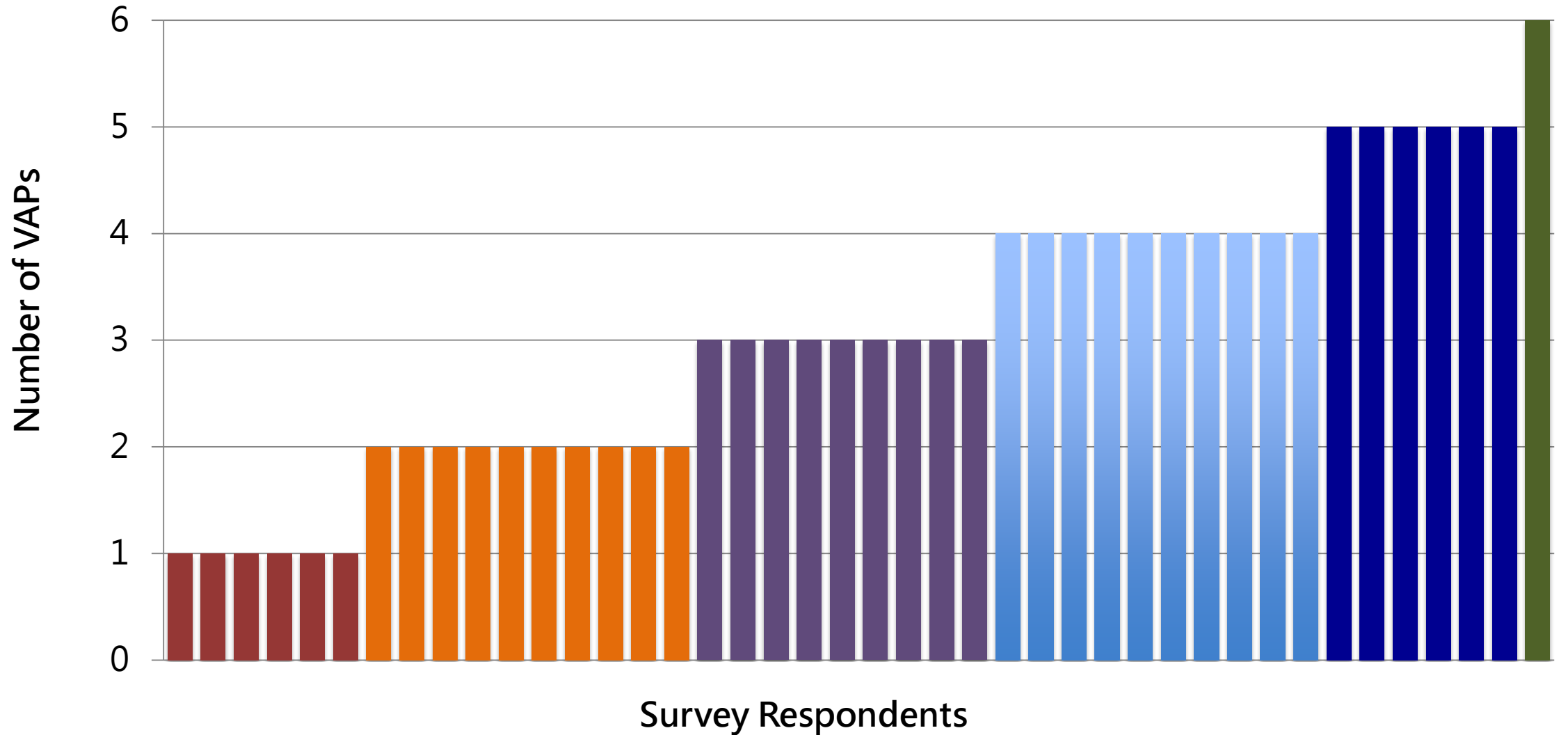
Non-Specific

Interobserver Agreement in VAP Surveillance

50 ventilated patients with respiratory deterioration

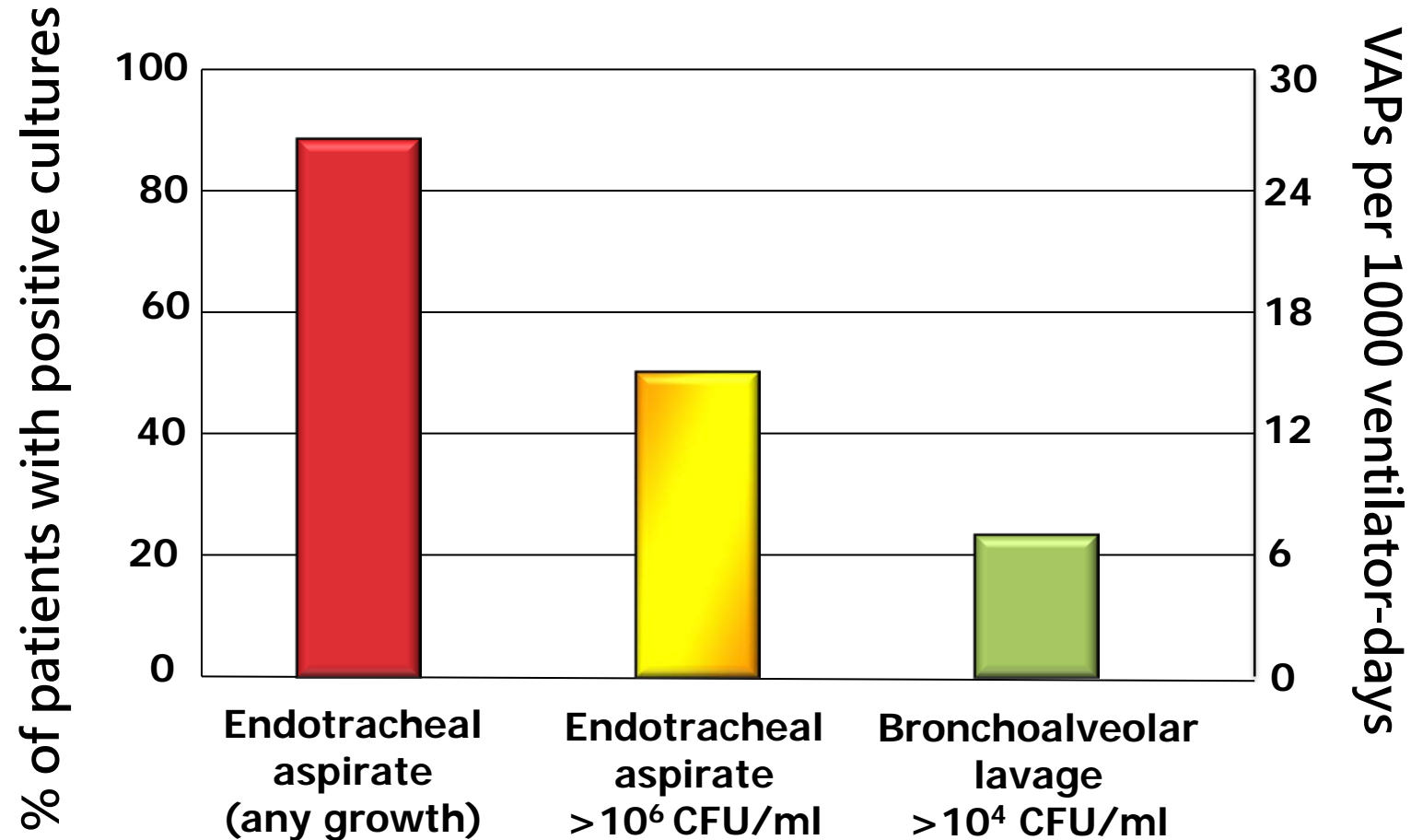


6 Case Vignettes Presented to 43 Reviewers



Impact of diagnostic technique on VAP rates

53 patients with clinically suspected VAP



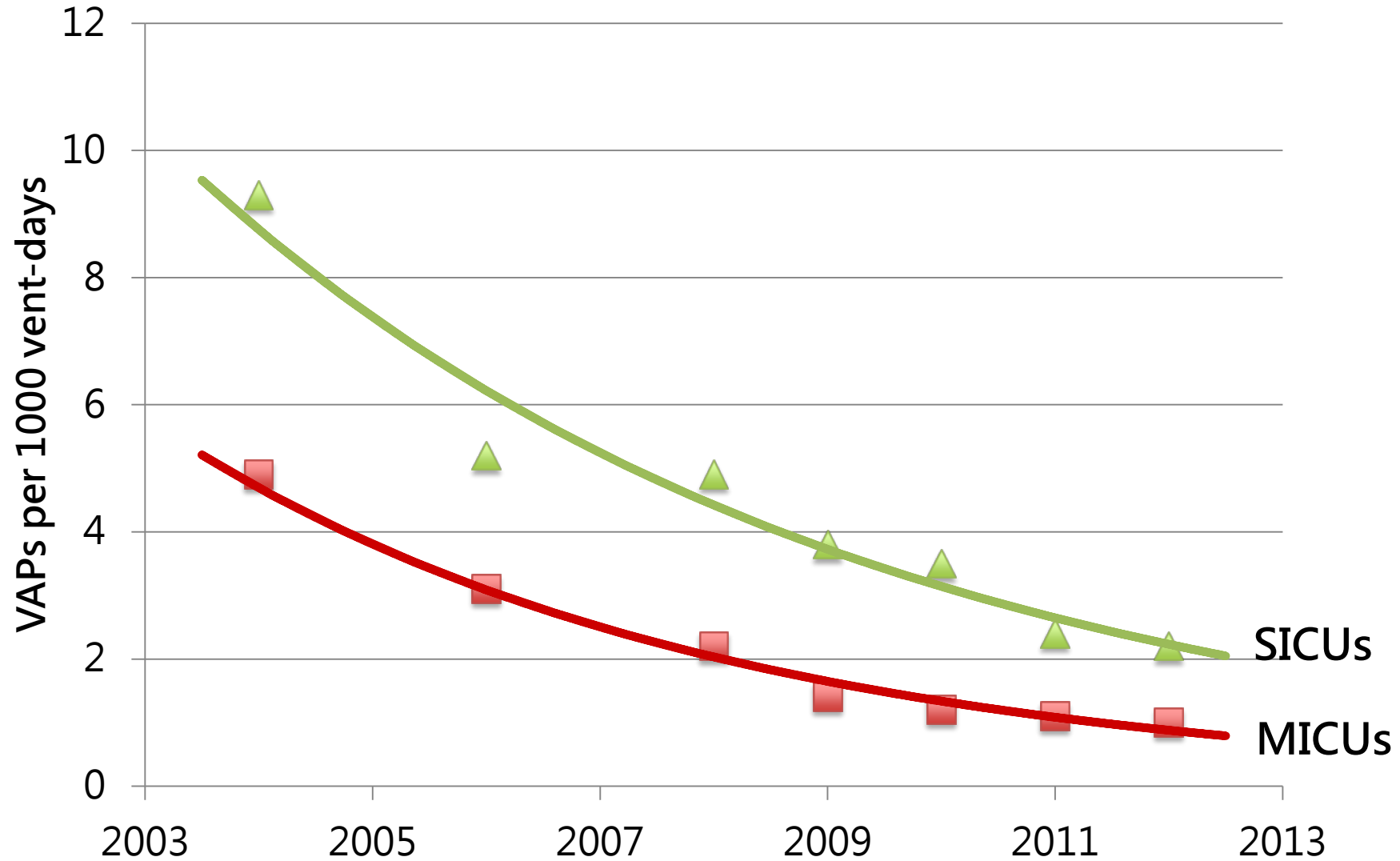
