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ORIGINAL ARTICLE

Development of an Algorithm for Surveillance of Ventilator-Associated Pneumonia With Electronic Data and Comparison of Algorithm Results With Clinician Diagnoses

Michael Klompas, MD, MPH; Ken Kleinman, ScD; Richard Platt, MD, MSc

OBJECTIVE. Surveillance for ventilator-associated pneumonia (VAP) using standard Centers for Disease Control and Prevention (CDC) criteria is labor intensive and involves many subjective assessments. We sought to improve the efficiency and objectivity of VAP surveillance by adapting the CDC criteria to make them amenable to evaluation with electronic data.

DESIGN. Prospective comparison of the accuracy of VAP surveillance by use of an algorithm with responses to prospective queries made to intensive care physicians. CDC criteria for VAP were used as a reference standard to evaluate the algorithm and clinicians' reports.

SETTING. Three surgical intensive care units and 2 medical intensive care units at an academic hospital.

METHODS. A total of 459 consecutive patients who received mechanical ventilation for a total of 2,540 days underwent surveillance by both methods during consecutive 3-month periods. Electronic surveillance criteria were chosen to mirror the CDC definition. Quantitative thresholds were substituted for qualitative criteria. Purely subjective criteria were eliminated. Increases in ventilator-control settings were taken to indicate worsening oxygenation. Semiquantitative Gram stain of pulmonary secretion samples was used to assess whether there was sputum purulence.

RESULTS. The algorithm applied to electronic data detected 20 patients with possible VAP. All cases of VAP were confirmed in accordance with standard CDC criteria (100% positive predictive value). Prospective survey of clinicians detected 33 patients with possible VAP. Seventeen of the 33 possible cases were confirmed (52% positive predictive value). Overall, 21 cases of confirmed VAP were identified by either method. The algorithm identified 20 (95%) of 21 known cases, whereas the survey of clinicians identified 17 (81%) of 21 cases.

CONCLUSIONS. Surveillance for VAP using electronic data is feasible and has high positive predictive value for cases that meet CDC criteria. Further validation of this method is warranted.

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Payers, politicians, and patients are increasingly advocating that hospitals measure and report their infection rates as a means of assessing their quality of care.[1,2] These parties propose to use the data to drive quality improvements, benchmark hospitals against each other, and determine hospitals' level of compensation. Among the infections frequently proposed for public reporting is ventilator-associated pneumonia (VAP). The de facto standard for identifying VAP is the definition published by the National Healthcare Safety Network of the Centers for Disease Control and Prevention (CDC) (see Figure 1).[3] The CDC definition is labor intensive and expensive to implement, however, because applying it depends on detecting changes in clinical signs that require frequent, repeated, and detailed bedside assessment on a patient-by-patient basis. In addition, the CDC definition includes subjective criteria such as "worsening oxygenation" or "increased sputum production" that might permit significant interobserver variability with respect to perceived VAP diagnoses. Routinely collected electronic clinical data offers a potential way to simultaneously increase the efficiency, objectivity, and reproducibility of VAP surveillance. We report on a pilot project to test the feasibility and accuracy of VAP surveillance by applying an adapted CDC definition to routinely collected electronic data. Cases of VAP identified by use of the algorithm were validated by comparison with traditional CDC criteria and completeness of case capture was assessed by regular, prospective querying of intensive care physicians for clinically diagnosed cases of VAP.

METHODS

Definition

We adapted the CDC definition of VAP to make it amenable to electronic assessment. We retained the central structure of

