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Automated Surveillance for Ventilator-Associated Events

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BACKGROUND: The US Centers for Disease Control and Prevention has implemented a new, multitiered definition for ventilator-associated events (VAEs) to replace their former definition of ventilator-associated pneumonia (VAP). We hypothesized that the new definition could be implemented in an automated, efficient, and reliable manner using the electronic health record and that the new definition would identify different patients than those identified under the previous definition.

METHODS: We conducted a retrospective cohort analysis using an automated algorithm to analyze all patients admitted to the ICU at a single urban, tertiary-care hospital from 2008 to 2013.

RESULTS: We identified 26,466 consecutive admissions to the ICU, 10,998 (42%) of whom were mechanically ventilated and 675 (3%) of whom were identified as having any VAE. Any VAE was associated with an adjusted increased risk of death (OR, 1.91; 95% CI, 1.53-2.37; $P < .0001$). The automated algorithm was reliable (sensitivity of 93.5%, 95% CI, 77.2%-98.8%; specificity of 100%, 95% CI, 98.8%-100% vs a human abstractor). Comparison of patients with a VAE and with the former VAP definition yielded little agreement ($\kappa = 0.06$).

CONCLUSIONS: A fully automated method of identifying VAEs is efficient and reliable within a single institution. Although VAEs are strongly associated with worse patient outcomes, additional research is required to evaluate whether and which interventions can successfully prevent VAEs.

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ABBREVIATIONS: CDC = Centers for Disease Control and Prevention; IVAC = infection-related ventilator-associated complication; NHSN = National Healthcare Safety Network; PNEU = pneumonia; SOFA = Sepsis-Related Organ Failure Assessment; VAC = ventilator-associated condition; VAE = ventilator-associated event; VAP = ventilator-associated pneumonia

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In 2013, the US Centers for Disease Control and Prevention (CDC) put forth new definitions for ventilator-associated events (VAEs), the result of a collaboration of the Critical Care Societies Collaborative, the American Association for Respiratory Care, the Association of Professionals in Infection Control and Epidemiology, the Council of State and Territorial Epidemiologists, the Healthcare Infection Control Practices Advisory Committee, the Infectious Diseases Society of America, and the Society for Healthcare Epidemiology of America, among others.[1] The new definition replaced the previous National Healthcare Safety Network (NHSN) definitions for ventilator-associated pneumonia (VAP) in adults.

The previous definitions were criticized for their lack of reliability and validity[2-6] primarily because of the subjective nature of several of the necessary elements, such as "change in character of sputum" and radiology interpretation.[5] These made the prior VAP definition difficult to use in surveillance, in research, and as a measure for pay-for-performance metrics and hospital assessment. Given the substantial mortality, morbidity, and cost attributed to the clinical entity of VAP,[7-11] however, there was considerable clinical, public health, and governmental interest[12] to measure and report VAP as a hospital benchmark.

The new NHSN definition corrects many of the shortcomings of the earlier definition. First, it creates a taxonomy of iatrogenic ventilator complications, differentiating between all iatrogenic ventilator-related injuries and infectious ones. Second, the new definition relies on concrete, discrete changes in vital signs, ventilator settings, and culture data, making it possible to automate the surveillance process. Third, the CDC removed subjective and problematic components of the previous definition, including the evaluation of radiology and change in the character of sputum, among others.

First, we hypothesized that an automated assessment of the new NHSN definition could be reliably implemented using existing hospital databases. Second, we sought to compare patients with VAEs to those patients who did not develop these events. Finally, we anticipated that the patients who had met the previous definition for VAP would be different from those patients identified under the new definition.

Materials and Methods

Setting

The study was performed at the Beth Israel Deaconess Medical Center, a tertiary care, urban hospital in Boston, Massachusetts, with >70 intensive care beds in nine ICUs. The study was reviewed by the hospital's institutional review board and was granted a waiver of informed consent (protocol number 2013-P000062).

Study Design and Data Sources

All patients aged ≥ 18 years admitted to any of the hospital's nine ICUs from July 1, 2008, to March 31, 2013, were included in the study. We extracted prospectively collected patient-level data from the detailed electronic medical record at our institution. We extracted age, race, sex, comorbidities defined using the Elixhauser method,[13] patient-level case mix,[14] severity of illness measured using the Sepsis-Related Organ Failure Assessment (SOFA),[15] medication use using pharmacy charges, ventilator use based on electronic medical record documentation, admission source (same-day surgery, ED, or other), emergent admissions, hospital disposition (home with or without services vs any other disposition), length of stay (discharge date minus admission date plus one), and in-hospital mortality (defined as any in-hospital death, including those associated with do-not-resuscitate orders or aggressive comfort care).

Primary Independent Variable

The primary independent variable of interest, VAE, was defined using CDC's NHSN new definitions.[1] We developed electronic algorithms to extract each of the four levels of the new definition: ventilator-associated condition (VAC), infection-related VAE (IVAC), possible VAP, and probable VAP. The algorithm by which patients were identified and the data abstracted are outlined in e-Figure 1, as is greater detail on the VAE definitions (e-Fig 2). The algorithm assigned each patient as having one of the four categories of VAE or no VAE. We then validated the output of the algorithm against cases that were manually categorized by a nurse with >5 years' experience in abstracting NHSN VAP cases (J. G.) using a convenience sample of months; the human reviewer used the CDC calculator for VAE[16] to ensure categorization consistent with the federal surveillance definition.

Outcomes

The primary outcome of interest was in-hospital mortality. Secondary outcomes included hospital length of stay, ICU length of stay, and likelihood of returning home rather than dying or going to a rehabilitation or extended-care facility. The outcomes of patients with VAE were compared with patients who were mechanically ventilated for at least 4 days but who did not develop VAE. This comparison group was chosen because patients who are ventilated for <4 days cannot, by definition, have a VAE. They must have 2 days of mechanical ventilation followed by a worsening in positive end-expiratory pressure or F_{IO_2} sustained for 2 days, for 4 total days of mechanical ventilation. We also assessed the relationship between VAE and the former definition of VAP (the pneumonia [PNEU] definition) over this same time period. As part of routine ICU operations, we had previously prospectively identified VAP using NHSN's former definitions. For logistical reasons, this surveillance included only 7 months of each calendar year and only four ICUs. As a result, we included only these ICUs and months in the analysis comparing VAE and the former definition of VAP. VAC (or any VAE) was chosen as the comparator group to patients who met the PNEU surveillance definition of VAP, as these rates are reported to the CDC currently.

Statistical Analysis

The unit of analysis was hospital admission. Estimates of the validity of the electronic algorithm as compared with the human abstractor are presented in terms of the sensitivity, specificity, and accuracy of the algorithm. When the algorithm's result differed from the human abstractor's, we performed chart review to evaluate the reason. Cohen's κ was used to compare agreement between patients identified as having VAE and as having VAP under the prior federal definition. Estimates of