Five Ways to lower VAP rates

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

U.S. National VAP Rates

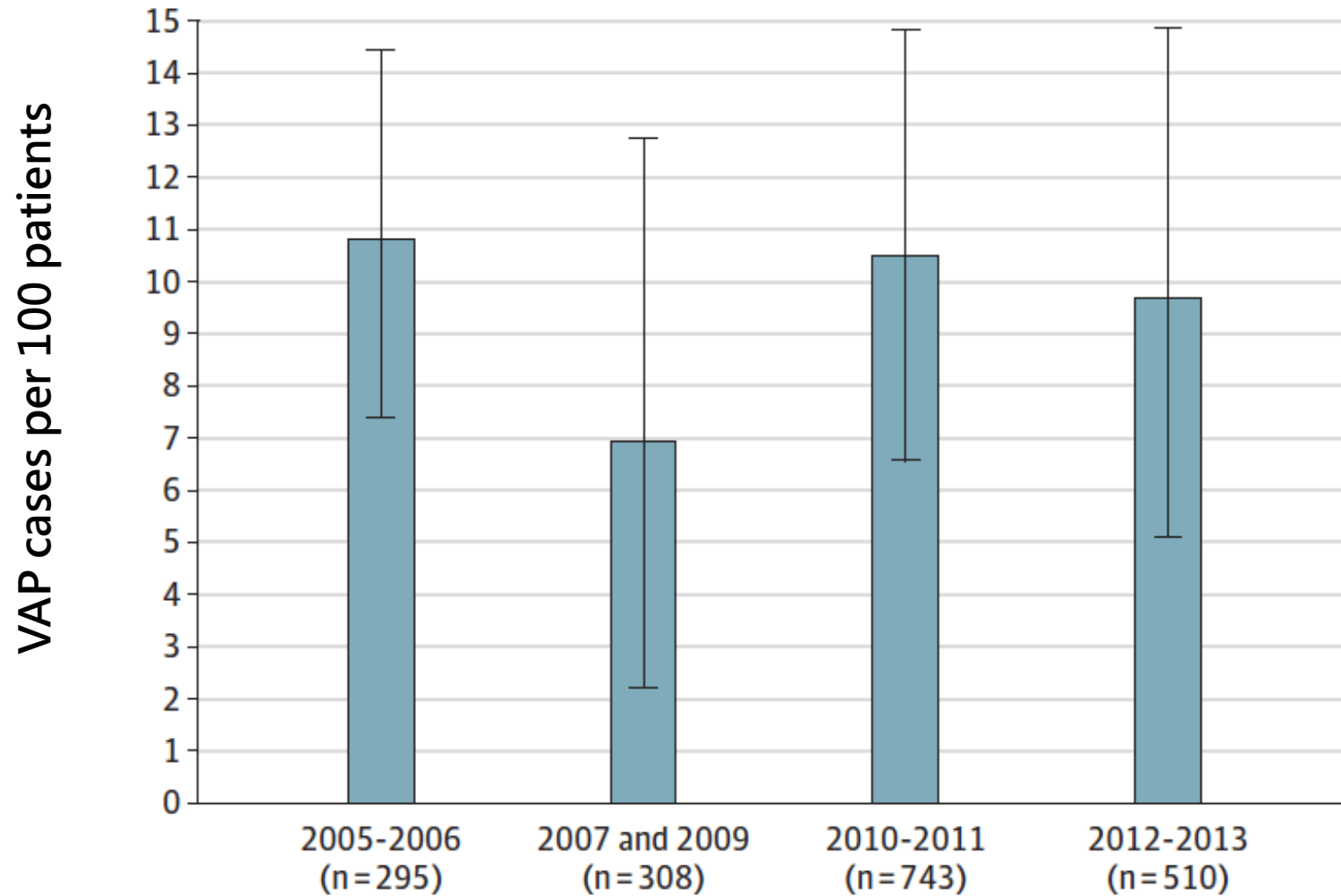
United States, 2004-2012



Source: CDC NNIS and NHSN

U.S. National VAP Rates, 2005-2013

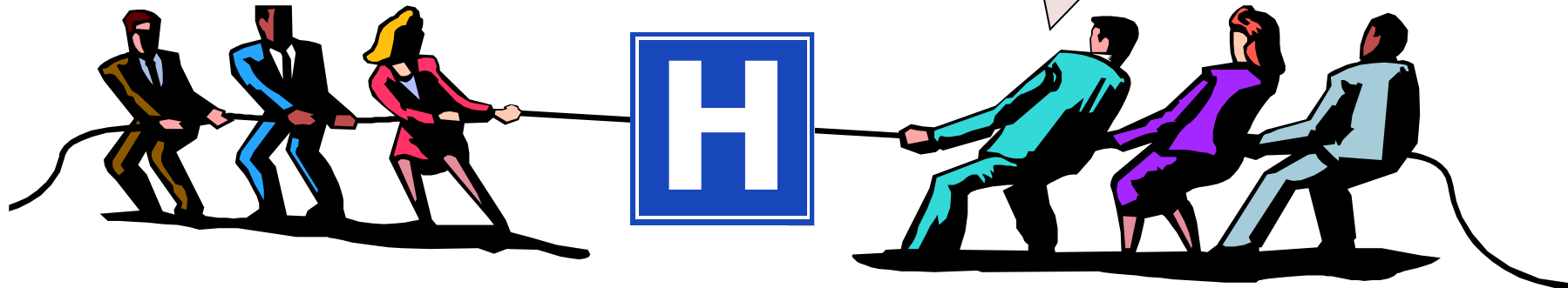
Centers for Medicare and Medicaid Services Audits



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!