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	Traditional CDC Criteria	Modified Criteria
	Patient must fulfill radiographic, systemic, and pulmonary criteria, as indicated below.	
Chest Radiograph	*Any 1 of the following:* 1. New, progressive, or persistent infiltrate 2. Consolidation 3. Cavitation	*Any 1 of the following:* 1. Opacity, infiltrate, or consolidation that appears, evolves, or persists over ≥72 hours 2. Cavitation
Systemic Signs	*Any 1 of the following:* 1. Temperature >38°C (100.4°F) 2. WBC <4,000 or >12,000 WBC/mm^3 3. For adults 70 years old, altered mental status with no other recognized cause	*Any 1 of the following:* 1. Temperature >38°C (100.4°F) within past 24 hours 2. WBC <4,000 or >12,000 WBC/mm^3 within past 24 hours
Pulmonary Signs	*Any 2 of the following:* 1. New onset of purulent sputum, change in character of sputum, increased respiratory secretions, or increased suctioning requirements 2. New onset or worsening cough, dyspnea, or tachypnea 3. Rales or bronchial breath sounds 4. Worsening gas exchange, increased oxygen requirements, or increased ventilation demand	*Both of the following* 1. Sustained rise in ventilator FiO_2 >15mm Hg over 48 hour period **OR** sustained rise in ventilator PEEP by ≥5cm H_2O over 48 hour period **OR** simultaneous rise in FiO_2 >10mm Hg AND rise in PEEP>2.5cm H_2O sustained over 48 hours 2. Gram stain of respiratory secretion sample with ≥25 neutrophils per high power field within past 72 hours

FIGURE 1. Traditional surveillance criteria for ventilator-associated pneumonia from the Centers for Disease Control and Prevention National Healthcare Safety Network and the Brigham and Women's Hospital modified surveillance criteria.

the CDC criteria, according to which patients must fulfill 1 radiographic criterion, 1 systemic criterion, and 2 pulmonary criteria, but we eliminated nonspecific signs, such as rales, dyspnea, cough, and delirium, that are not typically assigned codes in electronic medical records. Radiologists' reports on chest radiograph findings were used for the evaluation of radiographic criteria. Quantitative thresholds specified by the CDC for temperature and white blood cell counts were used to assess systemic criteria. Gram stain of pulmonary secretion samples and changes in patients' ventilator settings were used to evaluate pulmonary criteria. Detection of a moderate or greater number of neutrophils on semiquantitative analysis of Gram stain of samples of pulmonary secretions (ie, endotracheal aspirate or bronchoalveolar lavage fluid) was considered evidence of sputum purulence, corresponding to the CDC-specified threshold of 25 or more neutrophils per high-power field.[3]

A sustained increase in ventilator settings was considered evidence of worsening gas exchange. In particular, we took an increase in the fraction of inspired oxygen (FiO_2) of at least 15 points, an increase in the positive-end expiratory pressure (PEEP) of at least 5 cm H_2O, or a simultaneous increase in the FiO_2 of 10 points and an increase in the PEEP of 2.5 cm H_2O to be evidence of worsening gas exchange. These increases in ventilator settings were assessed relative to a baseline of the patient's lowest ventilator settings after 48 hours or more of decreasing ventilator support. (Typically, patients begin with high ventilator settings, which are then decreased with a view to extubation as soon as the patient begins to recover from the condition that precipitated intubation; an increase in ventilator settings after a period of decreasing ventilator support, therefore, suggests a complication of care.) Increases in ventilator settings had to persist for at least 48 hours to fulfill the criteria. These thresholds were selected on the basis of the investigators' clinical experience, in addition to trial-and-error experimentation before the beginning of the study. Changes in ventilator settings (hereafter, ventilator-change criteria) were chosen over arterial oxygenation measures or the ratio of arterial oxygen pressure to inspired oxygen fraction because the latter 2 measures are highly susceptible to transient changes in the patient's position, nursing procedures, and suctioning patterns that are typically insufficient to trigger a sustained increase in ventilator settings. In addition, the incorporation of ventilator-change criteria into the VAP surveillance algorithm established an efficient strategy for rapidly screening large numbers of patients receiving mechanical ventilation—only individuals who meet ventilator-change criteria were examined further to see whether they fulfilled the remaining criteria for VAP. The full modified criteria for VAP are summarized in Figure 1, presented alongside the traditional CDC criteria for comparison.

Setting

This study was conducted in 2 medical intensive care units (ICUs) and 3 surgical ICUs in Brigham and Women's Hospital (Boston, Massachusetts). Each 10-bed ICU was surveyed during a distinct 3-month period sometime between June and October 2006.

