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ORIGINAL ARTICLE

Economic Impact of Ventilator-Associated Pneumonia in a Large Matched Cohort

Marin H. Kollef, MD;[1] Cindy W. Hamilton, PharmD;[2] Frank R. Ernst, PharmD, MS[3]

OBJECTIVE. To evaluate the economic impact of ventilator-associated pneumonia (VAP) on length of stay and hospital costs.

DESIGN. Retrospective matched cohort study.

SETTING. Premier database of hospitals in the United States.

PATIENTS. Eligible patients were admitted to intensive care units (ICUs), received mechanical ventilation for ≥2 calendar-days, and were discharged between October 1, 2008, and December 31, 2009.

METHODS. VAP was defined by *International Classification of Diseases, Ninth Revision* (ICD-9), code 997.31 and ventilation charges for ≥2 calendar-days. We matched patients with VAP to patients without VAP by propensity score on the basis of demographics, administrative data, and severity of illness. Cost was based on provider perspective and procedural cost accounting methods.

RESULTS. Of 88,689 eligible patients, 2,238 (2.5%) had VAP; the incidence rate was 1.27 per 1,000 ventilation-days. In the matched cohort, patients with VAP ($n = 2{,}144$) had longer mean durations of mechanical ventilation (21.8 vs 10.3 days), ICU stay (20.5 vs 11.6 days), and hospitalization (32.6 vs 19.5 days; all $P < .0001$) than patients without VAP ($n = 2{,}144$). Mean hospitalization costs were $99,598 for patients with VAP and $59,770 for patients without VAP ($P < .0001$), resulting in an absolute difference of $39,828. Patients with VAP had a lower in-hospital mortality rate than patients without VAP (482/2,144 [22.5%] vs 630/2,144 [29.4%]; $P < .0001$).

CONCLUSIONS. Our findings suggest that VAP continues to occur as defined by the new specific ICD-9 code and is associated with a statistically significant resource utilization burden, which underscores the need for cost-effective interventions to minimize the occurrence of this complication.

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Ventilator-associated pneumonia (VAP) is of concern because of its frequency and economic burden. Pneumonia is the most common discharge diagnosis in the United States.[1] Between 1997 and 2008, use of respiratory intubation and mechanical ventilation (MV) escalated, and the cost of respiratory failure grew at 2–3 times those of total hospital costs.[1] Cost is relevant to providers because VAP is among the conditions being considered for nonreimbursement by the Centers for Medicare and Medicaid Services.

VAP prolongs length of stay (LOS) and increases hospital costs;[2-5] however, estimates are derived from data collected between the mid-1980s and 2004 and may not reflect the impact of inflation. On the other hand, estimates may not reflect the impact of economic pressure to minimize LOS or use new preventive strategies. In addition, previous studies often relied on nonspecific diagnostic criteria, such as the use of MV and the diagnostic code for bacterial pneumonia.

We hypothesized that VAP—as defined by the specific *International Classification of Diseases, Ninth Revision*, clinical modification (ICD-9) code 997.31 introduced in 2008—would be associated with increased LOS and hospital costs. To test this hypothesis, we performed a matched cohort study of the Premier database and evaluated the impact of VAP on LOS in the hospital and intensive care unit (ICU), duration of MV, and hospital costs. We also calculated the frequency of VAP and in-hospital mortality.

METHODS

To evaluate the economic impact of VAP on hospitals, we performed a retrospective matched cohort study of the Premier research database, which involves approximately 400 of >2,500 hospitals in the Premier healthcare alliance. The study was conducted in compliance with US federal regulations, the Health Insurance Portability and Accountability Act, and the Helsinki Declaration. Patient-specific data were deidentified.

