Hospital Patterns of Mechanical Ventilation for Patients with Exacerbations of COPD

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Abstract

Rationale: Randomized trials have shown that noninvasive ventilation (NIV) can reduce the need for intubation and improve the survival of patients with severe exacerbations of chronic obstructive pulmonary disease (COPD); however, it is not known whether hospitals with greater use of NIV achieve lower rates of intubation and better patient outcomes.

Objectives: To describe patterns of mechanical ventilation use for patients with COPD across a large sample of hospitals, and to analyze the relationship between use of NIV and other outcomes.

Methods: Cross-sectional analysis of 77,576 patients hospitalized for COPD between June 2009 and June 2011 at 386 U.S. hospitals.

Measurements and Main Results: Using hierarchical modeling, we estimated hospital risk-standardized percentages of ventilator starts that were noninvasive (RS-NIV%). We examined the association between RS-NIV% and other outcomes, including risk-standardized rates of invasive ventilation and NIV failure, total ventilation, in-hospital mortality, length of stay, and costs. At the hospital level, the median RS-NIV% was 75.1% (range: 9.2–94.1%). Smaller hospitals and those located in rural areas had higher RS-NIV%. When stratified into quartiles on the basis of the RS-NIV%, hospitals in the highest quartile had lower risk-standardized rates of invasive mechanical ventilation (Q4 vs. Q1: 4.0% vs. 13.3%, $P < 0.01$) and modestly higher risk-standardized total rates of ventilation (Q4 vs. Q1: 23.9% vs. 22.0%, $P = 0.03$). Hospitals with the highest RS-NIV% had lower risk-standardized mortality among ventilated patients who received ventilation (Q4 vs. Q1: 8.5% vs. 9.0%, $P = 0.01$) and marginally lower mortality rates among all patients with COPD (Q4 vs. Q1: 2.2% vs. 2.3%, $P = 0.03$) compared with hospitals with the lowest RS-NIV%. Higher RS-NIV% was associated with lower hospital costs (Q4 vs. Q1: $11,148 vs. $14,032, $P < 0.001$), shorter length of stay (Q4 vs. Q1: 5.5 vs. 6.8 d, $P < 0.001$), and lower NIV failure rates (Q4 vs. Q1: 12.8 vs. 32.5%, $P < 0.001$).

Conclusions: Use of NIV as the initial ventilation strategy for patients with COPD varies considerably across hospitals. Institutions with greater use of NIV have lower rates of invasive mechanical ventilation and better patient outcomes.

Keywords: COPD; costs and cost analysis; cross-sectional analysis; length of stay; outcomes research

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Chronic obstructive pulmonary disease (COPD) affects as many as 24 million individuals in the United States, is responsible for more than 800,000 hospitalizations annually, and is the nation's third leading cause of death (1–3). Inpatient mortality has been estimated at approximately 3% (4, 5); the 30-day mortality rate among Medicare beneficiaries is 8.6%; and approximately one in five patients are rehospitalized within 30 days of discharge (6, 7). COPD accounts for one-fourth of all cases of respiratory failure, following pneumonia and congestive heart failure (8).

Standard therapy for those requiring hospitalization includes supplemental oxygen, short-acting bronchodilators, systemic corticosteroids, and, frequently, broad-spectrum antibiotics (9). Beginning in the 1990s, a series of small, randomized trials demonstrated that, when applied to carefully selected patients with COPD with severe exacerbation, noninvasive ventilation (NIV) could reduce the need for invasive mechanical ventilation (IMV) and resulted in better short-term survival (10–13). In, meta-analyses, authors have estimated that, as an alternative to IMV, treatment of these patients with NIV is associated with a 40–55% reduction in mortality (14, 15).

Although use of NIV in the management of patients with COPD and other causes of respiratory failure has increased steadily over the past decade (8, 16, 17), little is known about the uniformity of its adoption across hospitals or about the association between hospital patterns of mechanical ventilation and other hospital outcomes. Using data from a large sample of U.S. hospitals, we studied the use of IMV and NIV in the management of patients hospitalized for COPD. On the basis of the results of randomized trials, we hypothesized that NIV would be used primarily as an alternative to IMV and that hospitals with higher rates of NIV would have better patient outcomes, including mortality, length of stay, and costs.

