Incidence and Characteristics of Ventilator-Associated Events Reported to the National Healthcare Safety Network in 2014*

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Objective: Ventilator-associated event surveillance was introduced in the National Healthcare Safety Network in 2013, replacing surveillance for ventilator-associated pneumonia in adult inpatient locations. We determined incidence rates and characteristics of ventilator-associated events reported to the National Healthcare Safety Network.

Design, Setting, and Patients: We analyzed data reported from U.S. healthcare facilities for ventilator-associated events that occurred in 2014, the first year during which ventilator-associated event surveillance definitions were stable. We used negative binomial regression modeling to identify healthcare facility and inpatient location characteristics associated with ventilator-associated events. We calculated ventilator-associated event incidence rates, rate distributions, and ventilator utilization ratios in critical care and noncritical care locations and described event characteristics.

Measurements and Main Results: A total of 1,824 healthcare facilities reported 32,772 location months of ventilator-associated event surveillance data to the National Healthcare Safety Network in 2014. Critical care unit pooled mean ventilator-associated event incidence rates ranged from 2.00 to 11.79 per 1,000 ventilator days, whereas noncritical care unit rates ranged from 0 to 14.86 per 1,000 ventilator days. The pooled mean proportion of ventilator-associated events defined as infection-related varied from 15.38% to 47.62% in critical care units. Pooled mean ventilator utilization ratios in critical care units ranged from 0.24 to 0.47.

Conclusions: We found substantial variability in ventilator-associated event incidence, proportions of ventilator-associated events characterized as infection-related, and ventilator utilization within and among location types. More work is needed to understand the preventable fraction of ventilator-associated events and identify patient care strategies that reduce ventilator-associated events. (Crit Care Med; 44:2154–2162)

Key Words: critical care; nosocomial infections; pneumonia, ventilator associated; public health surveillance; ventilators, mechanical

Ventilator-associated pneumonia (VAP) has long been recognized as a patient safety threat. The Centers for Disease Control and Prevention (CDC) began conducting VAP surveillance in U.S. healthcare facilities in the 1970s: first in the National Nosocomial Infections Surveillance system (NNIS) and then in the National Healthcare Safety Network (NHSN) from 2006 to the present. NNIS and NHSN VAP surveillance definitions and methods were developed for use by hospitals in internal quality improvement efforts, years before the advent of state healthcare-associated infection (HAI) public reporting mandates and federal pay-for-reporting and -performance programs. Public reporting and federal incentive programs highlighted the limitations of VAP diagnostic criteria (1, 2), spurring development of a more objective and potentially automatable approach to public health surveillance for ventilator-associated conditions (VAC) and complications.
This approach, termed “ventilator-associated event” (VAE) surveillance, was designed to capture an array of noninfection- and infection-related events in patients receiving mechanical ventilation and was implemented in NHSN in January 2013 for use in adult patients (3). VAE definitions were not designed to replace VAP as a clinical entity nor to be used in the clinical care of individual patients, and some studies, not surprisingly, have shown that there is poor correlation between VAEs and events detected by traditional VAP definitions (https://shea.confex.com/sheaweb2011/webprogram/Paper4111.html) (4–7).

Between 2013 and 2014, based on feedback from NHSN users and input from an expert working group, several changes to the VAE definitions were made. The first full year of surveillance using stable definitions occurred in 2014. We analyzed VAE data reported to NHSN according to the surveillance protocol to determine incidence rates and describe event characteristics.

**MATERIALS AND METHODS**

**Data Source and Definitions**

We analyzed VAE data reported to NHSN with event dates in 2014, using data reported through May 2015. Users are able to update their NHSN data at any time, and analyses of datasets from later months may yield slightly different results. In 2014, participation in VAE surveillance was limited to adult inpatient locations in acute care hospitals, long-term acute care hospitals (LTACHs), and inpatient rehabilitation facilities, and surveillance was voluntary. Among states, only Pennsylvania had a VAE reporting mandate, and VAE was not included in federal pay-for-reporting or -performance programs. We included VAEs and denominator data from locations that reported both numerator and denominator data during at least 1 month of 2014 in accordance with the NHSN surveillance protocol. This project was determined to be nonresearch public health surveillance by CDC.