To be included in the study, adults (age ≥18 years) had to have spent at least 1 day in the ICU and to have been dis-

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TABLE 1. Demographic, Admission, and Discharge Data

Characteristic	All patients			Matched cohort		
	With VAP (N = 2,238)	Without VAP (N = 86,451)	P	With VAP (N = 2,144)	Without VAP (N = 2,144)	P
Age, years			<.0001			
18–44	459 (20.5)	11,730 (13.6)		412 (19.2)	404 (18.8)	
45–64	860 (38.4)	31,360 (36.3)		831 (38.8)	850 (39.7)	
65–79	669 (29.9)	28,515 (33.0)		653 (30.5)	651 (30.4)	
≥80	250 (11.2)	14,846 (17.2)		248 (11.6)	239 (11.2)	
Mean ± SD	62.9 ± 16.6	58.8 ± 17.5		59.3 ± 17.3	59.4 ± 17.1	
Sex, male	1,415 (63.2)	46,642 (54.0)	<.0001	1,337 (62.4)	1,335 (62.3)	
Race			<.0001			
White	1,343 (60.0)	54,351 (62.3)		1,311 (61.2)	1,332 (62.1)	
Black	432 (19.3)	13,310 (15.4)		406 (18.9)	408 (19.0)	
Hispanic	159 (7.1)	4,088 (4.7)		133 (6.2)	122 (5.7)	
Other/unknown	304 (13.6)	14,702 (17.0)		294 (13.7)	282 (13.2)	
Primary payor			<.0001			
Medicare	1,044 (46.7)	49,150 (56.9)		1,027 (47.9)	1,028 (48.0)	
Medicaid	391 (17.5)	10,402 (12.0)		364 (17.0)	363 (16.9)	
Managed care	399 (17.8)	13,185 (15.3)		383 (17.9)	397 (18.5)	
Commercial	171 (7.6)	5,176 (6.0)		159 (7.4)	150 (7.0)	
Other	233 (10.4)	8,538 (9.9)		211 (9.8)	206 (9.6)	
Admission source			<.0001			
Physician referral	329 (14.7)	13,223 (15.3)		319 (14.9)	296 (13.8)	
Transfer from another health facility	532 (23.8)	14,883 (17.2)		496 (23.1)	489 (22.8)	
Emergency room	1,293 (57.8)	57,109 (66.1)		1,257 (58.6)	1,293 (60.3)	
Other or unknown	84 (3.8)	1,236 (1.4)		72 (3.4)	66 (3.1)	
Admission type			<.0001			
Emergency	1,558 (69.6)	62,277 (72.0)		1,517 (70.8)	1,554 (72.5)	
Urgent	317 (14.2)	12,697 (14.7)		310 (14.5)	291 (13.6)	
Elective	239 (10.7)	9,348 (10.8)		226 (10.5)	209 (9.8)	
Trauma center/other/unknown	124 (5.5)	2,129 (2.5)		91 (4.2)	90 (4.2)	
Discharge status			<.0001			<.0001
Expired	498 (22.3)	25,053 (29.0)		482 (22.5)	630 (29.4)	
Transferred to home	378 (16.9)	23,177 (26.8)		356 (16.6)	561 (26.2)	
Transferred to skilled nursing facility	440 (19.7)	14,737 (17.1)		426 (19.9)	366 (17.1)	
Transferred to rehab	273 (12.2)	6,492 (7.5)		260 (12.1)	191 (8.9)	
Transferred to short-term hospital	153 (6.8)	4,409 (5.1)		149 (7.0)	82 (3.8)	
Other or unknown	496 (22.2)	12,583 (14.6)		471 (22.0)	314 (14.6)	
APR-DRG severity of illness			<.0001			
Minor or moderate	3 (0.1)	1,337 (1.5)		3 (0.1)	2 (0.1)	
Major	116 (5.2)	9,828 (11.4)		112 (5.2)	99 (4.6)	
Extreme	2,119 (94.7)	75,286 (87.1)		2,029 (94.6)	2,043 (95.3)	
APR-DRG risk of mortality			<.0001			
Minor or moderate	71 (3.2)	4,670 (5.4)		62 (2.9)	41 (1.9)	
Major	538 (24.0)	19,797 (22.9)		499 (23.3)	490 (22.9)	
Extreme	1,629 (72.8)	61,984 (71.7)		1,583 (73.8)	1,613 (75.2)	
Geographic area			<.0001			
Northeast	380 (17.0)	14,596 (16.9)		362 (16.9)	357 (16.7)	
Midwest	614 (27.4)	19,227 (22.2)		581 (27.1)	567 (26.5)	
South	969 (43.3)	37,433 (43.3)		932 (43.5)	949 (44.3)	
West	275 (12.3)	15,195 (17.6)		269 (12.6)	271 (12.6)	
Urban population	168 (7.5)	8,630 (10.0)	<.0001	1,979 (92.3)	1,980 (92.4)	
Teaching hospital	1,478 (66.0)	41,221 (47.7)	<.0001	1,388 (64.7)	1,386 (64.7)	
Hospital size, beds			<.0001			
6–199	116 (5.2)	8,099 (9.4)		114 (5.3)	108 (5.0)	
200–299	195 (8.7)	12,019 (13.9)		194 (9.1)	196 (9.1)	
300–499	752 (33.6)	33,924 (39.2)		727 (33.9)	728 (34.0)	
≥500	1,175 (52.5)	32,409 (37.5)		1,109 (51.7)	1,112 (51.9)	