Methods

Design, Setting, and Subjects

We conducted a cross-sectional study of patients hospitalized for exacerbations of COPD between June 2009 and June 2011 at a geographically and structurally diverse set of 386 U.S. hospitals that participate in a voluntary, fee-supported database used for quality improvement (Premier Healthcare Informatics, Charlotte, NC). Data are collected electronically from these sites, are audited regularly to ensure validity, and the database has been used extensively in outcomes research (18–20). In addition to the information contained in the standard hospital discharge abstract (i.e., UB-04), the database contains a date-stamped log of all items and services charged to patients or their insurers, including medications, laboratory and other diagnostic tests, and therapeutic services, such as respiratory and physical therapy.

Patients were included in the analysis if they were 40 years of age or older, received a principal discharge diagnosis (coded according to the International Classification of Diseases, Ninth Revision, Clinical Modification [ICD-9-CM]) consistent with acute exacerbation of COPD (491.21, 492.22, 491.8, 491.9, 492.8, or 496) or a secondary diagnosis of COPD when accompanied by a principal diagnosis of acute respiratory failure (518.81, 518.82, or 518.84) (21), and were treated with short-acting bronchodilators and systemic corticosteroids. We excluded patients if they were transferred from or to another acute care facility, if their length of stay was

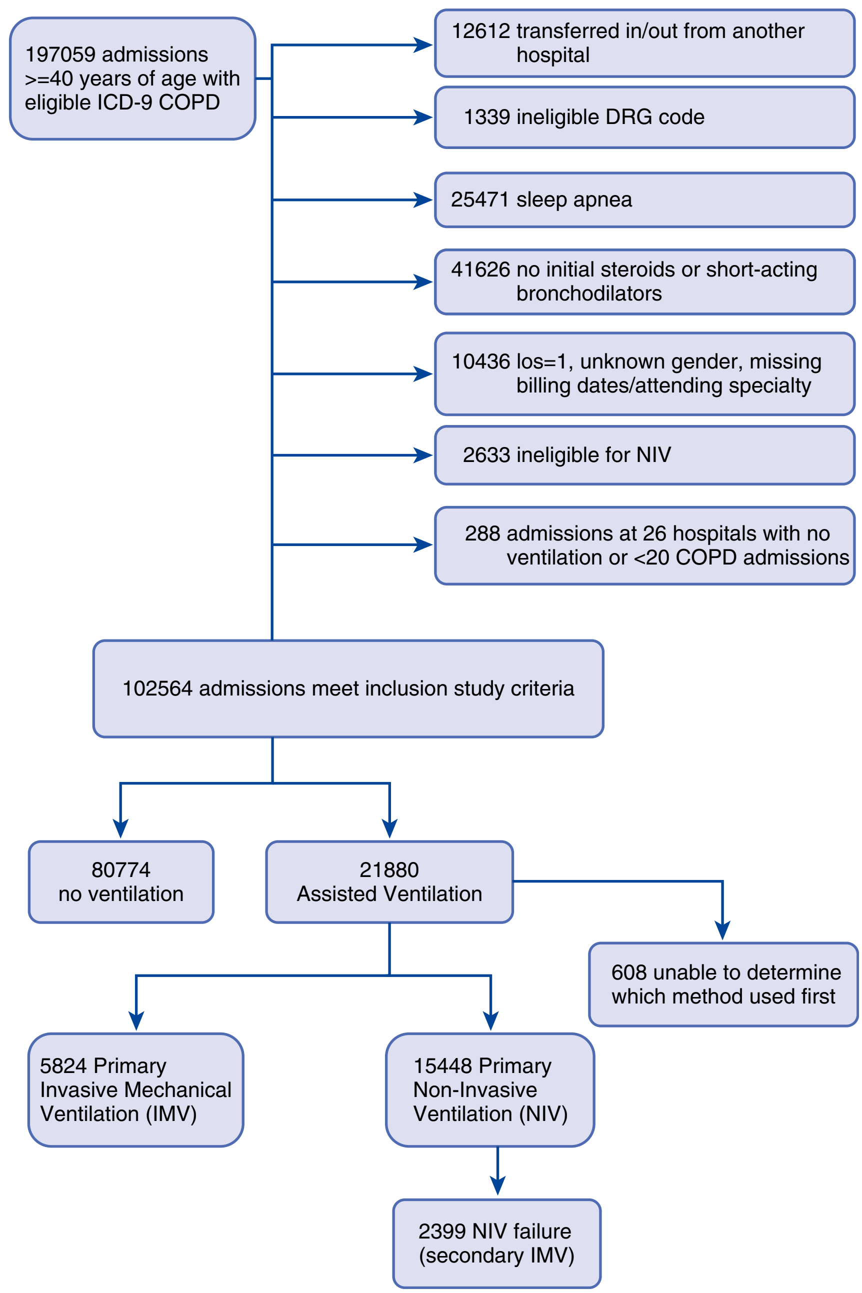

Figure 1. Study cohort flowchart. COPD = chronic obstructive pulmonary disease; DRG = Medicare Severity-Diagnosis Related Group; ICD-9 = International Classification of Diseases, Ninth Revision, Clinical Modification.

less than 2 days, if they were cared for by an attending physician whose specialty would not be expected to care for patients with COPD (e.g., psychiatry), or if they were classified in a Medicare severity diagnosis-related group inconsistent with COPD. We also excluded patients with sleep apnea because we could not differentiate chronic use of NIV (i.e., positive airway pressure devices) from treatment for acute respiratory failure. Finally, to obtain stable estimates of mechanical ventilation rates, we excluded patients cared for at hospitals with fewer than 20 eligible COPD admissions during the 2-year study period.