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Council of State and Territorial Epidemiologists

Leaders in Applied Public Health Epidemiology



Developing a New, National Approach to Surveillance for Ventilator-Associated Events*

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Daniel Diekema, MD^{9,10}; Scott Fridkin, MD¹; Linda Greene, RN, MPS^{11,12};
Alice Guh, MD, MPH¹; David Gutterman, MD^{6,13}; Beth Hammer, RN, MSN, ANP-BC^{6,14};
David Henderson, MD¹⁵; Dean Hess, PhD, RRT^{16,17,18}; Nicholas S. Hill, MD^{6,19};
Teresa Horan, MPH¹; Marin Kollef, MD^{6,20}; Mitchell Levy, MD^{6,21}; Edward Septimus, MD^{22,23};
Carole VanAntwerpen, RN, BSN^{24,25}; Don Wright, MD, MPH²⁶; Pamela Lipsett, MD, MHPE^{6,27}

An Alternative Approach to Surveillance

- **Broaden the focus of surveillance 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 Events (VAE)

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

Date	PEEP (min)	FiO ₂ (min)
Jan 1	10	100
Jan 2	5	50
Jan 3	5	40
Jan 4	5	40
Jan 5	8	60
Jan 6	8	50
Jan 7	8	40
Jan 8	5	40
Jan 9	5	40

VAE

VAC
Ventilator-Associated Condition



IVAC
Infection-related
Ventilator-Associated
Complication



**Possible
Pneumonia**

National Healthcare Safety Network (NHSN)

CDC > NHSN > Materials for Enrolled Facilities

NHSN Ventilator-Associated Event (VAE) Calculator Ver. 5.0

MV Day	Date	Hide... (cmH ₂ O)	Min. PEEP	Hide... (20 - 100)	Min. FiO ₂	VAE	T<36° or T>38°	WBC ≤ 4,000 or WBC ≥ 12,000 cells/mm ³	<input type="button" value="Add..."/> <input type="button" value="Remove..."/> Choose a Drug: PIPERACILLIN/TAZOBACTAM	QAD
1	4/1/2018	5		40					<input type="checkbox"/>	
2	4/2/2018	5		40					<input type="checkbox"/>	
† 3	4/3/2018	5		40			<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
† 4	4/4/2018	10		60		‡ IVAC	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	¶ yes
† 5	4/5/2018	8		50			<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	¶ yes
† 6	4/6/2018	8		40			<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	¶ yes
7	4/7/2018	6		40					<input checked="" type="checkbox"/>	¶ yes
8	4/8/2018	5		40					<input checked="" type="checkbox"/>	¶ yes
9	4/9/2018	5		40					<input checked="" type="checkbox"/>	¶ yes
10	4/10/2018								<input checked="" type="checkbox"/>	¶ yes

Legend: † - VAE Window ‡ - VAE Date ¶ - Qualifying Antimicrobial Day (QAD)

Brief report

Assessment of an automated surveillance system for detection of initial ventilator-associated events

Dooshanveer Nuckchady MD^a, Michael G. Heckman MS^b, Nancy N. Diehl BS^b, Tara Creech RN^c, Darlene Carey RN, MSN^c, Robert Domnick BS^d, Walter C. Hellinger MD^{a,*}

Major Article

Development and validation of an automated ventilator-associated event electronic surveillance system: A report of a successful implementation

Courtney Hebert MD, MS^{a,b,*}, Jennifer Flaherty RN, MPH, CIC^c,)CM, MPH, CIC^d, Jing Ding PhD^e, Julie E. Mangino MD^{b,c}

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

Peter M. C. Klein Klouwenberg^{1,2,3*}, Maaïke S. M. van Mourik^{1*}, David S. Y. Ong^{1,2,3}, Janneke Horn⁴, Marcus J. Schultz⁴, Olaf L. Cremer², and Marc J. M. Bonten^{1,3}; on behalf of the MARS Consortium

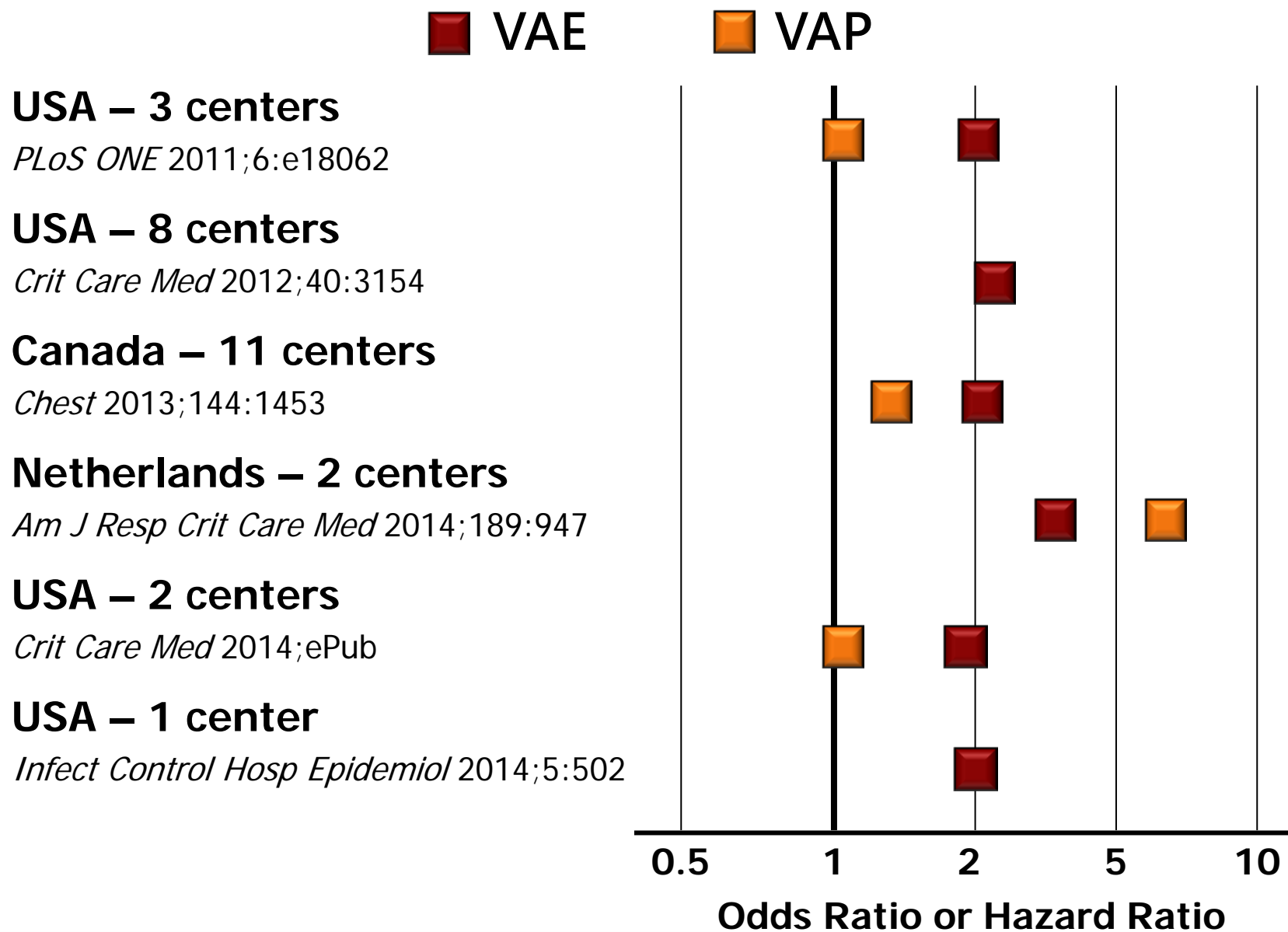
Building and Validating a Computerized Algorithm for Surveillance of Ventilator-Associated Events

Tal Mann, MD;^{1,6} Joseph Ellsworth, BSHA;² Najia Huda, MD;³ Anupama Neelakanta, MD, MPH;⁴ Thomas Chevalier, BSN, CIC;² Kristin L. Sims, MPH, CIC;⁵ Sorabh Dhar, MD;⁶ Mary E. Robinson, BSBA;² Keith S. Kaye, MD, MPH⁶