NOTE. Data are number of discharges (%), unless otherwise indicated. APR-DRG, all patient refined diagnosis-related group; SD, standard deviation; VAP, ventilator-associated pneumonia.

TABLE 2. Diagnostic Codes in All Patients

MS-DRG code	Population	Abbreviated description	No. of discharges (%)	
			With VAP (N = 2,238)	Without VAP (N = 86,451)
3	ECMO or tracheostomy with mechanical ventilation ≥96 h or principal diagnosis except face, mouth, and neck with major OR	MS-DRG 3: trach with MV ≥96 h with major OR	658 (29.4)	7,005 (8.1)
4	Tracheostomy with mechanical ventilation ≥96 h or principal diagnosis except face, mouth, and neck without major OR	MS-DRG 4: trach with MV ≥96 h without major OR	372 (16.6)	6,100 (7.1)
207	Respiratory system diagnosis with ventilator support ≥96 h	MS-DRG 207: respiratory diagnosis with MV ≥96 h	232 (10.4)	9,898 (11.4)
870	Septicemia or severe sepsis with mechanical ventilation ≥96 h	MS-DRG 870: sepsis with MV ≥96 h	177 (7.9)	6,572 (7.6)
853	Infectious and parasitic diseases with OR with major complication or comorbidity	MS-DRG 853: infection with OR and major complication	47 (2.1)	2,927 (3.4)
208	Respiratory system diagnosis with ventilator support <96 h	MS-DRG 208: respiratory diagnosis with MV <96 h	39 (1.7)	9,782 (11.3)
329	Major small and large bowel procedure with major complication or comorbidity	MS-DRG 329: bowel procedure with major complication	35 (1.6)	2,480 (2.9)

NOTE. ECMO, extracorporeal membrane oxygenation; MS-DRG, Medicare severity diagnosis-related group; MV, mechanical ventilation; OR, operating room procedure; trach, tracheostomy; VAP, ventilator-associated pneumonia.

charged from the hospital between October 1, 2008, and December 31, 2009. Patients on continuous MV were identified using ICD-9 procedure codes 96.71 or 96.72; they also had to have undergone MV for ≥2 calendar-days, as defined by billing charges. VAP was defined by ICD-9 code 997.31.

Economic data were based on true hospital costs, including direct and indirect medical costs (eg, fixed, variable, and overhead costs were indirect costs from an accounting perspective); indirect costs incurred by patients and their caregivers were excluded. ICU costs were determined using room and board billing (eg, coronary care unit and surgical, medical, cardiac, and cardiovascular ICUs) and did not include step-down or telemetry units. Cost analysis proceeded from the hospital perspective. Cost data were obtained from hospital accounting systems and reported to Premier. Most hospitals used procedural cost accounting methods; ≤25% used ratios of costs to charges and total patient-level charges. Actual costs were available for each revenue department as well as for each billing item. Patient billing codes for products and services received during hospitalization were captured. In-hospital mortality was indicated by a discharge status of expired.