Patient, Physician, and Hospital Information

In addition to patient age, sex, race, and ethnicity, we computed a comorbidity score using diagnosis codes as described by Gagne and colleagues (22). To better assess the severity of the patient's lung disease and its impact on health, we calculated the number of hospitalizations for COPD in the year prior to the index admission. Given the high incidence of pneumonia and its association with NIV failure, we also recorded whether the patient received a diagnosis of pneumonia at the time of hospital admission by using present on admission indicator codes (23).

For each hospital, we recorded the number of beds, the annual number of admissions for COPD, teaching status, geographic region, and whether the hospital served an urban or rural population. Using data from the American Hospital Association annual survey, we computed the ratios of full-time equivalent hospitalists, intensivists, nurses, and respiratory therapists to beds for each hospital (24).

Noninvasive and Invasive Ventilation

For each patient, we examined standardized charge codes generated daily by respiratory therapists, as well as dated ICD-9-CM procedure codes, to determine whether or not the patient was treated with assisted ventilation and, if so, whether it was NIV or IMV. We considered a patient to have received ventilation if either the respiratory therapist charge or ICD-9-CM procedure code (93.90 for NIV; 96.04, 96.70–96.72 for IMV) indicated treatment. We defined the primary method of ventilation as the first method by date, and we noted any changes that occurred throughout the hospitalization. In those cases where both NIV and IMV were initially recorded on the same date, we used service charges on subsequent days to infer the initial therapy. We validated the NIV procedure codes and respiratory therapy charge codes by retrospective medical chart review of 200 patients who had been admitted to Baystate Medical Center with an ICD-9-CM code for respiratory failure at any time from 2010 through 2011. Using ICD-9-CM codes alone yielded a sensitivity of 86% (95% confidence interval [CI], 81–92%) and specificity of 92% (95% CI, 84–98%) for NIV. The approach of using ICD-9-CM procedure codes and/or respiratory therapist charges increased sensitivity to 99% (95% CI, 98–100%) without reducing specificity (92%; 95% CI, 84–99%).