Review Rrotocol

Each day, an infection control practitioner generated a list of all patients who were receiving mechanical ventilation in the target ICUs. The list was abstracted from a database of ventilator-setting information maintained by our hospital's re-

spiratory therapy department. The respiratory therapy database included a single daily snapshot of each patient's current ventilator settings, as recorded by the respiratory therapist at the time of his or her routine morning rounds. The daily ventilator settings for each patient since admission were then scanned for increases in FiO_2 and PEEP that met the thresholds specified above. The relatively limited subset of patients who met ventilator-change criteria were reviewed further by querying the hospital's clinical information system for data on patient temperature, white blood cell count, Gram stain results for endotracheal aspirate or bronchoalveolar lavage fluid samples (within a 72 hour window before or during the period of increased ventilator settings), and recent radiographic findings. These were then assessed to determine how they fit with the rest of our VAP criteria. Figure 2 depicts the diagnostic algorithm followed by the infection control practitioner.

Accuracy of Case Identification

Suspected cases of VAP that were identified by use of the algorithm were validated by comparison with the traditional CDC criteria. An infectious diseases physician from the hospital's infection control department who was familiar with infection surveillance methodology reviewed the paper and electronic records for each patient with suspected VAP to apply the CDC criteria. The reviewer was not involved in the care of the patients surveyed in this study.

Completeness of Case Capture

We sought to identify cases of VAP independently of the electronic surveillance protocol by prospectively querying ICU clinicians each week about cases of clinically suspected VAP. The attending physician, fellows, and senior residents of each ICU were all surveyed. The medical record for each patient with clinically suspected VAP was then reviewed by an infectious diseases physician who applied the CDC criteria as a reference standard to confirm or reject the diagnosis of VAP for each possible case patient.

Completeness of case capture for the algorithm was calculated relative to the subset of patients with confirmed VAP identified either by the algorithm or by survey of clinicians. We pooled the confirmed cases of VAP found by either surveillance technique, because all clinical surveillance methods potentially miss cases of VAP.[4-7] As a result, pooling the confirmed cases found by multiple techniques gives a closer approximation of the true burden of VAP in the population than any single technique used alone.[8]

The completeness of case capture for each surveillance technique is reported as a percentage of known cases identified, rather than as "sensitivity," because personnel and cost

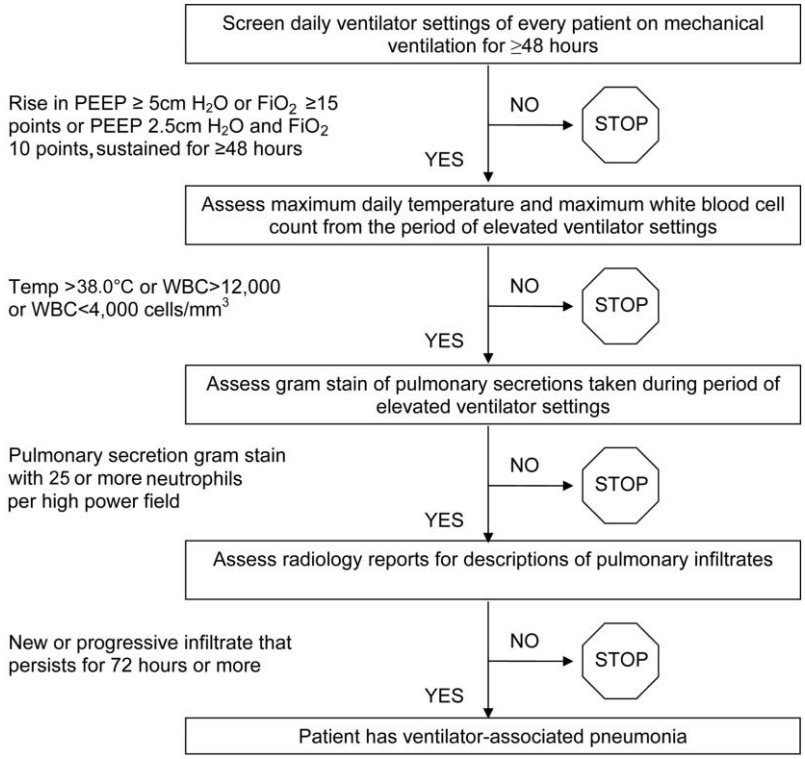

FIGURE 2. Diagnostic algorithm followed by the infection control practitioner to identify cases of ventilator-associated pneumonia. PEEP, positive-end expiratory pressure; WBC, white blood cell.