Statistical Analysis

Categorical data were expressed as percentages of patients; between-group differences (with vs without VAP) were compared using χ^2 or Fisher exact tests. Continuous data were expressed as means and standard deviations; between-group differences were compared using 1-way ANOVA. Statistical analyses were conducted using WinSQL (Synametrics Technologies) and SAS (ver. 9.1; SAS Institute). All statistical tests of comparison were 2 sided based on $\alpha < .05$. All analyses were conducted for the overall VAP population as well as for the 7 Medicare severity diagnosis-related groups (MS-DRGs) with the highest volume of VAP patients.

Propensity score matching was used to adjust for between-group imbalances. Logistic regression was performed to estimate the propensity score for each patient using available covariates, which were selected a priori and on the basis of ability to maximize the receiver operator characteristic curve of the selection model. Propensity scoring was used to match each case patient with VAP to 1 control patient without VAP, using a greedy algorithm,[6,7] which matches the highest digit in a hierarchical sequence until each case is matched; matching was performed at ≥4 digits. Patient characteristics used in matching were age, gender, race/ethnicity, primary payor type, attending physician specialty, admission source, admission type, 3M all patient refined (APR)-DRG severity of illness, and APR-DRG risk of mortality. Hospital characteristics were geographic region, bed size, urban/rural status, and teaching status.

Matching was conducted on the overall VAP population and on the 7 MS-DRGs with the most VAP patients. Match quality was evaluated using a quantile distribution of the propensity scores for each population as well as univariate

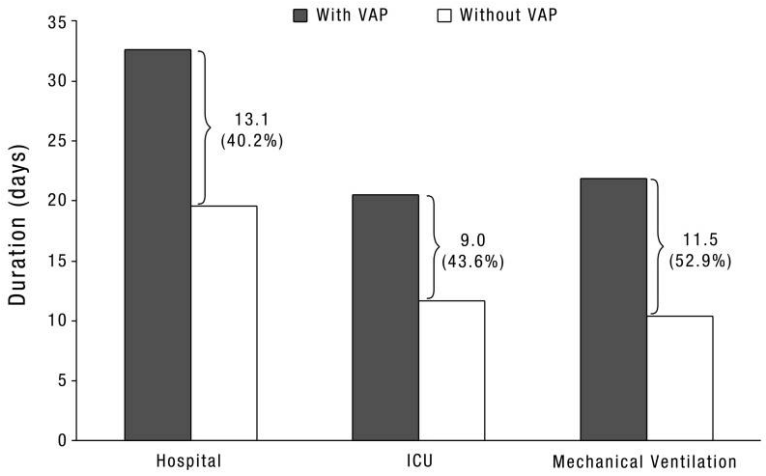

FIGURE 1. Duration of mechanical ventilation, intensive care unit (ICU) stay, and hospital stay in a matched cohort of 2,144 patients with ventilator-associated pneumonia (VAP) and 2,144 patients without VAP. All $P < .0001$ for between-cohort differences in durations of hospitalization, ICU stay, and mechanical ventilation.

ANOVA to test for between-group differences. Tests of comparison of each of patient and hospital variables were conducted using the matched population to further test between-group imbalances in covariates.

RESULTS

All Patients

Of 88,689 patients who had undergone MV for ≥2 calendar-days, 2,238 (2.5%) had the ICD-9 code for VAP. The incidence rate was 1.27 cases per 1,000 MV-days. Patients with VAP were older and more likely to be male than patients without VAP (Table 1). Patients with VAP were more likely to have been transferred from another healthcare facility and to have been discharged to skilled nursing or rehabilitation facilities. Patients with VAP represented 161 different MS-DRGs, but the 7 most common comprised 70% of all patients with VAP (Table 2). The most common in patients with VAP was MS-DRG 3 (29.4%; for descriptions of abbreviated diagnostic codes, see Table 2).