**Incidence and Event Characteristics**

VAE surveillance definitions identify three syndromes: VAC, infection-related ventilator-associated complications (IVAC), and possible or probable ventilator-associated pneumonias (PoVAP or PrVAP; combined in 2015 into a single possible VAP [PVAP] definition) (Supplemental Material, Supplemental Digital Content 1, http://links.lww.com/CCM/B934). We determined rates of overall VAE (i.e., all events meeting at least the VAC definition) and IVAC-plus (i.e., all events meeting at least the IVAC definition) per 1,000 ventilator days. Data were analyzed in SAS version 9.3 (SAS Institute, Cary, NC). VAE rates were first stratified based on NHSN inpatient location type (http://www.cdc.gov/nhsn/PDFs/pscmanual/16pstkterms_current.pdf), which has been a standard approach for reporting NHSN device-associated event data (8). To determine whether these location types should be further stratified, we used negative binomial regression modeling to explore additional variables, including facility medical school affiliation and postgraduate medical training program type (for cardiac, medical, medical-surgical, cardiothoracic surgical, and surgical ICUs) and unit bed size (for medical-surgical ICUs without major teaching affiliations). Facility medical training program types are defined in NHSN documentation (http://www.cdc.gov/nhsn/pdfs/pscmanual/16pstkterms_current.pdf). The final model was selected based on parsimony and goodness of fit using the Akaike Information Criterion, Bayesian Information Criterion, and $R^2$ statistics; multiple comparison-adjusted $p$ values less than 0.05 were considered statistically significant. For location type strata with greater than or equal to five units reporting VAE data in 2014, we calculated pooled mean overall VAE and IVAC-plus incidence rates and ventilator utilization ratios (VURs, total number of ventilator days divided by the total number of patient days). We calculated overall VAE and IVAC-plus rate distributions and VUR distributions for location type strata with greater than or equal to 20 units reporting greater than or equal to 50 ventilator days (or $\geq 50$ patient days, for VUR) in 2014.

Characteristics of VAEs, including patient age, sex, proportions of patients with VAE who died, and times to events, were determined. Differences in time to event medians and distributions were tested for statistical significance using Mood median test and Kuiper empirical distribution function. We also described the pathogens reported for PoVAP and PrVAP, including methicillin-resistant Staphylococcus aureus (MRSA) and selected carbapenem-resistant Gram-negative bacteria (Supplemental Material, Supplemental Digital Content 1, http://links.lww.com/CCM/B934).

**RESULTS**

**Healthcare Facilities and Locations**

In 2014, 3,207 units in 1,824 healthcare facilities submitted 32,772 adult location months of VAE data. Facilities participating in VAE surveillance were general acute care hospitals (1,588; 87.06%), LTACHs (110; 6.03%), critical access (69; 3.78%), military (27; 1.48%), and surgical hospitals (10; 0.55%). Twenty hospitals (1.10%) were other types. Common location types were medical/surgical (1,478; 46.09%), medical (383; 11.94%), and surgical cardiothoracic critical care units (232; 7.23%).

**VAE and IVAC-Plus Incidence**

VAE and IVAC-plus rates were calculated for noncritical care and critical care location types. Based on modeling results (Supplemental Material, Supplemental Digital Content 1, http://links.lww.com/CCM/B934), medical, medical-surgical, and surgical critical care units were further stratified according to academic affiliation (major teaching affiliation vs other or no affiliation), and medical-surgical critical care units with nonmajor teaching affiliations were further stratified by unit bed size ($> 15$ vs $\leq 15$ beds) (Tables 1 and 2).

Among critical care units, locations with the highest pooled mean rates per 1,000 ventilator days were trauma (11.79) and neurology (8.92) critical care units. Locations with the lowest
### TABLE 1. Overall Ventilator-Associated Event Incidence Rates, by Healthcare Facility Location Type, 2014