Development, Implementation and Use of Electronic Surveillance for Ventilator-Associated Events (VAE) in Adults

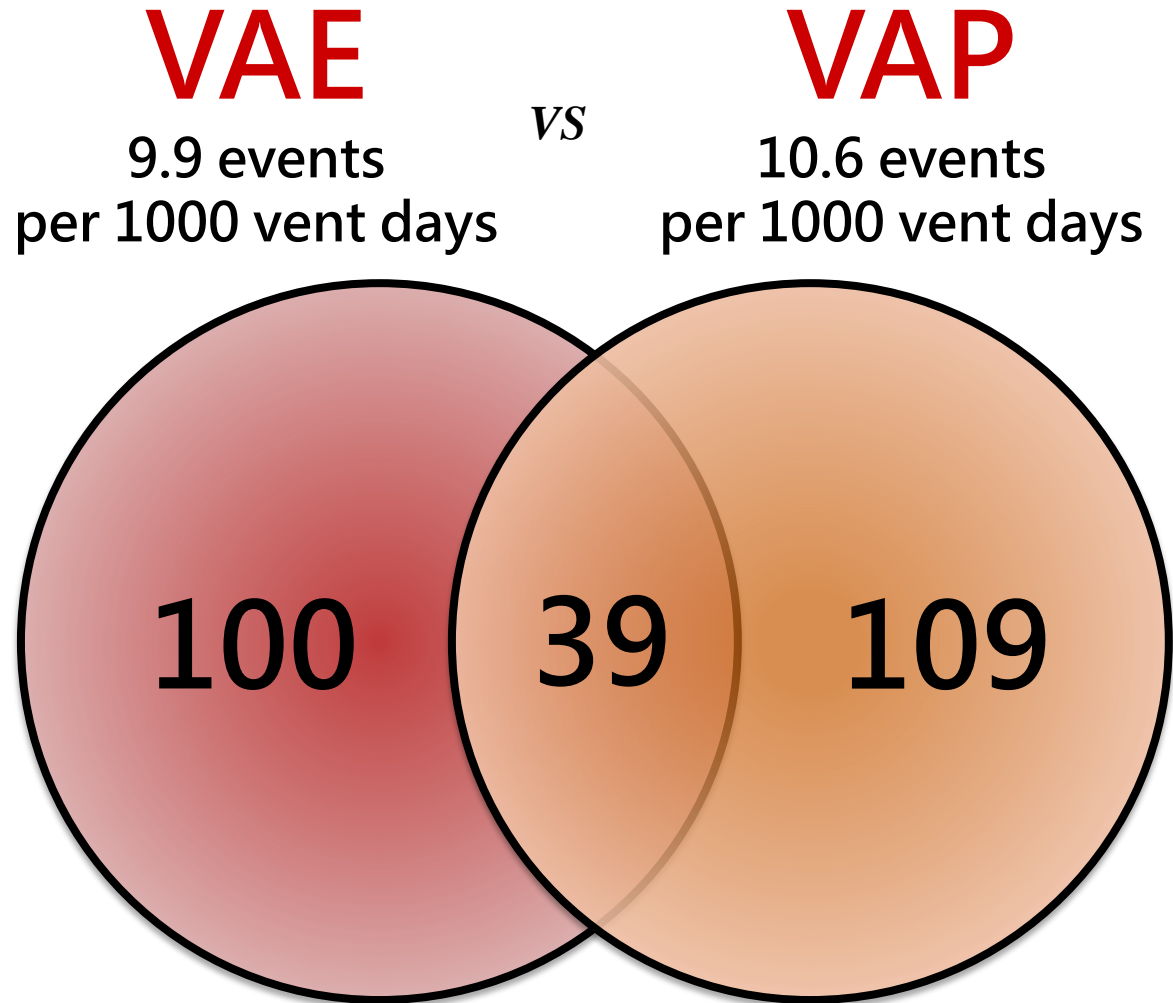
Ervina Resetar, MIM, PMP^{1,3}, Kathleen M. McMullen, MPH, CIC², Anthony J. Russo MPH², Joshua A. Doherty, BS³, Kathleen A. Gase, MPH, CIC³, Keith F. Woeltje, MD,

Attributable Mortality of VAE versus VAP



Canadian Critical Care Trials Group ABATE Study

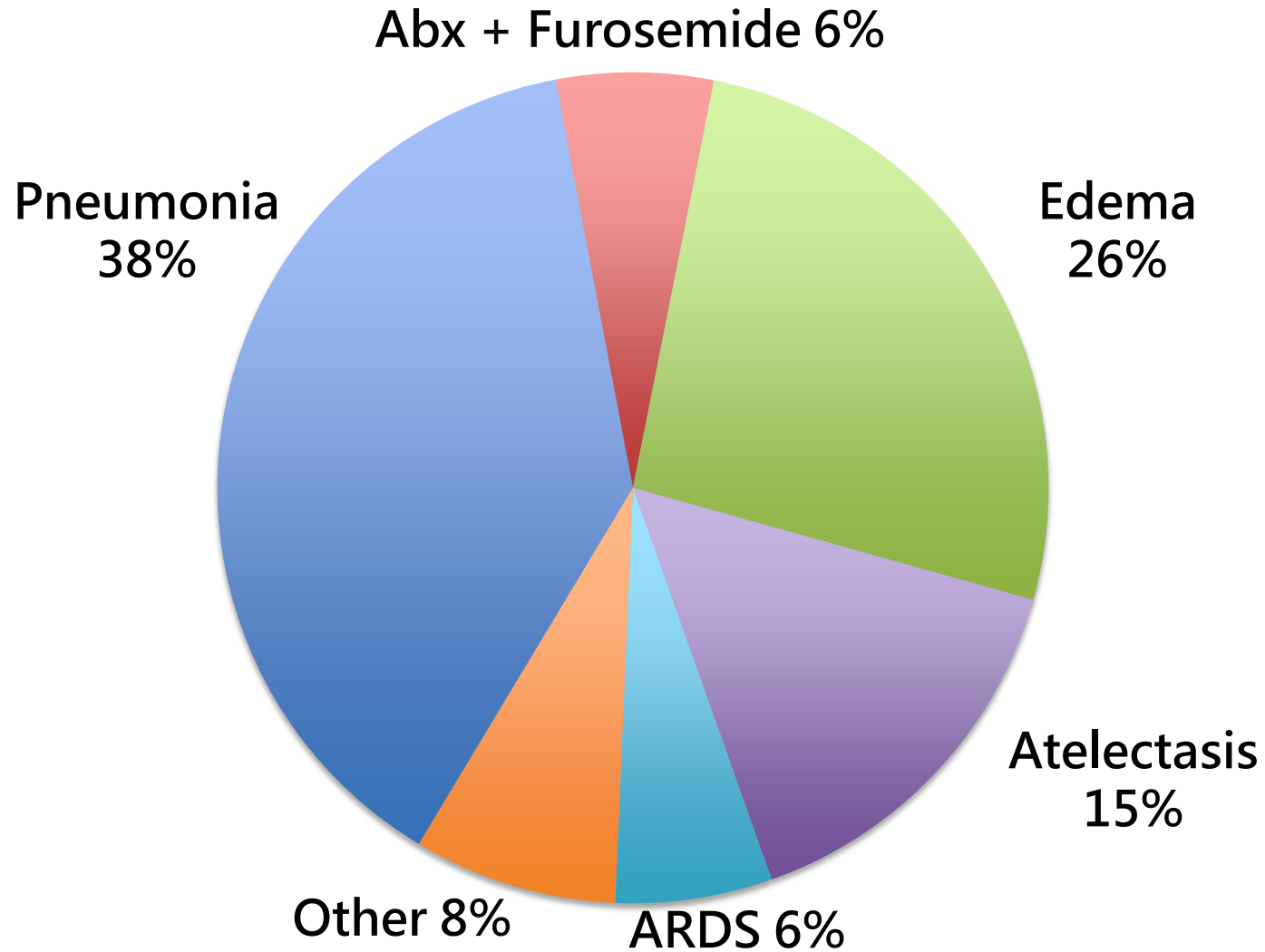
11 ICUs, 1330 patients, VAE vs VAP Surveillance