Matched Cohort

A total of 2,144 case patients with VAP were matched with 2,144 control patients without VAP, representing 96% of the VAP population. There were no between-group differences in patient or hospital characteristics except for discharge status, which was excluded from matching because mortality was an outcome of interest (see Table 1). Matching captured 86%–100% of the VAP population for the 7 MS-DRG populations.

Patients with VAP had longer durations of MV (mean ± standard deviation [SD], 21.8 ± 25.0 vs 10.3 ± 10.5 days), ICU stay (20.5 ± 15.8 vs 11.6 ± 10.3 days), and hospitalization (32.6 ± 31.9 vs 19.5 ± 17.9 days; all $P < .0001$) than patients without VAP (Figure 1). At least 1 of these 3 outcomes (duration of MV, ICU stay, or hospitalization) was longer for patients with VAP in 6 of 7 MS-DRG populations; the exception was MS-DRG 329 (authors' online Table 1 available at their Web site http://hamiltonhouseva.com/KollefVAPeconomicsICHEtables.pdf).

Patients with VAP had higher mean costs for hospitalization, pharmacy, antibiotics, vancomycin, propofol, ventilation both overall and in the ICU, respiratory therapy, and chest x-rays (Table 3). For example, mean hospitalization costs were $99,598 for patients with VAP and $59,770 for patients without VAP ($P < .0001$), resulting in an absolute difference of $39,828 between these matched cohorts. Mean hospitalization costs were higher for patients with VAP than for those without in the following MS-DRG populations: MS-DRG 4, MS-DRG 870, MS-DRG 853, and MS-DRG 207 (Table 4). Selected costs—such as those related to antibiotic use or pharmacy as a whole, MV, respiratory therapy, or chest x-rays—were also higher in patients with VAP, especially in MS-DRG 4, MS-DRG 870, and MS-DRG 853 (authors' online Table 2 available at their Web site http://hamiltonhouseva.com/KollefVAPeconomicsICHEtables.pdf).

Patients with VAP had a lower overall in-hospital mortality rate than patients without VAP (482/2,144 [22.5%] vs 630/2,144 [29.4%]; $P < .0001$; data not shown). There were no between-group differences in 30-day all-cause readmissions, excluding mortality (287/1,662 [17.3%] vs 271/1,514 [17.9%]; $P = .64$). There were no between-group differences in any of the MS-DRG populations except MS-DRG 853. In that population, patients with VAP had higher rates of mortality (19/46 [41.3%] vs 7/46 [15.2%]; $P = .01$) and 30-day all-

TABLE 3. Costs in a Matched Cohort of 2,144 Patients with Ventilator-Associated Pneumonia (VAP) and 2,144 Patients without VAP

Outcome type	Cost, dollars, mean ± SD[a]		*P*	Difference in dollars (%)
	With VAP	Without VAP		
Hospitalization	99,598 ± 86,359	59,770 ± 58,278	<.0001	39,828 (40.0)
Nursing time	3,369 ± 16,487	2,980 ± 14,109	.568	389 (11.5)
Pharmacy	14,345 ± 16,992	8,547 ± 14,497	<.0001	5,798 (40.4)
Antibiotic	1,947 ± 4,095	1,011 ± 2,039	<.0001	936 (48.1)
Vancomycin	327 ± 564	248 ± 420	<.0001	79 (24.2)
Propofol for sedation	947 ± 1,768	585 ± 1,202	<.0001	362 (38.2)
Ventilator	4,710 ± 6,251	2,184 ± 2,807	<.0001	2,526 (53.6)
Ventilator in ICU	3,716 ± 4,479	1,909 ± 2,304	<.0001	1,807 (48.6)
Respiratory therapy	2,650 ± 4,007	1,496 ± 2,539	<.0001	1,154 (43.5)
Chest x-rays	1,762 ± 1,594	1,009 ± 958	<.0001	753 (42.7)

NOTE. ICU, intensive care unit; SD, standard deviation.