| Location Type                                | No. of Locationsa | No. of Events | Ventilator Days | Pooled Mean | Percentileb, % | 10  | 25  | 50  | 75  | 90  |
|----------------------------------------------|-------------------|---------------|-----------------|-------------|----------------|-----|-----|-----|-----|-----|
| **Critical care units**                      |                   |               |                 |             |                |     |     |     |     |     |
| Burn                                         | 36 (34)           | 125           | 19,087          | 6.55        | 0.00           | 0.94| 6.52| 12.84| 18.07|
| Medical cardiac                              | 185 (181)         | 1,028         | 160,389         | 6.41        | 0.00           | 0.63| 5.45| 10.13| 13.61|
| Surgical cardiothoracic                      | 232 (231)         | 1,457         | 236,350         | 6.16        | 0.00           | 0.84| 4.93| 8.68 | 12.79|
| Long-term acute care                         | 18 (18)           | 34            | 16,968          | 2.00        |                |     |     |     |     |     |
| Medical: major teaching                      | 143 (142)         | 2,324         | 269,448         | 8.63        | 1.19           | 4.20| 7.73| 11.78| 15.15|
| Medical: nonmajor teaching                   | 240 (212)         | 1,217         | 211,264         | 5.76        | 0.00           | 0.00| 3.37| 8.13 | 11.24|
| Medical/surgical: major teaching             | 222 (216)         | 2,613         | 336,602         | 7.76        | 0.00           | 2.50| 6.41| 10.93| 14.33|
| Medical/surgical: nonmajor teaching, ≤ 15 beds| 846 (701)         | 1,843         | 411,695         | 4.48        | 0.00           | 0.00| 1.10| 6.12 | 10.31|
| Medical/surgical: nonmajor teaching, > 15 beds| 410 (408)         | 3,717         | 711,915         | 5.22        | 0.00           | 0.74| 4.05| 7.64 | 10.60|
| Neurologic                                   | 25 (25)           | 228           | 25,574          | 8.92        | 1.16           | 3.14| 8.60| 12.29| 19.23|
| Neurosurgical                                | 99 (99)           | 955           | 115,225         | 8.29        | 0.00           | 3.13| 6.66| 12.86| 19.44|
| Oncology medical/surgical                    | 7 (6)             | 13            | 5,028           | 2.59        |                |     |     |     |     |     |
| Respiratory                                  | 5 (5)             | 21            | 5,925           | 3.54        |                |     |     |     |     |     |
| Surgical: major teaching                     | 106 (106)         | 1,351         | 152,512         | 8.86        | 0.50           | 3.78| 9.01| 12.20| 16.19|
| Surgical: nonmajor teaching                  | 80 (77)           | 476           | 84,383          | 5.64        | 0.00           | 1.20| 3.58| 8.35 | 12.45|
| Trauma                                       | 83 (82)           | 1,615         | 136,924         | 11.79       | 2.07           | 5.71| 10.95| 16.26| 21.45|
| **Inpatient wards**                          |                   |               |                 |             |                |     |     |     |     |     |
| Long-term acute care                         | 118 (114)         | 143           | 163,611         | 0.87        | 0.00           | 0.00| 0.00| 0.82 | 2.99 |
| Medical                                      | 52 (32)           | 51            | 15,236          | 3.35        | 0.00           | 0.00| 0.00| 3.64 | 8.55 |
| Medical/surgical                            | 65 (38)           | 53            | 21,646          | 2.45        | 0.00           | 0.00| 0.00| 1.97 | 6.06 |
| Hematopoietic stem cell transplant           | 6 (4)             | 16            | 1,077           | 14.86       |                |     |     |     |     |     |
| Pulmonary                                    | 13 (10)           | 36            | 8,582           | 4.19        |                |     |     |     |     |     |
| Rehabilitation                               | 6 (4)             | 1             | 1,019           | 0.98        |                |     |     |     |     |     |
| Surgical                                     | 15 (2)            | 0             | 351             | 0.00        |                |     |     |     |     |     |
| Telemetry                                    | 12 (9)            | 0             | 2,704           | 0.00        |                |     |     |     |     |     |
| Adult step-down units                        | 124 (94)          | 239           | 50,319          | 4.75        | 0.00           | 0.00| 0.00| 4.59 | 9.95 |
| Adult mixed acuity units                     | 33 (26)           | 133           | 16,728          | 7.95        | 0.00           | 0.00| 4.78| 9.15 | 15.18|

*aNumbers in parentheses represent the total number of units reporting ≥ 50 ventilator days in 2014.

bPercentile distributions shown for locations with ≥ 20 units reporting ≥ 50 ventilator days in 2014.
# TABLE 2. Incidence Rates of Events Meeting the Infection-Related Ventilator-Associated Complications, Possible Ventilator-Associated Pneumonia, or Probable Ventilator-Associated Pneumonia Definitions (Infection-Related Ventilator-Associated Complication-Plus), by Healthcare Facility Location Type, 2014