TABLE 1. Comparison of Completeness and Accuracy of Case Identification of Ventilator-Associated Pneumonia (VAP) by Prospective Survey of Clinicians and by Algorithm

Case identification method	Cases of suspected VAP identified	Cases of suspected VAP that met CDC criteria for VAP	Known cases of VAP that were missed[a]	PPV	Proportion (%) of all known[a] cases of VAP identified
Survey of clinicians	33	17	4	17/33 (52%)	17/21 (81)
Algorithm	20	20	1	20/20 (100%)	20/21 (95)

NOTE. CDC, Centers for Disease Control and Prevention; PPV, positive predictive value.
[a] As determined by either of the 2 methods.

considerations prevented direct application of the reference standard (ie, the CDC criteria) to the entire study population. We have avoided the term "sensitivity" because the proportion of known cases identified is likely to be an overestimate of the true sensitivity.[8]

Comparison of the 2 Surveillance Techniques

Positive predictive values were calculated for VAP case identification by algorithm and for case identification by ICU clinicians. Positive predictive values are reported rather than specificity, because the calculation of specificity requires knowledge of the prevalence of VAP among patients who were not identified as having VAP by either the algorithm or the survey of clinicians. A positive predictive value, however, can be calculated purely by analyzing whether patients identified by the algorithm also fulfilled the CDC criteria.

To gauge the clinical severity of illness among patients identified by the algorithm alone, compared with that of patients identified both by the algorithm and by survey of clinicians, we compared the duration of mechanical ventilation, length of stay (LOS) in the ICU, hospital LOS, and in-hospital mortality rate for both groups of patients. To better understand the sources of clinicians' misclassifications of patients with and without VAP, we compared the demographic and clinical characteristics of patients who were falsely suspected of having VAP with those of patients who had confirmed VAP.

Statistical analysis

Categorical variables were compared using the Fisher exact test. Continuous variable distributions were compared using the Wilcoxon rank sum test for nonparametric variables. All statistical calculations were performed using SAS, version 9.1 (SAS Institute).

RESULTS

During the study period, 459 patients received mechanical ventilation for a total of 2,540 days. Of these, 266 patients were cared for in surgical ICUs, and 193 were admitted to medical ICUs. The algorithm detected 20 episodes of VAP in this population. This corresponds to a VAP incidence rate of 8.3 cases per 1,000 ventilator-days. This rate is in line with the mean national VAP incidence rate of 5.4 cases per 1,000 ventilator-days, as reported by the National Nosocomial Infection Surveillance network for medical-surgical ICUs in teaching hospitals.[9] By contrast, ICU clinicians identified 33 cases of suspected VAP.

Accuracy and Completeness of Case Identification for Both Techniques

The CDC criteria for VAP were applied to all cases identified by the algorithm and/or by clinicians. All 20 suspected cases identified by the algorithm met CDC criteria (100% positive predictive value). Of the 33 suspected cases identified by clinicians, 17 met CDC criteria (52% positive predictive value). Of the 17 confirmed cases found by clinicians, 16 were also identified by the algorithm. An additional 4 true-positive cases were identified by the algorithm alone. Overall, the algorithm detected 20 (95%) of 21 cases of VAP identified by all techniques in this population. By contrast, clinicians detected 17 (81%) of 21 cases of VAP. These results are summarized in Table 1.