VAE \neq VAP

Qualitative analysis of 153 VAEs

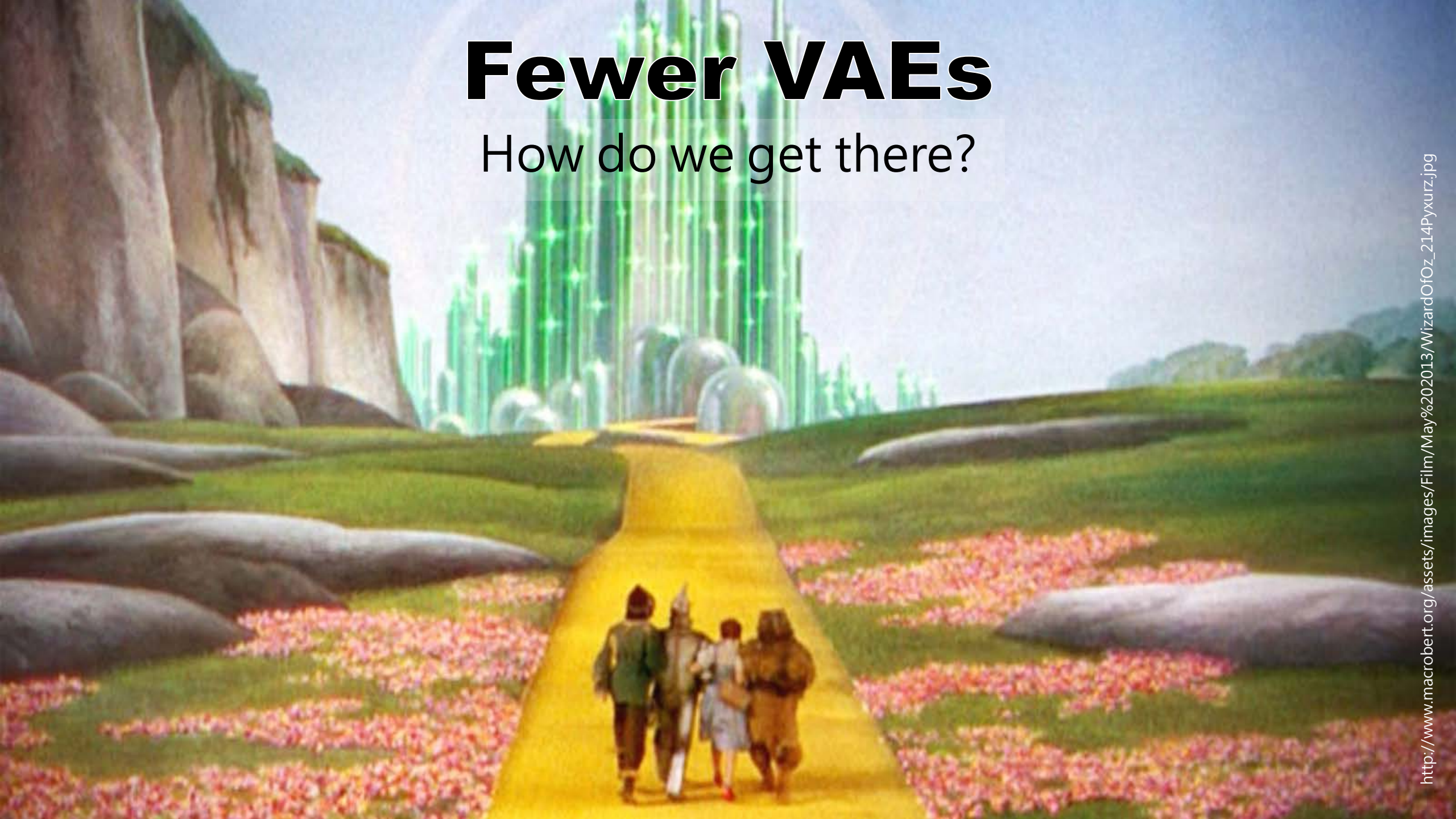
Royal Brisbane & Women's Hospital, Queensland, Australia



**VAE = VAP +
Fluid +
ARDS +
Atelectasis**

Fewer VAEs

How do we get there?