Outcomes

The primary study outcomes were the hospital rate of IMV, total mechanical ventilation, NIV failure, in-hospital mortality, median length of stay, and median costs. The NIV failure rate was defined as the percentage of patients who were treated with IMV after an initial exposure to NIV.

Analysis

For each hospital, we calculated the percentage of patients treated according to each of the primary ventilatory strategies: no assisted ventilation, NIV, and IMV. We then calculated the percentage of patients initially treated with NIV among those who received assisted ventilation. We used hierarchical logistic regression with

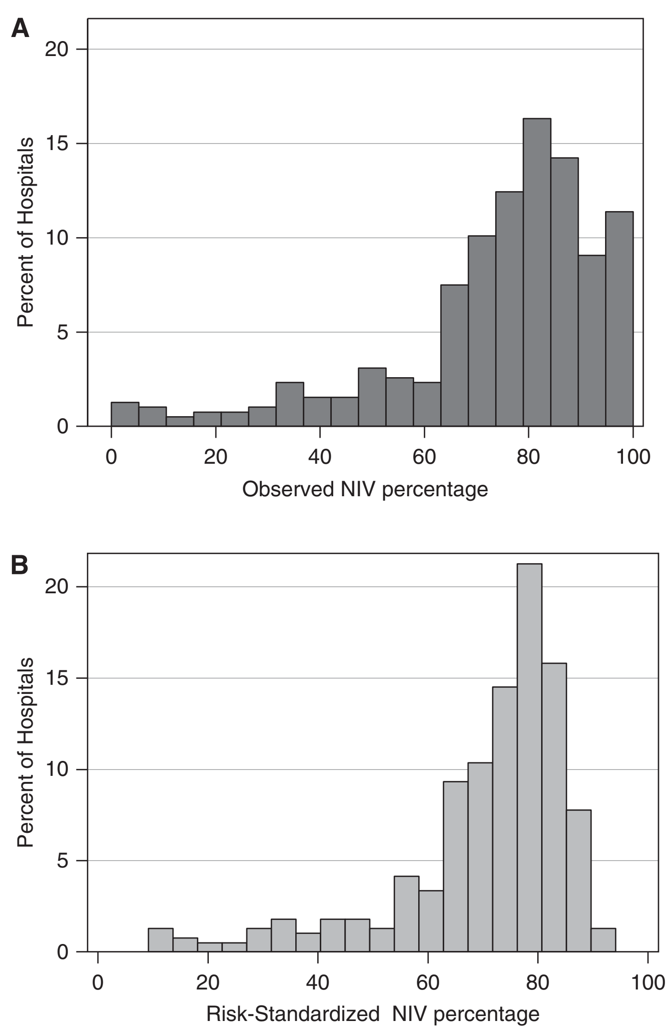

Figure 2. Distribution of percentage of ventilator starts that were noninvasive at hospitals included in the analysis. NIV = noninvasive ventilation.

a random hospital effect to model initial use of NIV among patients started on ventilation, adjusting for demographics, comorbidity score, prior COPD admissions, and the presence of comorbid pneumonia (25). From the model, a predicted NIV percentage for each hospital was computed as the NIV percentage that would be anticipated at a particular hospital by using its hospital random effect, given the patient case mix.

The expected NIV percentage was computed as the rate that would be expected if the same patient mix were treated at an "average" hospital, using the average hospital effect. A hospital risk-standardized NIV percentage was computed as the ratio of predicted to expected NIV percentage standardized by the overall unadjusted mean NIV percentage for all admissions in our model. We used analogous methods to compute risk-standardized rates of IMV, total ventilation, NIV failure, and mortality. For patients with multiple admissions during the study period, mortality models were restricted to a randomly selected admission to address the threat of survival bias associated with high admission rates. We evaluated the Spearman correlation between the hospital risk-standardized NIV percentage and risk-standardized total IMV rates. We then evaluated variation in hospital characteristics across quartiles of risk-standardized NIV percentage using Kruskal-Wallis tests. Finally, we compared risk-standardized rates of IMV, total ventilation, NIV failure, and mortality, as well as hospital median length of stay and hospital median costs, across quartiles based on the risk-standardized NIV percentage by using Kruskal-Wallis analysis of variance, adjusting for hospital characteristics.