Comparison of Patients Identified by Each Technique

There were no significant differences in the duration of mechanical ventilation, ICU LOS, hospital LOS, or in-hospital mortality rate for patients identified by the algorithm alone, compared with patients identified by both the algorithm and by survey of clinicians. The demographic and clinical characteristics, risk factors, and outcomes for patients who were confirmed to have VAP and those whom clinicians falsely suspected of having VAP are presented in Table 2. Patients with and patients without VAP did not differ significantly with respect age, sex ratio, comorbidities, or reason for intubation. Patients with confirmed VAP, however, were more likely to have a new or persistent infiltrate, purulent sputum, and evidence of worsening gas exchange. Patients with and without VAP did not differ significantly with respect to their probability of having fever or an abnormal white blood cell count. Patients with confirmed VAP spent significantly more time receiving mechanical ventilation ($P = .001$) and more days in the ICU ($P = .022$). There was a trend towards greater total hospital LOS among patients with confirmed VAP ($P = .070$). When duration of illness was recalculated using the time at which VAP was diagnosed as the starting point, patients with confirmed VAP remained on mechanical

TABLE 2. Demographic and Clinical Characteristics of Patients Confirmed to Have Ventilator-Associated Pneumonia (VAP), Compared With Patients Who Were Falsely Suspected of Having VAP

Characteristic	Falsely suspected VAP group (N = 16)	Confirmed VAP group (N = 21)	P[a]
Age, years	57.0 (52.5-74.0)	54.0 (49.0-67.0)	.461
Male sex	10/16 (62.5)	12/21 (57.1)	.99
Reason for intubation			
Trauma	4/16 (25.0)	3/21 (14.3)	.437
Sepsis	4/16 (25.0)	4/21 (19.1)	.705
Respiratory failure	1/16 (6.3)	4/21 (19.1)	.364
Surgery	6/16 (37.5)	9/21 (42.9)	.99
Other	1/16 (6.3)	1/21 (4.8)	.99
Comorbidities			
Transplantation	2/16 (12.5)	1/21 (4.8)	.568
Cancer	4/16 (25.0)	7/21 (33.3)	.723
Immunocompromise	4/16 (25.0)	2/21 (9.5)	.371
Diabetes mellitus	1/16 (6.3)	2/21 (9.5)	.99
Renal disease	6/16 (37.5)	11/21 (52.4)	.509
Liver disease	2/16 (12.5)	5/21 (23.8)	.675
Heart disease	9/16 (56.3)	9/21 (42.9)	.515
Lung disease	3/16 (18.8)	8/21 (38.1)	.285
Clinical criterion for VAP			
Infiltrate[b]	9/16 (56.3)	21/21 (100)	.001
Fever[c]	10/16 (62.5)	15/21 (71.4)	.726
Abnormal white blood cell count[d]	15/16 (93.8)	20/21 (95.2)	.99
Purulent sputum[e]	6/16 (37.5)	21/21 (100)	<.001
Worsening gas exchange[f]	5/16 (31.3)	21/21 (100)	<.001
Total duration of illness			
No. of ventilation-days	11.5 (8.5-19.5)	36.0 (21.0-61.0)	.001
LOS, days			
ICU	17.0 (13.0-41.5)	49.0 (26.0-63.0)	.022
Hospital	33.0 (16.5-43.5)	49.0 (32.0-70.0)	.070
Duration of illness after diagnosis of VAP, days			
Before extubation	4.0 (0.5-14.0)	19.0 (10.0-23.0)	.001
Before ICU discharge	14.0 (6.5-20.5)	20.0 (11.0-33.0)	.167
Before hospital discharge	20.0 (11.5-32.0)	21.0 (14.0-33.0)	.529
Death during index admission	4/16 (25.0)	10/21 (47.6)	.191

NOTE. Data are proportion (%) of patients or median (interquartile range), unless otherwise indicated. ICU, intensive care unit; LOS, length of stay.

[a] Categorical variables were compared using the Fisher exact test, and continuous variable distributions were compared using the Wilcoxon rank sum test for nonparametric variables (which compares distributions, rather than the medians specified in the adjacent columns).

[b] New or progressive and sustained.

[c] Temperature of >38.0°C (100.4°F).

[d] Count of <4,000 or >12,000 white blood cells per mm^3.

[e] Count of >25 neutrophils per high power field on Gram stain of pulmonary secretion sample.