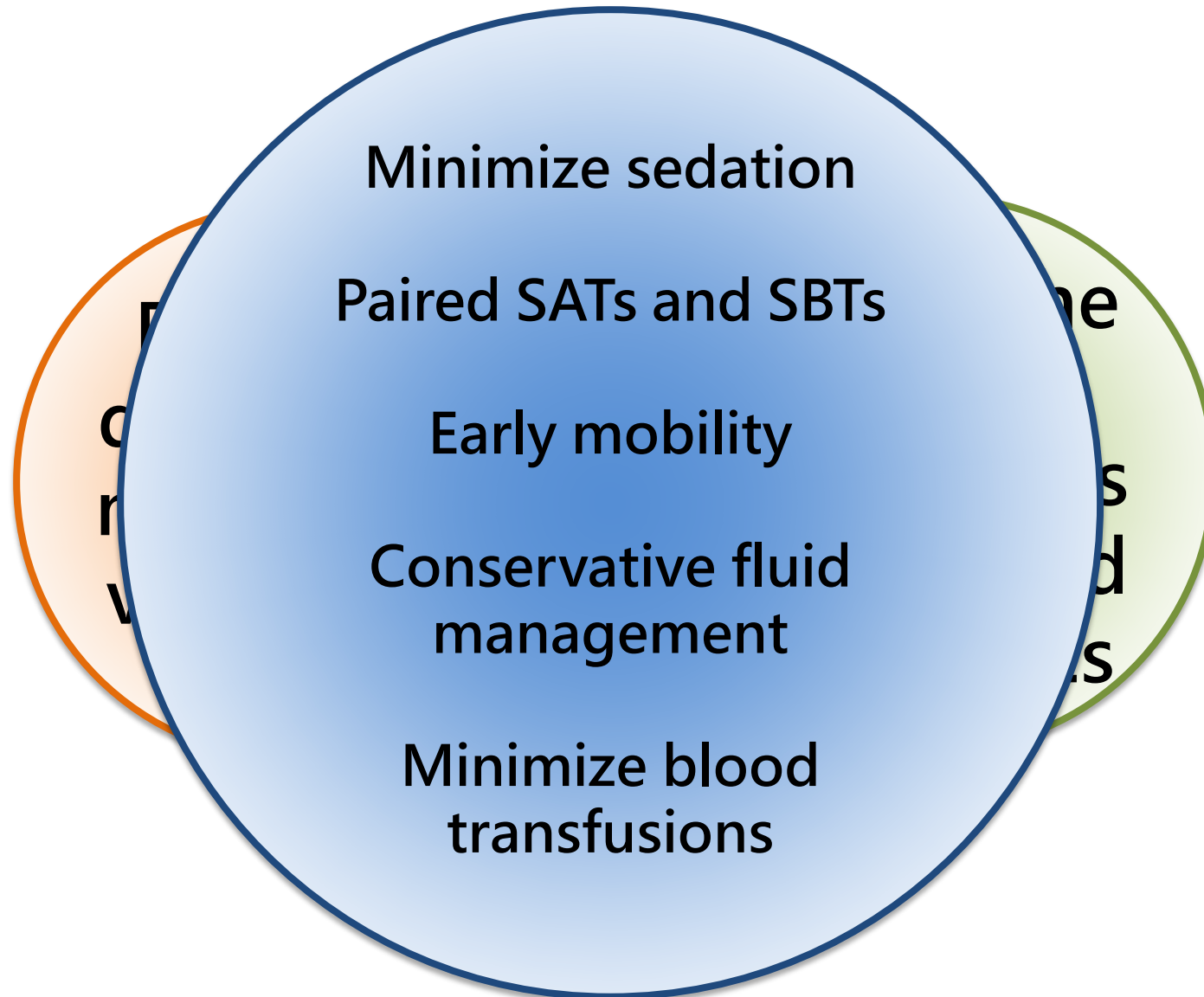


Strategies for Preventing VAEs

**Decrease
duration of
mechanical
ventilation**

**Target the
primary
conditions
associated
with VAEs**

Strategies for Preventing VAEs



VAE Prevention Strategies

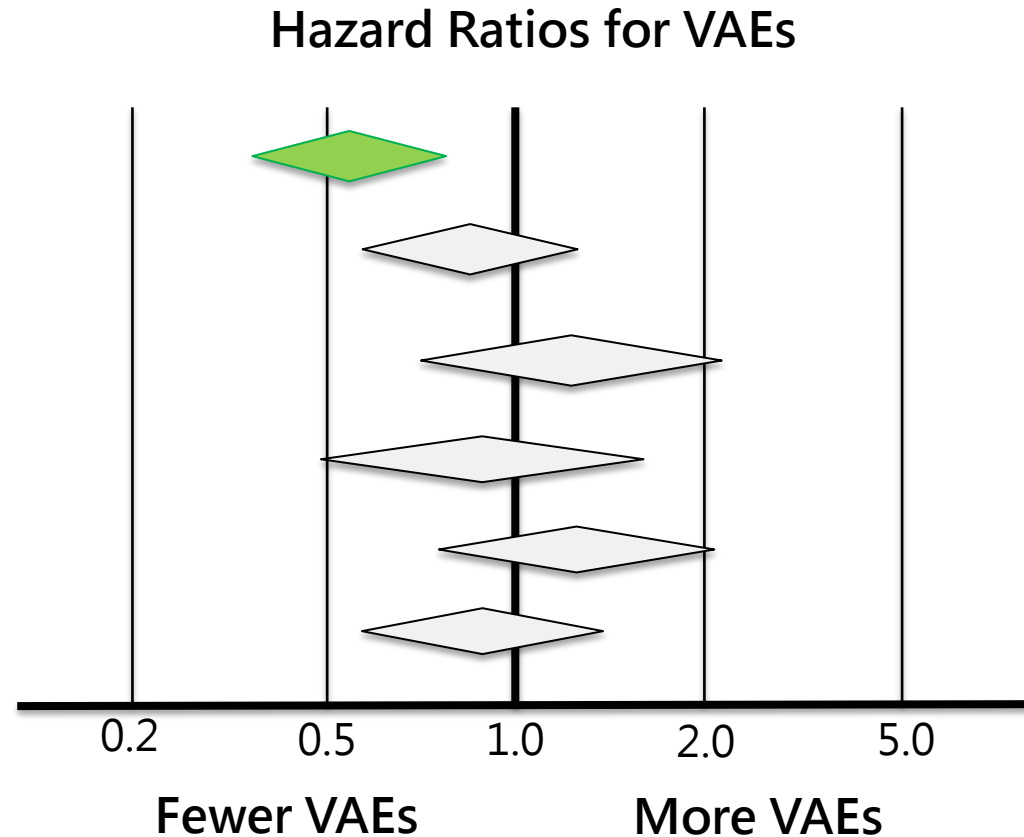
Well aligned with other best practice initiatives

	ABCDE	Choosing Wisely	PAD Guidelines	Surviving Sepsis	Strategies to Prevent VAP
Minimize sedation	✓	✓	✓	✓	✓
Paired SATs and SBTs	✓	✓	✓	✓	✓
Early Mobility	✓		✓	✓	✓
Conservative fluid management				✓	
Conservative transfusion thresholds		✓		✓	

Ventilator Bundle Compliance and VAEs

Retrospective analysis of 5,539 patients on mechanical ventilation
adjusted for comorbidities, severity of illness, contraindications, etc.

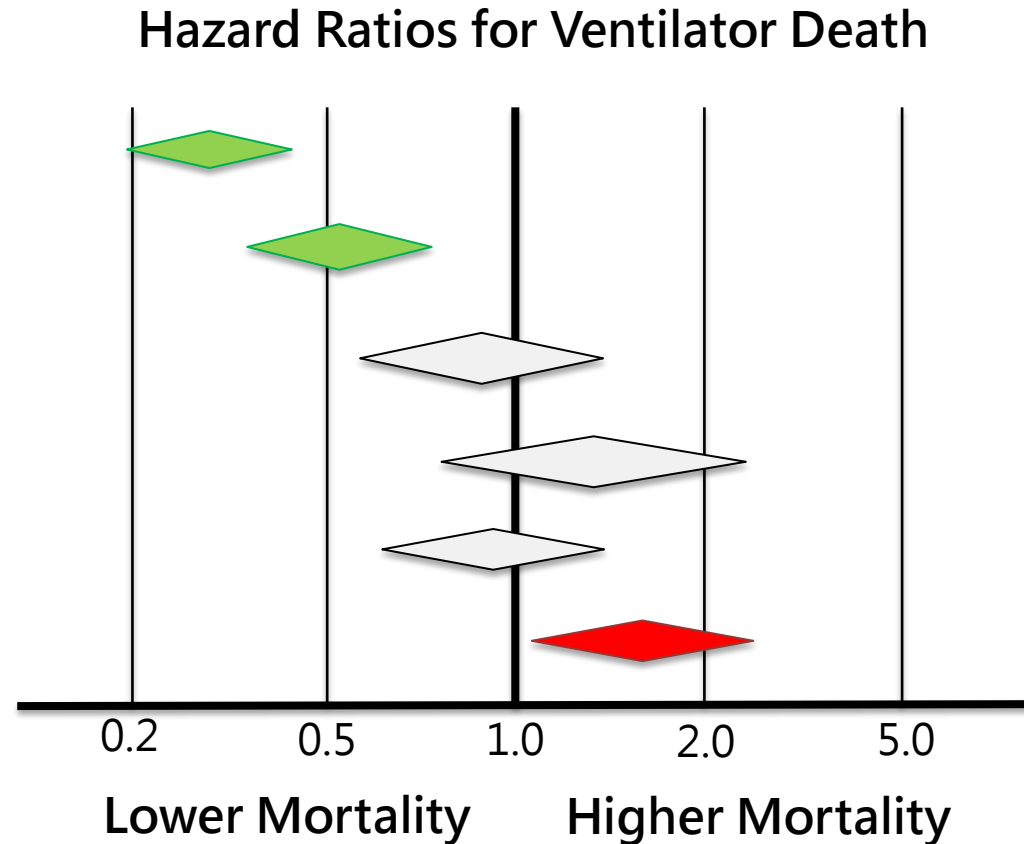
Spontaneous breathing trials
Spontaneous awakening trials
Head of bed elevation
Thromboprophylaxis
Stress ulcer prophylaxis
Oral care with chlorhexidine



Ventilator Bundle Compliance and Death

Retrospective analysis of 5,539 patients on mechanical ventilation
adjusted for comorbidities, severity of illness, contraindications, etc.