All analyses were performed using SAS version 9.3 software (SAS Institute, Cary, NC). The Institutional Review Board at Baystate Medical Center approved the study and waived the requirement for explicit participant consent.

Results

Patient and Hospital Characteristics

We identified 102,654 admissions among 77,576 patients for COPD between June 2009 and June 2011 at 386 U.S. hospitals (Figure 1). The patients' median age was 70 years, and 58.6% were female. Heart failure, anemia, and diabetes were the most common comorbidities, and the median comorbidity score was 2 (range, 1–4). A total of 33,245 (32.4%) had at least one admission for COPD in the year prior to the index admission, and pneumonia was present at the time of admission in 18.9% of cases. The median length of stay in the hospital was 4 days, and 2,023 (2.0%) of admissions resulted in death before discharge. Approximately 38% of hospitals included in the study operated fewer than 200 beds, and 24% had more than 400 beds, 76% served an urban population, and 25% were engaged in house staff training.

Use of Noninvasive and Invasive Ventilation

A total of 15,448 (15.1%) patients admitted for exacerbations of COPD were initially treated with NIV, and 5,824 (5.7%) received

Table 1. Risk-standardized percentage of ventilator starts that were noninvasive by characteristics of hospitals included in the analysis

	Number	Risk-standardized NIV percentage, *Median % (Q1–Q4)*	*P* Value*
Overall	386	75.1 (66.1–80.7)	
Hospital characteristics			
Teaching status			0.143
Nonteaching	289	75.3 (66.9–81.0)	
Teaching	97	73.3 (63.4–79.7)	
Rural/urban status			0.0037
Rural	94	77.8 (70.1–81.8)	
Urban	292	74.2 (63.7–79.9)	
Region			0.073
Midwest	71	74.8 (63.8–81.3)	
Northeast	56	72.3 (64.2–77.7)	
South	177	76.2 (67.0–80.9)	
West	82	76.7 (66.1–81.7)	
Beds			0.064
Small, <200	148	76.7 (67.1–81.6)	
Medium, 200–400	146	74.8 (64.9–80.1)	
Large, >400	92	74.0 (63.2–79.5)	
Annual COPD case volume			0.063
10–64 admissions	96	77.4 (71.1–81.4)	
65–117	97	73.2 (63.8–79.9)	
118–184	95	74.2 (65.3–80.5)	
185+	98	74.5 (62.8–79.7)	
Staffing ratios†			
Hospitalists			0.127
Missing	134	73.5 (61.6–79.9)	
<1.42	86	74.9 (66.3–80.7)	
1.42–3.65	85	76.2 (68.5–79.6)	
3.66+	81	77.1 (68.9–82.6)	
Respiratory therapists			0.629
Missing	102	74.5 (62.8–80.1)	
<5.36	90	75.3 (65.1–79.6)	
5.36–8.45	93	77.0 (66.9–81.4)	
8.46+	103	74.6 (66.9–81.0)	
Nurses			0.860
Missing	134	74.7 (63.5–80.2)	
<107.68	80	75.9 (67.7–80.7)	
107.68–150.47	82	76.0 (66.3–82.1)	
150.48+	90	74.9 (63.6–80.6)	
Intensivists			0.0056
Missing	140	72.2 (59.0–79.7)	
None	124	76.4 (69.0–81.3)	
>0–1.91	64	74.0 (59.4–80.1)	
1.92+	58	77.4 (71.6–81.4)	

Definition of abbreviations: COPD = chronic obstructive pulmonary disease; NIV = noninvasive ventilation.
*Calculated using the Kruskal-Wallis test.
†Each staff member is FTE to 100 beds.

initial treatment with IMV. In 2,339 (15.5%) of the NIV-treated admissions, patients were later treated with IMV (due to NIV failure). Additionally, in 1,631 (28.0%) admissions, patients initially treated with IMV were later treated with NIV.