| Location Type                           | No. of Locations\(^a\) | No. of Events | Ventilator Days | Pooled Mean | Percentile\(^b\), % |
|-----------------------------------------|-------------------------|---------------|-----------------|-------------|---------------------|
|                                         |                         |               |                 | 10          | 25                  | 50   | 75  | 90   |
| Critical care                           |                         |               |                 |             |                     |
| Burn                                    | 36 (34)                 | 56            | 19,087          | 2.93        | 0.00  | 1.24  | 6.29  | 10.46 |
| Medical cardiac                         | 185 (181)               | 326           | 160,389         | 2.03        | 0.00  | 1.42  | 3.18  | 5.06  |
| Surgical cardiothoracic                 | 232 (231)               | 574           | 236,350         | 2.43        | 0.00  | 1.46  | 3.44  | 5.65  |
| Long-term acute care                    | 18 (18)                 | 15            | 16,968          | 0.88        | --    | --    | --    | --    |
| Medical: major teaching                 | 143 (142)               | 793           | 269,448         | 2.94        | 0.00  | 1.14  | 2.34  | 4.12  | 5.84  |
| Medical: nonmajor teaching              | 240 (212)               | 421           | 211,264         | 1.99        | 0.00  | 0.94  | 2.40  | 4.27  |
| Medical/surgical: major teaching        | 222 (216)               | 943           | 336,602         | 2.80        | 0.00  | 2.01  | 3.97  | 5.61  |
| Medical/surgical: nonmajor teaching, ≤15 beds | 846 (701)               | 593           | 411,695         | 1.44        | 0.00  | 0.00  | 1.87  | 3.91  |
| Medical/surgical: nonmajor teaching, >15 beds | 410 (408)               | 1,293         | 711,915         | 1.82        | 0.00  | 1.10  | 2.67  | 4.34  |
| Neurologic                              | 25 (25)                 | 96            | 25,574          | 3.75        | 0.00  | 1.77  | 5.98  | 8.24  |
| Neurosurgical                           | 99 (99)                 | 397           | 115,225         | 3.45        | 0.00  | 0.90  | 2.46  | 5.30  | 7.16  |
| Oncology medical/surgical               | 7 (6)                   | 2             | 5,028           | 0.40        | --    | --    | --    | --    |
| Respiratory                             | 5 (5)                   | 10            | 5,925           | 1.69        | --    | --    | --    | --    |
| Surgical: major teaching                | 106 (106)               | 526           | 152,512         | 3.45        | 0.00  | 0.59  | 2.98  | 5.57  | 7.41  |
| Surgical: nonmajor teaching             | 80 (77)                 | 200           | 84,383          | 2.37        | 0.00  | 1.38  | 2.96  | 6.40  |
| Trauma                                  | 83 (82)                 | 748           | 136,924         | 5.46        | 0.31  | 2.64  | 4.21  | 8.32  | 11.23 |
| Inpatient wards                         |                         |               |                 |             |                     |
| Long-term acute care                    | 118 (114)               | 64            | 163,611         | 0.39        | 0.00  | 0.00  | 0.00  | 0.00  | 1.51  |
| Medical                                 | 52 (32)                 | 14            | 15,236          | 0.92        | 0.00  | 0.00  | 0.00  | 0.00  | 2.78  |
| Medical/surgical                        | 65 (38)                 | 9             | 21,646          | 0.42        | 0.00  | 0.00  | 0.00  | 0.00  | 1.49  |
| Hematopoietic stem cell transplant      | 6 (4)                   | 3             | 1,077           | 2.79        | --    | --    | --    | --    |
| Pulmonary                                | 13 (10)                 | 7             | 8,582           | 0.82        | --    | --    | --    | --    |
| Rehabilitation                          | 6 (4)                   | 0             | 1,019           | 0.00        | --    | --    | --    | --    |
| Surgical                                | 15 (2)                  | 0             | 351             | 0.00        | --    | --    | --    | --    |
| Telemetry                               | 12 (9)                  | 0             | 2,704           | 0.00        | --    | --    | --    | --    |
| Adult step-down units                   | 124 (94)                | 75            | 50,319          | 1.49        | 0.00  | 0.00  | 1.15  | 4.01  |
| Adult mixed acuity units                | 33 (26)                 | 46            | 16,728          | 2.75        | 0.00  | 0.00  | 0.94  | 3.37  | 8.77  |

\(^a\)Numbers in parentheses represent the total number of units reporting ≥50 ventilator days in 2014.