[a] Costs represent medical direct and indirect costs (not Medicare charges). Costs were not additive (eg, antibiotic and propofol costs were a subset of pharmacy costs).

cause readmissions, excluding mortality (9/46 [19.6%] vs 3/46 [6.5%]; $P = .01$).

DISCUSSION

Our database analysis revealed VAP in 2.6% of 88,689 hospitalized patients who had undergone MV ≥2 calendar-days. A unique feature of our study was the analysis of VAP rate by MS-DRG population. The highest rates were 8.6% in patients with MS-DRG 3 and 5.7% in those with MS-DRG 4, which is consistent with the prolonged duration of MV in these populations (authors' online Table 1 available at their Web site http://hamiltonhouseva.com/KollefVAPeconomicsICHEtables.pdf). In patients matched by propensity scores comprising severity of illness and other possible confounders, VAP added approximately $40,000 to absolute hospital costs and at least 10 days to the absolute durations of MV, ICU stay, and overall hospitalization.

Our findings add to those of previous studies involving large databases[2,3] or literature reviews of mechanically ventilated patients;[4,5] however, differences in study methods may have affected VAP rates. Rello et al[2] reported that VAP occurred in 9.3% of 9,080 ICU patients who had undergone MV ≥24 hours and who had ICD-9 codes for bacterial pneumonia. Similarly, Safdar et al[4] reported a cumulative incidence of 9.7% in 48,112 patients in 38 cohort or nonrandomized studies, whereas the incidence was 22.8% in 4,802 patients in 51 randomized studies. Buczko[3] reported VAP in 24.5% of 13,759 Medicare patients in long-term care hospitals. These between-study differences could be attributable to differences in study populations, diagnostic criteria, use of preventive strategies, and other factors. Our low rate is consistent with the use of a VAP-specific code, which probably reduced the risk of false positive identification. Alternatively, the new diagnostic code may have had poor sensitivity.

The LOS in our study was within the range of previous studies involving large databases[2,3] or a literature review;[4] LOS was not reported in the other literature review.[5] Specifically, the 10-day additional LOS in our study was generally consistent with that in 1 of the database studies.[2] VAP added 6.1 days to the mean ICU stay in the literature review.[4] Not surprisingly, LOS was prolonged for patients in long-term care hospitals, where total LOS was 46.5 days for patients with VAP and 43.8 days for patients without VAP.[3]

The incremental hospital cost of VAP was higher in our study than in previous studies. VAP was associated with attributable hospital costs of $10,000–$13,500 per 5–7 days in a review of studies conducted between 1984 and 2002.[4] In the remaining studies, VAP was associated with additional charges of approximately $15,000 in long-term care patients in 2004[3] and of $40,000 in the database analysis conducted in the late 1990s.[2] These between-study differences are attributable to timing differences, with inflation contributing to the higher cost in our more recent study. In addition, charges in 2 studies[2,3] are inherently higher than costs in our study and in another study.[4]

Another unique feature of our study was the breakdown of costs for expense categories. Many costs were higher among patients with VAP than among patients without VAP, especially pharmacy, MV, respiratory therapy, and chest x-rays—all of which were at least 40% higher. The increase in nursing time, however, was not significantly higher among cases. Restrepo et al[8] also reported higher breakdown costs in a matched cohort study of 30 case patients and 90 control patients. As in our study, the costs of overall hospitalization and respiratory therapy were higher among patients with VAP; however, between-cohort differences in pharmacy were not statistically significant, possibly because of sample size. Additional categories with significant between-cohort differences were cardiology, operating room, electrocardiogram, and recovery room; we did not collect data on these categories.