We observed substantial variation in the risk-standardized NIV percentage across the hospitals included in the analysis, varying from 47.4% at the 10th percentile to 84.7% at the 90th percentile (Figure 2). We found modest association between the hospital risk-standardized NIV percentage and other hospital characteristics. Hospitals that were smaller, had lower annual COPD case volumes, and those located in rural areas had slightly higher risk-standardized NIV percentages; however, physician, nurse, and respiratory therapist staffing ratios were not associated with ventilation patterns (Table 1).

Association between Use of Noninvasive Ventilation and Outcomes

We observed a strong negative correlation (−0.70) between the risk-standardized percentage of ventilator starts that were noninvasive and risk-standardized rates of IMV. (Figure 3). When grouped into quartiles, the median percentage of ventilator starts that were noninvasive ranged from 54.5% in the first quartile (Q1) to 83.7% in Q4. We observed strong associations between the risk-standardized NIV percentage and other hospital outcomes (Figure 4 and Table 2). As the hospital risk-standardized NIV percentage increased, there was a large decline in the risk-standardized rate of IMV (rate in Q1 vs. Q4: 13.3% vs. 4.0%, $P < 0.01$) and a modest increase in the risk-standardized total rate of mechanical ventilation (rate in Q1 vs. Q4: 22.0% vs. 23.9%, $P = 0.03$). Across quartiles of risk-standardized NIV percentage, the overall percentage of patients experiencing NIV failure remained relatively constant; however, when viewed as the percentage of patients initially treated with NIV, the rate of failure declined dramatically (rate in Q1 vs. Q4: 32.5% vs. 12.8%, $P < 0.01$) (Figure 4 and Table 2). A higher percentage of ventilator starts that were noninvasive was associated with reduced risk-standardized mortality among patients who received ventilation (rate in Q1 vs. Q4: 9.0% vs. 8.5%, $P = 0.01$). We found that hospitals with the highest risk-standardized NIV percentage had costs for patients who received ventilation that were approximately $3,000 lower and length of stay that was 1 day shorter (costs in Q1 vs. Q4: $14,032 vs. $11,148 and 6.8 vs. 5.5, respectively; $P < 0.001$ for both).

In a secondary analysis that included all patients with COPD, and was thus not limited to those requiring ventilation, we found that hospitals with the highest risk-standardized NIV percentage had marginally lower risk-standardized mortality (rate in Q1 vs. Q4: 2.3% vs. 2.2%, $P = 0.03$) (Table 2). Hospitals with the highest risk-standardized NIV percentage also had lower median costs (median costs in Q1 vs. Q4: $7,169 vs. $6,653, $P = 0.04$) but similar length of stay compared with hospitals in the lowest quartile.

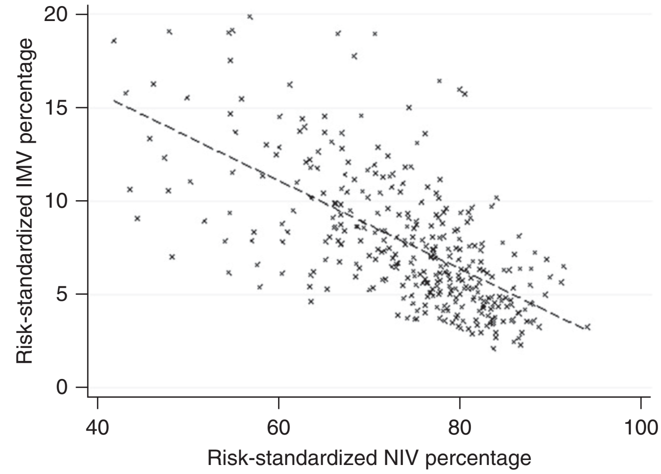

Figure 3. Correlation between risk-standardized percentage of ventilator starts that were noninvasive and risk-standardized rates of invasive ventilation. NIV = noninvasive ventilation.