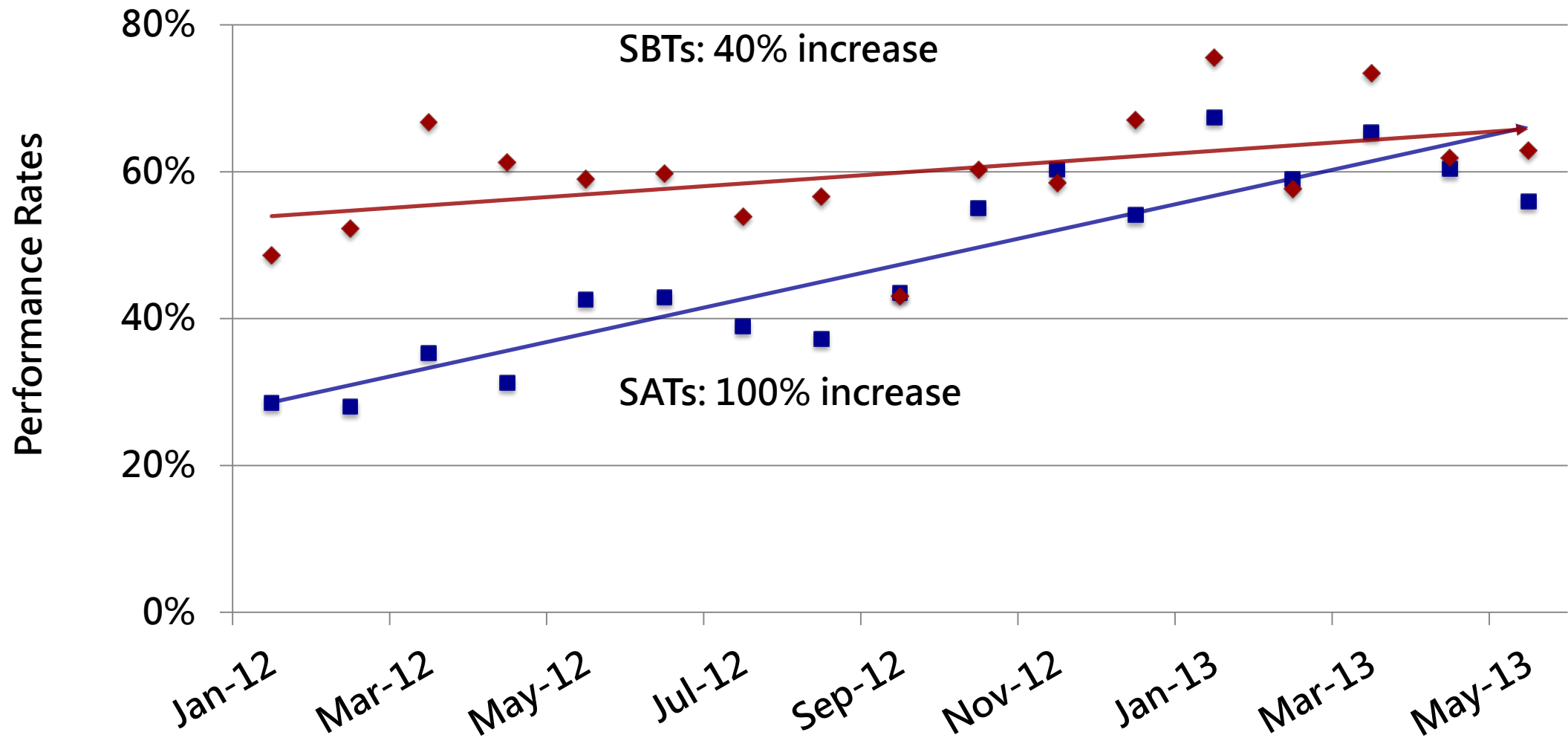
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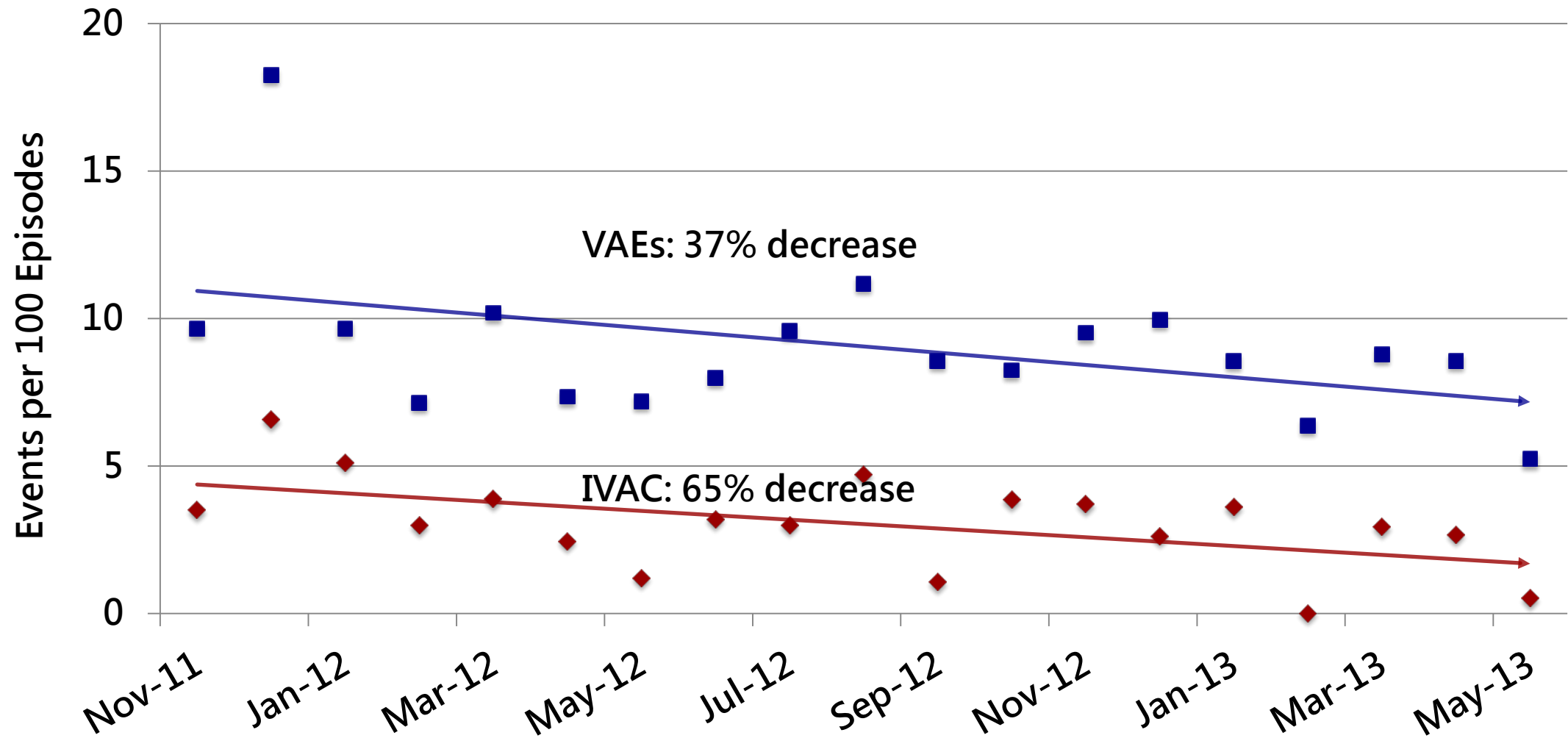
CDC Prevention Epicenters' Wake Up and Breathe Study

- Prospective care improvement collaborative
- 12 ICUs (mix of med, surg, mixed & academic, community)
- 19 months
- Goal: prevent VAEs through earlier liberation from mechanical ventilation
- Mechanism: enhance the uptake and performance of paired daily SATs and SBTs ("Every Patient, Every Day")