\(^b\)Percentile distributions shown for location type strata with ≥20 units reporting ≥50 ventilator days in 2014.
**TABLE 3. Percentages of Ventilator-Associated Events Comprised of Infection-Related Ventilator-Associated Complication-Plus Events, by Healthcare Facility Location Type, 2014**

| Location Type                           | No. of Locations* | No. of Infection-Related Ventilator-Associated Complication-Plus Events | No. of Ventilator-Associated Events | Pooled Mean Percentageb | 10  | 25  | 50  | 75  | 90  |
|----------------------------------------|-------------------|------------------------------------------------------------------------|-------------------------------------|--------------------------|-----|-----|-----|-----|-----|
| Critical care                          |                   |                                                                        |                                     |                          |     |     |     |     |     |
| Burn                                   | 36 (34)           | 56                                                                     | 125                                 | 44.80                    | 0.00| 12.50| 46.43| 62.50| 100.00 |
| Medical cardiac                        | 185 (181)         | 326                                                                    | 1,028                               | 31.71                    | 0.00| 14.29| 28.57| 50.00| 66.67  |
| Surgical cardiothoracic                | 232 (231)         | 574                                                                    | 1,457                               | 39.40                    | 0.00| 15.59| 40.00| 53.33| 100.00 |
| Long-term acute care                   | 18 (18)           | 15                                                                     | 34                                  | 44.12                    |     |     |     |     |       |
| Medical: major teaching                | 143 (142)         | 793                                                                    | 2,324                               | 34.12                    | 10.71| 14.29| 28.57| 50.00| 66.67  |
| Medical: nonmajor teaching             | 240 (212)         | 421                                                                    | 1,217                               | 34.59                    | 0.00| 16.67| 33.33| 50.00| 100.00 |
| Medical/surgical: major teaching       | 222 (216)         | 943                                                                    | 2,613                               | 36.09                    | 0.00| 21.11| 33.33| 50.00| 66.67  |
| Medical/surgical: nonmajor teaching, ≤15 beds | 846 (701)   | 593                                                                    | 1,843                               | 32.18                    | 0.00| 0.00 | 30.00| 50.00| 100.00 |
| Medical/surgical: nonmajor teaching, >15 beds | 410 (408)   | 1,293                                                                  | 3,717                               | 34.79                    | 0.00| 16.67| 33.33| 50.00| 80.00  |
| Neurologic                             | 25 (25)           | 96                                                                     | 228                                 | 42.11                    | 0.00| 0.00 | 27.27| 50.00| 69.23  |
| Neurosurgical                          | 99 (99)           | 397                                                                    | 955                                 | 41.57                    | 0.00| 25.00| 39.74| 58.65| 100.00 |
| Oncology medical/surgical              | 7 (6)             | 2                                                                      | 13                                  | 15.38                    |     |     |     |     |       |
| Respiratory                            | 5 (5)             | 10                                                                     | 21                                  | 47.62                    |     |     |     |     |       |
| Surgical: major teaching               | 106 (106)         | 526                                                                    | 1,351                               | 38.93                    | 0.00| 23.53| 38.59| 50.00| 62.50  |
| Surgical: nonmajor teaching            | 80 (77)           | 200                                                                    | 476                                 | 42.02                    | 0.00| 26.79| 43.25| 53.39| 87.50  |
| Trauma                                 | 83 (82)           | 748                                                                    | 1,615                               | 46.32                    | 28.57| 35.00| 48.65| 60.00| 72.00  |
| Inpatient wards                        |                   |                                                                        |                                     |                          |     |     |     |     |       |
| Long-term acute care                   | 118 (114)         | 64                                                                     | 143                                 | 44.76                    | 0.00| 0.00 | 45.00| 100.00| 100.00 |
| Medical                                | 52 (32)           | 14                                                                     | 51                                  | 27.45                    | 0.00| 0.00 | 29.09| 50.00| 83.33  |
| Medical/surgical                       | 65 (38)           | 9                                                                     | 53                                  | 16.98                    | 0.00| 0.00 | 33.33| 100.00|       |
| Hematopoietic stem cell transplant     | 6 (4)             | 3                                                                     | 16                                  | 18.75                    |     |     |     |     |       |
| Pulmonary                              | 13 (10)           | 7                                                                     | 36                                  | 19.44                    |     |     |     |     |       |
| Rehabilitation                         | 6 (4)             | 0                                                                     | 1                                   | 0.00                     |     |     |     |     |       |
| Surgical                               | 15 (2)            | 0                                                                     | 0                                   |     |     |     |     |       |
| Telemetry                              | 12 (9)            | 0                                                                     | 0                                   |     |     |     |     |       |
| Adult step-down units                  | 124 (94)          | 75                                                                     | 239                                 | 31.38                    | 0.00| 0.00 | 27.21| 50.00| 100.00 |
| Adult mixed acuity units               | 33 (25)           | 46                                                                     | 133                                 | 34.59                    | 0.00| 15.38| 33.33| 50.00| 100.00 |

*Numbers in parentheses represent the total number of units reporting ≥ 50 ventilator days in 2014.

bPooled mean percentage of infection-related ventilator-associated complication (IVAC)-plus events = (No. of IVAC-plus/No. of overall ventilator-associated events) × 100.