Discussion

In this large observational study, we found that the use of NIV among patients hospitalized with COPD varied widely across hospitals. The percentage of ventilator starts that were noninvasive ranged from 9% to 94%, even after adjusting for differences in patient case mix. This suggests that whether a patient with

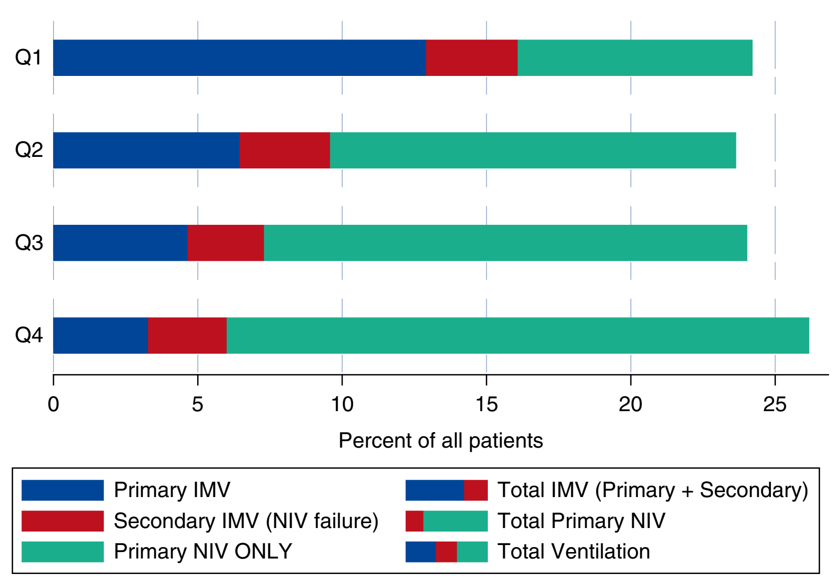

Figure 4. Use of invasive and noninvasive ventilation (NIV) by quartile of risk-standardized NIV percentage. IMV = invasive mechanical ventilation.

Table 2. Hospital risk-standardized rates of mortality, length of stay, and costs and ventilation by quartiles of risk-standardized percentage of ventilated patients started on noninvasive ventilation

Risk-Standardized Hospital Rates	Quartiles of Risk-Standardized NIV Percentage				*P* Value*	Q4 vs. Q1 *P* Value*
	Q1, <66.1%	Q2, 66.1–75.0%	Q3, 75.1–80.7%	Q4, >80.7%		
Any ventilation	22.0	21.6	22.3	23.9	0.121	0.026
Primary invasive ventilation	13.3	6.8	5.1	4.0	<0.0001	<0.0001
Any invasive ventilation	16.1	9.8	7.5	6.4	<0.0001	<0.0001
NIV failure	32.5	20.2	15.2	12.8	<0.0001	<0.0001
Mortality among patients who received ventilation	8.96	9.02	8.46	8.48	0.0009	0.006
Mortality among all patients	2.34	2.31	2.21	2.22	0.038	0.034
Length of stay (median days) among patients who received ventilation	6.8	6.0	5.8	5.5	0.0007	<0.0001
Length of stay (median days) among all patients	4.1	4.1	4.1	4.0	0.400	0.176
Cost (median $) among patients who received ventilation	$14,032	$13,295	$10,985	$11,148	<0.0001	<0.0001
Cost (median $) among all patients	$7,169	$7,435	$6,892	$6,653	0.002	0.044

Definition of abbreviations: NIV = noninvasive ventilation.
*Kruskal-Wallis *P* value adjusted for hospital region, size and urban/rural location, teaching status, staffing ratios, and annual COPD patient volume.

a severe exacerbation of COPD will be intubated or receive NIV is highly dependent on which hospital they are admitted to. When compared with hospitals with a lower percentage of NIV starts, those with a higher percentage had substantially lower rates of IMV and similar rates of NIV failure. Further, hospitals with higher rates of NIV use had modestly lower mortality, lower costs, and shorter length of stay among patients who received ventilation.