[f] Any increase in fraction of inspired oxygen or positive end expiratory pressure that occurred after 48 hours of ventilation and was sustained for ⩾48 hours.

ventilation longer than patients whose VAP diagnosis was not confirmed (P = .001). There was no significant difference between the 2 groups, however, in time from VAP diagnosis to ICU discharge or hospital discharge. Likewise, there was no significant difference in the in-hospital mortality rates of the 2 groups.

Sources of False Case Identification

Of the 16 patients whom clinicians wrongly suspected of having VAP, 5 met the criteria for hospital-acquired pneumonia but were not classified as having VAP because of technical issues (ie, they were not receiving ventilation within 48

hours prior to onset of pneumonia). The remaining 11 patients were excluded as a result of a combination of stable radiograph results (7 patients), stable oxygenation levels (9 patients), and/or the absence of a change in the quality, quantity, or purulence of sputum (2 patients).

DISCUSSION

This pilot study suggests that it might be feasible to conduct surveillance for VAP with electronic data sources. The algorithm found 20 of 21 known cases of VAP and had a 100% positive predictive value. There are 2 major advantages to using electronic data sources for VAP surveillance: (1) the adoption of quantitative variables for VAP criteria decreases the subjectivity permitted by the current CDC definition, thereby making VAP surveillance more objective and reproducible; and (2) surveillance that relies on electronic data is less labor intensive and time consuming than daily visits to the bedside or the retrospective review of medical records for all patients receiving mechanical ventilation. In particular, the incorporation of ventilator-change thresholds into the surveillance strategy allows for highly efficient surveillance. Practitioners can rapidly screen large numbers of patients for possible VAP by intermittently reviewing patients' daily ventilator settings. Only the records of individuals who meet the ventilator-change criteria need to be reviewed further to apply the full surveillance definition.

VAP surveillance using an algorithm and electronic data had higher positive predictive value and identified more cases, compared with a prospective survey of clinicians. Although clinicians were able to identify a high proportion of confirmed cases of VAP (17 of 21), only about half of the cases they found met the formal CDC criteria for VAP. This is not surprising, because epidemiologic surveillance definitions are intentionally made more rigorous and restrictive than clinical definitions to enable comparisons of consistent disease entities over time, as well as comparisons between institutions. It is, therefore, to be expected that clinical diagnosis will identify more cases and be less specific than formal epidemiologic surveillance. Indeed, a high proportion of clinicians' false diagnoses were likely the result of a lack of familiarity with the technical CDC surveillance definition. One-third of the patients whom clinicians falsely suspected of having VAP (5 of 16) met the CDC criteria for hospital-acquired pneumonia but they did not receive ventilation in the 48 hours before the onset of pneumonia, which thus did not permit their complication to be classified as ventilator associated. This suggests that a variant strategy for efficient VAP surveillance without electronic data might consist of clinician screening for possible cases followed by infection control practitioner review to apply the technical CDC definition.

The algorithm identified 4 cases of VAP that were not diagnosed by clinicians. Analysis of these cases revealed 2 patients with transient pulmonary deterioration of unclear etiology that resolved without specific therapy. A third patient had generalized *Enterobacter* sepsis from an unclear source, attributed by clinicians to a central venous catheter but arguably related to undiagnosed pneumonia. The fourth patient developed *Candida* empyema after a pneumonectomy that was treated but not considered to be an episode of VAP by the patient's clinicians. These cases that were identified by the algorithm but not by clinicians seem to reflect a combination of the lack of specificity of the CDC criteria, the clinical uncertainty sometimes encountered in trying to identify the source of deterioration in patients with complex illnesses, and a lack of familiarity with the technical definition of VAP.