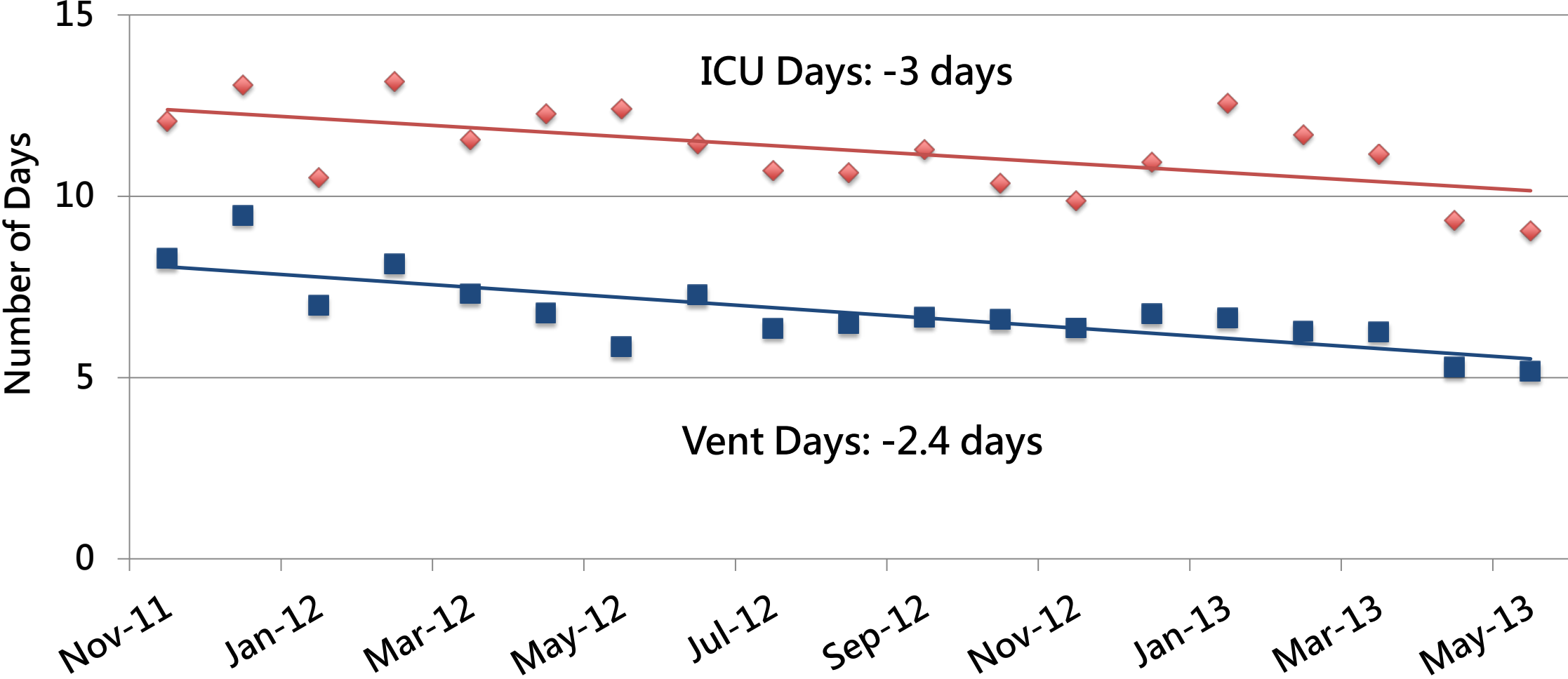
SATs and SBTs



Ventilator-Associated Events

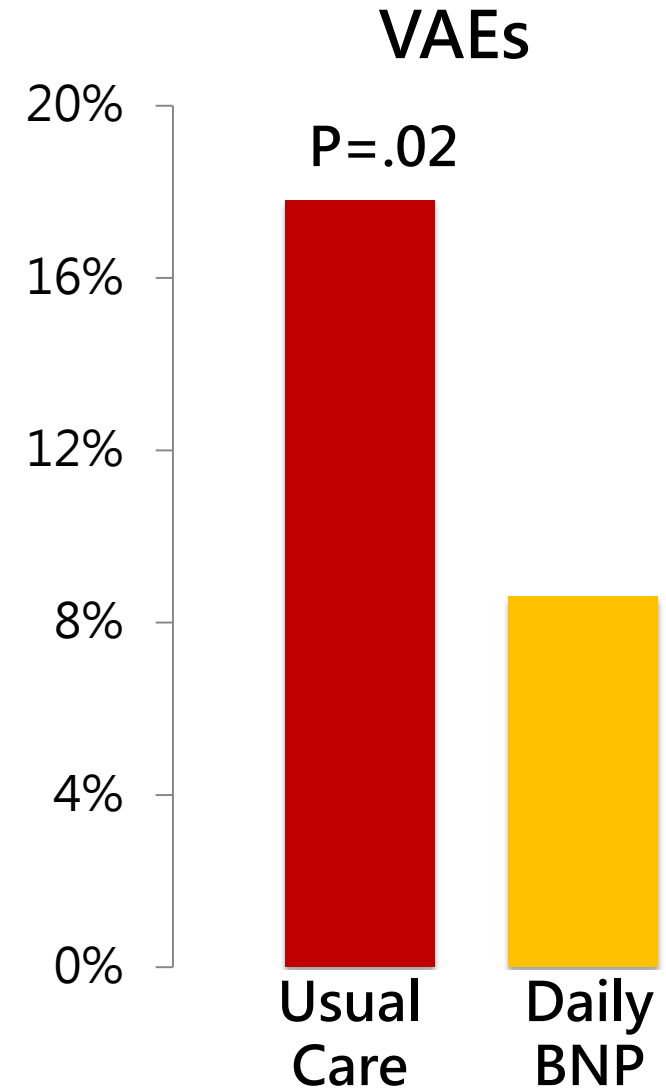


Ventilator Days and ICU Days



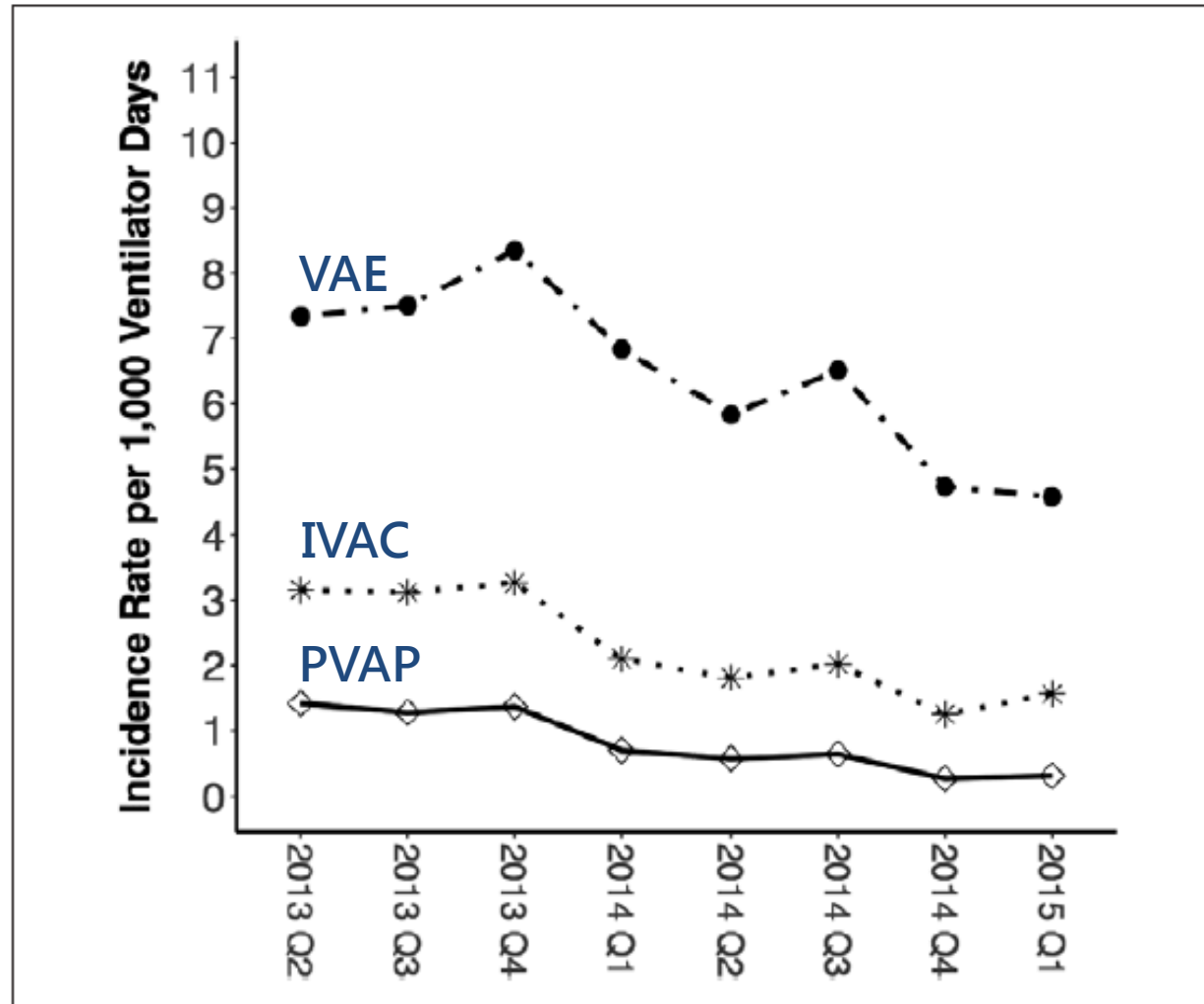
Depletive Fluid Management

- Randomized controlled trial of ventilator weaning
- 304 patients randomized to daily BNP levels versus usual care
- Patients randomized to daily BNP levels had:
 - More diuretics
 - More negative fluid balance
 - Less time to extubation
 - 50% fewer VAEs



Two State Collaborative to Prevent VAEs

56 ICUs in Maryland and Pennsylvania, Oct 2012 to Mar 2015



Ventilator-associated events

A patient safety opportunity

- **Broaden Awareness**

- Provides hospitals with a fuller picture of serious complications in mechanically ventilated patients

- **Catalyze Prevention**

- A significant portion of VAEs are preventable through well-accepted best practices in critical care

- **Reflect and Inform Progress**

- VAE surveillance provides an efficient and objective yardstick to measure and benchmark progress

Summary

- VAP is a **poor metric for benchmarking** and quality improvement
 - Diagnosis subjective and inaccurate
 - High interobserver variability
 - Poor guide to selecting prevention practices that will improve patient outcomes
 - CDC created **ventilator-associated event definitions** to enhance objectivity, automation, and expand prevention efforts
 - Suitable for automated surveillance
 - Lower VAE rates and improve outcomes by implementing strategies to **reduce duration of mechanical ventilation and prevent the primary conditions associated with VAEs** (pneumonia, ARDS, atelectasis, edema)
 - Minimize sedation
 - Paired daily SATs and SBTs
 - Early mobility
 - Conservative fluid management
 - Minimize blood transfusions
-

Thank You!

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