Percentile distributions shown for locations with ≥ 20 units reporting ≥ 50 ventilator days in 2014.
rates per 1,000 ventilator days were LTACH (2.00) and oncology medical-surgical (2.59) critical care units. Among noncritical care units, the highest rates were in hematopoietic stem cell transplant (14.86) and mixed acuity units (7.95), whereas the lowest rates were in surgical and telemetry wards (with no reported VAEs). IVAC-plus rates largely mirrored overall VAE rates (Table 2).

The proportion of VAEs that were IVAC-plus varied among and within location types (Table 3). Among critical care location types, those with the highest proportion of IVAC-plus events were respiratory critical care units, where the pooled mean percentage was 47.62%. By contrast, the critical care locations with the lowest proportion of IVAC-plus events (15.38%) were oncology medical-surgical critical care units. Within individual location types, the proportion of IVAC-plus events varied widely: for example, from 0% in some medical critical care units to 100% in others.

### TABLE 4. Ventilator Utilization Ratios, by Healthcare Facility Location Type, 2014

| Location Type                      | No. of Locations | Ventilator Days | Patient Days | Pooled Mean | Percentile a, %  |
|------------------------------------|------------------|-----------------|--------------|-------------|-----------------|
|                                    |                  |                 |              |             | 10   | 25   | 50   | 75   | 90   |
| Critical care                      |                  |                 |              |             |      |      |      |      |      |
| Burn                               | 36 (36)          | 19,087          | 79,163       | 0.24        | 0.09 | 0.17 | 0.21 | 0.33 | 0.42 |
| Medical cardiac                    | 185 (185)        | 160,389         | 614,321      | 0.26        | 0.12 | 0.18 | 0.25 | 0.35 | 0.43 |
| Surgical cardiothoracic            | 232 (232)        | 236,350         | 736,590      | 0.32        | 0.14 | 0.20 | 0.28 | 0.39 | 0.49 |
| Long-term acute care               | 18 (18)          | 16,968          | 55,281       | 0.31        |      |      |      |      |      |
| Medical: major teaching            | 143 (143)        | 269,448         | 605,647      | 0.44        | 0.25 | 0.36 | 0.45 | 0.54 | 0.61 |
| Medical: nonmajor teaching         | 240 (237)        | 211,264         | 615,223      | 0.34        | 0.08 | 0.18 | 0.30 | 0.42 | 0.52 |
| Medical/surgical: major teaching   | 222 (221)        | 336,602         | 879,742      | 0.38        | 0.16 | 0.26 | 0.37 | 0.46 | 0.54 |
| Medical/surgical: nonmajor teaching, ≤ 15 beds | 846 (822) | 411,695         | 1,580,000    | 0.26        | 0.05 | 0.11 | 0.21 | 0.33 | 0.45 |
| Medical/surgical: nonmajor teaching, > 15 beds | 410 (410) | 711,915         | 2,190,000    | 0.32        | 0.18 | 0.25 | 0.34 | 0.42 | 0.50 |
| Neurologic                         | 25 (25)          | 25,574          | 73,069       | 0.35        | 0.19 | 0.31 | 0.34 | 0.39 | 0.44 |
| Neurosurgical                      | 99 (99)          | 115,225         | 368,353      | 0.31        | 0.17 | 0.23 | 0.32 | 0.40 | 0.46 |
| Oncology medical/surgical          | 7 (7)            | 5,028           | 16,696       | 0.30        |      |      |      |      |      |
| Respiratory                        | 5 (5)            | 5,925           | 20,258       | 0.29        |      |      |      |      |      |
| Surgical: major teaching           | 106 (106)        | 152,512         | 402,782      | 0.38        | 0.24 | 0.30 | 0.38 | 0.47 | 0.54 |
| Surgical: nonmajor teaching        | 80 (79)          | 84,383          | 235,738      | 0.36        | 0.19 | 0.27 | 0.35 | 0.41 | 0.50 |
| Trauma                             | 83 (82)          | 136,924         | 291,852      | 0.47        | 0.34 | 0.40 | 0.46 | 0.52 | 0.57 |