The superior positive predictive value of the algorithm-based surveillance was a predictable consequence of designing the algorithm to closely mirror the CDC definition. As with the CDC definition, patients were required to manifest 1 radiographic sign, 1 systemic sign, and 2 pulmonary signs of pneumonia. The specific criteria for changes in radiographic findings, fever, and abnormal white blood cell count were unchanged from the original CDC definition. The 2 pulmonary criteria were both selected from among the 4 pulmonary options in the CDC definition, but we defined them numerically, rather than permitting subjective assessment. As would be predicted, close retention of the structure and core criteria of the CDC definition led to high specificity relative to the CDC definition but decreased sensitivity. Nonetheless, the single known case of VAP that was missed by the algorithm met all the criteria of the modified algorithm except for a sufficient increase in ventilator settings. This patient's PEEP value did increase for a sustained period by 2.5 cm H_2O during the time corresponding to the episode of VAP, but his FiO_2 value during this period was steady. This could suggest that the ventilator-change criteria in our algorithm are too restrictive. Future refinement of the algorithm might include revised ventilator-change criteria.

The potential value of this surveillance algorithm needs to be interpreted in the context of the limitations of this study. The true sensitivity of the algorithm is unknown. We used prospective surveys of clinicians followed by formal application of CDC criteria to identify as many patients with VAP as possible so that we could assess the completeness of case capture for the algorithm. It is possible, however, that both the clinicians and the algorithm missed some cases. Likewise, the accuracy of the algorithm was assessed by comparison with the CDC surveillance definition as a reference standard. The CDC criteria, however, constitute an imperfect "gold standard." Because the CDC criteria allow for the subjective assessment of many clinical signs, it is possible that a different reviewer might have determined the confirmed diagnoses of VAP differently. Moreover, the concordance between the CDC criteria and histological evidence of VAP is unknown. Studies of patients who received mechanical ventilation and later underwent autopsy have shown that use of clinical criteria similar to those advocated by the CDC misdiagnoses VAP in some patients who do not have it and misses about one-third

of patients with histologically confirmed VAP.[4,10,11] Nonetheless, we opted to use the CDC criteria because of the absence of a superior "gold standard" and in recognition that it is the de facto standard for infection control surveillance in the United States.[3] Another possible source of error was that the infectious diseases physician who applied the CDC criteria was aware that suspected cases had already been identified by computer algorithm or by clinicians, thereby possibly biasing his assessment.

The incorporation of ventilator-change criteria into the algorithm makes the detection of cases of VAP contingent on clinicians' ventilator management practices. The algorithm is built on the assumption that clinicians strive to wean their patients from mechanical ventilation as soon as it is medically safe, and hence that they consistently try to stabilize or decrease ventilator settings. This is in accordance with published ventilator management guidelines.[12] A new increase in ventilator settings after the initial 48 hours of intubation is consequently likely to be a reliable indicator of a possible complication of care. Nonetheless, the specific ventilator setting changes and thresholds selected for the algorithm could reflect the ventilator management strategies favored in our institution.

We only used a single reading of patients' ventilator settings each day, as recorded by respiratory therapists on their routine daily rounds. Ventilator settings can fluctuate over the course of a day, and a single daily reading might not be an accurate reflection of a patient's oxygenation status. We looked for patients with a sustained increase in ventilator settings that persisted for 48 hours or more, however, because VAP is known to significantly extend the duration of mechanical ventilation.[13] The algorithm proved robust, even though it was used in 5 different ICUs where both medical and surgical patients were cared for by many different clinicians.

Widespread implementation of this algorithm might be limited by the breadth of data captured by other hospitals' information systems. The algorithm was predicated on leveraging a rich set of electronic clinical data that are not available in many hospitals. Institutions that wish to adopt this surveillance strategy will need electronic access to data on daily readings of ventilator settings, patients' temperature and white blood cell counts, pulmonary secretion Gram stain results, chest radiographic findings, and monthly totals ventilator-days. Finally, this surveillance algorithm suffers from the same defects as other clinical measures for VAP insofar as clinical signs for VAP have been shown to correlate poorly with histologic findings.[14]

This new strategy for VAP surveillance using electronic data has performance criteria that appear comparable to the traditional surveillance methods recommended by the CDC, but it has the advantages of being less labor intensive and less subject to observer variability. This approach warrants further evaluation to better characterize its sensitivity and specificity, as well as the feasibility of implementing this surveillance algorithm in other institutions.

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