Mortality was lower in patients with VAP than patients

TABLE 4. Hospitalization Costs in a Matched Cohort of Patients with Ventilator-Associated Pneumonia (VAP) and Patients without VAP

MS-DRG code	Population	Cost, dollars, mean ± SD[a]		P
		With VAP	Without VAP	
3	ECMO or tracheostomy with mechanical ventilation ≥96 h or principal diagnosis except face, mouth, and neck with major OR	153,625 ± 105,696	142,827 ± 125,400	.113
4	Tracheostomy with mechanical ventilation ≥96 h or principal diagnosis except face, mouth, and neck without major OR	112,865 ± 77,784	83,187 ± 44,590	<.0001
207	Respiratory system diagnosis with ventilator support ≥96 h	46,928 ± 34,145	41,627 ± 24,701	.060
870	Septicemia or severe sepsis with mechanical ventilation ≥96 h	59,238 ± 58,111	44,642 ± 25,851	.005
853	Infectious and parasitic diseases with OR procedure with major complication or comorbidity	103,082 ± 91,291	66,972 ± 51,444	.022
208	Respiratory system diagnosis with ventilator support <96 h	25,612 ± 20,324	17,593 ± 8,269	.027
329	Major small and large bowel procedure with major complication or comorbidity	90,799 ± 62,532	69,767 ± 77,229	.215

NOTE. ECMO, extracorporeal membrane oxygenation; MS-DRG, Medicare Severity diagnosis-related group; OR, operating room procedure; SD, standard deviation.

without VAP (22.5% vs 29.4%; $P < .0001$), which contrasts with popular perception but has been previously reported. Only 1[4] of the studies involving large databases[2,3] or literature reviews[4,5] revealed an association between VAP and mortality (odds ratio [OR], 2.03 [95% confidence interval (CI), 1.16–3.56]). In the remaining studies, between-cohort differences were not significant[2,3] or mortality was not reported.[5] This is not surprising in view of the results of a recent systematic review.[9] The relative risk of mortality was 1.27 (95% CI, 1.15–1.39) in a pooled analysis of 52 observational studies of patients with and without VAP; however, considerable heterogeneity confounded interpretation of these findings. Interestingly, VAP was not associated with mortality in the only 2 populations that had limited heterogeneity, namely, trauma (OR, 1.09 [95% CI, 0.87–1.37]) and acute respiratory distress syndrome (OR, 0.86 [95% CI, 0.72–1.04]).[9]

Collectively, current and previous[2-5] findings have important clinical implications because they suggest that VAP continues to be associated with a substantial resource utilization burden, which can be used to justify the use of preventive strategies. In addition to reducing the incidence of VAP, the ideal strategy should not increase healthcare costs or burden healthcare providers.[10,11] Examples of strategies shown to reduce the incidence of VAP and to be cost effective include multifaceted preventive bundles,[12-14] which include education, semirecumbent positioning, good oral hygiene, and other infection control practices.

Our study had several limitations. It was subject to the inherent bias of retrospective analysis; however, the data were collected prospectively. To limit bias, we matched patients at the 4-digit propensity score precision level or higher. The cohorts appeared to be balanced, as demonstrated by the lack of differences in patient and hospital characteristics other than discharge status. Including severity of illness as a variable may have biased the matching process because VAP can worsen this variable; however, this would have attenuated the impact of VAP. The database did not include information on preventive strategies or some risk factors for VAP, such as supine positioning. We did not collect information on microbiology, detailed antibiotic use, or appropriateness of initial therapy and therefore could not assess the role of these variables on outcome. We were not able to specifically link all costs directly to VAP, such as incremental antibiotic costs. We did not validate use of the new VAP diagnosis code against patient charts or alternate database methods that relied on post-MV initiation of treatment for pneumonia to identify VAP. If the code lacked sensitivity as suggested by the low VAP rate, our study population may not be representative of patients with VAP; however, this limitation would have attenuated the impact of VAP on economic findings. Our findings do not prove that VAP caused the observed increased LOS; it is possible that the increased duration of hospitalization caused the increased risk of infection, an inherent limitation of epidemiologic studies of time-dependent events such as VAP.[15]

In conclusion, our findings suggest that VAP continues to occur amidst lack of agreement regarding diagnostic criteria and the exact prevalence. More importantly, VAP continues to be associated with a statistically significant resource utilization burden. Therefore, hospitals should attempt to target patients at risk for VAP with cost-effective interventions aimed at minimizing the occurrence of this complication.

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performed a courtesy review of the study design and manuscript but did not influence the content.

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