Inpatient wards

| Location Type                      | No. of Locations | Ventilator Days | Patient Days | Pooled Mean | Percentile a, %  |
|------------------------------------|------------------|-----------------|--------------|-------------|-----------------|
|                                    |                  |                 |              |             | 10   | 25   | 50   | 75   | 90   |
| Long-term acute care               | 118 (118)        | 163,611         | 794,483      | 0.21        | 0.06 | 0.09 | 0.19 | 0.28 | 0.45 |
| Medical                            | 52 (52)          | 15,236          | 294,965      | 0.05        | 0.00 | 0.00 | 0.03 | 0.05 | 0.07 |
| Medical/surgical                   | 65 (65)          | 21,646          | 379,475      | 0.06        | 0.00 | 0.01 | 0.02 | 0.05 | 0.19 |
| Hematopoietic stem cell transplant | 6 (6)            | 1,077           | 19,045       | 0.06        |      |      |      |      |      |
| Pulmonary                          | 13 (13)          | 8,582           | 75,666       | 0.11        |      |      |      |      |      |
| Rehabilitation                     | 6 (6)            | 1,019           | 19,909       | 0.05        |      |      |      |      |      |
| Surgical                           | 15 (15)          | 351             | 32,644       | 0.01        |      |      |      |      |      |
| Telemetry                          | 12 (12)          | 2,704           | 85,844       | 0.03        |      |      |      |      |      |
| Adult step-down units              | 124 (124)        | 50,319          | 572,899      | 0.09        | 0.01 | 0.02 | 0.05 | 0.13 | 0.23 |
| Adult mixed acuity units           | 33 (33)          | 16,728          | 105,178      | 0.16        | 0.03 | 0.05 | 0.12 | 0.23 | 0.36 |

aNumbers in parentheses represent the total number of units reporting ≥ 50 patient days in 2014.
bPercentile distributions shown for locations with ≥ 20 units reporting ≥ 50 patient days in 2014.
TABLE 5. Characteristics of Patients With Ventilator-Associated Events, 2014

| Characteristic | Overall Ventilator-Associated Event (n = 19,676) | Ventilator-Associated Condition Only (n = 12,474) | Infection-Related Ventilator-Associated Complication-Plus (n = 7,202) | p* |
|----------------|-----------------------------------------------|-----------------------------------------------|-------------------------------------------------|----|
| Age, median years (IQR) | 60.48 (49.51–70.44) | 61.25 (50.69–71.17) | 59.09 (47.15–69.20) | < 0.0001 |
| Male, n (%) | 12,117 (61.58) | 7,538 (60.43) | 4,579 (63.58) | < 0.0001 |
| Time to admissiona to event, median days (IQR)b | 8 (5–14) | 8 (5–14) | 8 (5–13) | < 0.0001 |
| Time from intubation to event, median days (IQR)c | 6 (4–9) | 5 (4–9) | 6 (4–9) | < 0.0001 |
| Died, n (%) | 6,094 (31.38) | 4,151 (33.65) | 1,943 (27.43) | < 0.0001 |

IQR = interquartile range.
aFor the comparison of ventilator-associated condition only to infection-related ventilator-associated complication-plus.
bAdmission dates were missing for five events.
cCalculated to include day of admission as day 1.
dMood median test and Kuiper empirical distribution function.
eCalculated to include day of intubation as day 1.
fTwo hundred fifty-eight events have missing values.
gOne hundred forty events have missing values.
hOne hundred eighteen events have missing values.

Ventilator Utilization

Ventilator utilization also varied widely (Table 4). In critical care units, the pooled mean VUR was highest in trauma (0.47) and lowest in burn critical care units (0.24). Not surprisingly, pooled mean VURs were lower in noncritical care locations, ranging from 0.01 in surgical wards to 0.21 in LTACH wards.

Event Characteristics

Of 19,714 VAEs, 19,689 were from location types with greater than or equal to five units reporting data and 25 were from location types with less than five units reporting data. Thirty-eight events were excluded because of errors in reported mechanical ventilation initiation or event dates. Among the remaining 19,676 VAEs, 12,474 (63.4%) were VACs, 4,002 (20.3%) were IVACS, and 3,200 (16.3%) were PoVAPs or PrVAPs.

Mortality among patients with VAEs was high, with approximately 31% dying during their hospitalizations (Table 5). Patients with VAC only were significantly older, less likely to be male and more likely to die during their hospitalizations than patients with IVAC-plus. Patients with VAC only tended to have event onset dates earlier in mechanical ventilation than patients with IVAC-plus. Approximately 36% of VAEs had onset dates on days 3 or 4 of mechanical ventilation. Overall, 15,458 VAEs (78.6%) had onset dates on or after ventilator day or hospital day 5.

Among the 3,200 PoVAP and PrVAP events, 3,151 pathogens were reported for 2,517 events (78.7%). Common pathogens were S. aureus (892; 28.3%), Pseudomonas aeruginosa (412; 13.1%), Klebsiella pneumoniae (249; 7.9%), Escherichia coli (188; 6.0%), and untypable Haemophilus influenzae (147; 4.7%). Among 826 tested S. aureus isolates, 308 (37.3%) were reported to be MRSA. Among 331 tested P. aeruginosa isolates, 103 (31.1%) were reported to be carbapenem resistant. Among 171 tested K. pneumoniae and 142 tested E. coli isolates, 24 (14.0%) and 0, respectively, were reported to be carbapenem resistant.

DISCUSSION

This is the first national report of VAE rates and characteristics. VAE incidence, proportions of VAEs defined as infection-related, and ventilator utilization varied within and among inpatient location types. Furthermore, VAEs occurred in patients with substantial inpatient mortality. The pathogen profile of VAEs defined as PoVAP or PrVAP was similar to previously reported traditional VAP pathogen profiles. Methicillin resistance among VAE S. aureus isolates was lower than previously reported for VAP (https://shea.confex.com/shea/2011/webprogram/Paper4109.html), and carbapenem resistance in selected Gram-negative pathogens was high: 31% in P. aeruginosa and 14% in K. pneumoniae. We did not determine whether laboratories were using revised carbapenem breakpoints for Enterobacteriaceae.

Studies have shown that most VAEs are due to pneumonia, pulmonary edema, atelectasis, and acute respiratory distress syndrome (7, 9, 10). Data suggest that some of these conditions may be prevented (11, 12), so it stands to reason that VAEs may also be prevented. Still, there is a paucity of published evidence establishing VAE preventability. This is VAE's most important limitation, and additional studies are needed. Boyer et al (7) evaluated 67 events meeting modified VAE definitions and found that most were due to the conditions above; 25 (37.3%) were deemed preventable. In a matched case-control analysis, Lewis et al (13) identified case-related factors associated with VAC, including positive fluid balance and mandatory mechanical ventilation modes, and with IVAC, including...
VTACs and IVACs are often used interchangeably; however, the definitions are quite different.

- **VTACs** (ventilator-associated conditions) are considered serious events, often related to the use of mechanical ventilation.
- **IVACs** (infectious ventilator-associated conditions) are defined as events with a high suspicion for infection, usually related to the patient’s airway.

In a study that compared the definitions of VTACs and IVACs, researchers found that the two definitions were not always consistent. This led to discrepancies in the reporting of these events, which can affect the accuracy of surveillance data.

One reason for the variability in surveillance definitions is the lack of consensus among healthcare providers on how to classify certain events. For example, patients who receive broad-spectrum antibiotics might be classified differently depending on the healthcare setting.

Another reason for the variability is the use of different definitions in different regions or countries. This can lead to inconsistencies in the reporting of surveillance data.

Despite these challenges, the use of electronic surveillance systems can help to standardize the process and improve the accuracy of surveillance data. These systems can also alert healthcare providers to potential issues in a timely manner, allowing for prompt interventions to prevent further complications.

In summary, the use of electronic surveillance systems can help to improve the accuracy and consistency of surveillance data related to VTACs and IVACs. However, ongoing research is needed to refine the definitions and improve the reliability of these systems.

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definitions, which typically arose from differences in the assessments of subjective definition criteria and was difficult to resolve, the variability in VAE detection in the Mann et al (23) study was due to readily correctable errors in applying VAC criteria. McMullen et al (24) also reported good agreement when comparing a strategy of automated VAC and IVAC detection plus manual chart review by infection preventionists for PVAPs to an approach using prospective, manual VAE surveillance by pulmonary physicians and critical care unit staff (κ, 0.81). This is better agreement than has been reported previously for traditional VAP surveillance definitions (25, 26).

CONCLUSIONS
There is an increasing need for objective, practical approaches to national HAI surveillance that facilitate valid comparisons among facilities and that lead to healthcare quality improvement. It seems likely, then, that the healthcare-associated event surveillance of the future will increasingly involve automated, electronic detection and reporting of measures that are proxies for clinical events rather than measures that hew to diagnostic approaches at the bedside, which are often too complex and subjective to be used in national surveillance. VAE surveillance is a step in that direction.

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