Numerous factors are probably responsible for the variation we observed in the use and outcomes of NIV across hospitals. First, providers must be familiar with the selection of appropriate patients, as well as with proper application, to achieve optimal outcomes. Successful implementation of NIV also requires trained personnel, appropriate technology, and interdisciplinary coordination. A survey of hospitals in Massachusetts and Rhode Island suggested that factors that may lead to variation in use of NIV across hospitals include lack of knowledge, inadequate training of staff, and insufficient equipment (26). If NIV is viewed as similar to other complex sociotechnical undertakings, such as ensuring that patients with acute coronary syndrome are brought to the cardiac catheterization laboratory in a timely manner, then the variation we observed should not be surprising.

The most significant finding of our study was the relationship that we observed between the use of NIV and other outcomes, including intubation rates, mortality, and costs. We hypothesized that NIV would be used primarily as an alternative to intubation. Our finding that greater use of NIV was associated with lower rates of IMV supports this view. For example, compared with hospitals in the lowest quartile of NIV use, those in the highest quartile intubated 30 fewer patients per 100 admissions requiring mechanical ventilation. However, this was not a foregone conclusion. An alternative possibility was that greater use of NIV might have reflected a lower threshold for initiating assisted ventilation among patients with exacerbations of COPD. Had that been the case, we should have found that hospitals with higher NIV use had similar rates of IMV and higher overall rates of ventilation. Although we observed modestly higher rates of ventilation at the hospitals with the greatest use of NIV, almost all of the increase in NIV was offset by a decrease in IMV. It is important to emphasize, though, that using NIV as an alternative to IMV does not mean that it can be used as a substitute. Typically, NIV is used early in the course of respiratory failure to avert the need for intubation, but use of NIV should not delay a needed intubation.

Our finding that higher NIV use is associated with lower risk-standardized mortality rates, as well as shorter length of stay, in the hospital suggests that the benefits observed in clinical trials are translating into better outcomes for patients. Interestingly, the NIV failure rate remained stable in the face of higher NIV rates and declined as a percentage of all noninvasive starts. Although our study was not designed to address this directly, it is possible that as hospitals become more experienced with using NIV, they may become better at selecting patients likely to tolerate it and be treated successfully. Similarly, hospitals may develop the skills and confidence that enable them to continue the use of NIV in a patient whose treatment might be considered a failure and switched to IMV at another site without increasing the mortality rate.

Our findings should be interpreted in light of several recent studies. Chandra and colleagues reported on trends in the use of invasive and NIV based on 1998–2008 data from the Nationwide Inpatient Sample (16). They found a dramatic increase in the use of NIV over the period, with a concomitant reduction in the use of IMV and improved survival. Our analysis, conducted at the hospital level, corroborates those aggregate findings by demonstrating that institutions with higher use of NIV have lower rates of intubation. At the same time, our analysis identified wide variation in the use of NIV that suggests opportunities for quality improvement. Using the Nationwide Emergency Department Sample, Tsai and colleagues compared the effectiveness of invasive and noninvasive forms of ventilation in patients with COPD and respiratory failure (27). They reported that rates of NIV varied from 0 to 100% across hospitals included in the sample and found that hospitals in the Northeast, hospitals in nonmetropolitan areas, and hospitals with higher annual case volumes had higher rates of NIV. Our results extend the findings of that study by suggesting that hospitals with a preference for NIV achieve better outcomes, including lower rates of intubation, mortality, and costs. The 2008 UK national audit of COPD care (28) included data from 9,716 patients at 232 hospitals. It found that 12% of hospitalized patients received ventilatory support, including 11% treated with NIV and only 1% with IMV. Our results suggest that the provision of ventilatory assistance is far more common in the United States than in the United Kingdom, whereas use of NIV, as a proportion of all ventilator starts, lags our UK counterparts. Interestingly, whereas NIV was reportedly unsuccessful in 27% of cases in the UK audit, only 2% of those patients went on to receive intubation, a far lower percentage than the 15% found in our analysis.

Making causal inferences about the relationship between hospital patterns of ventilation and patient outcomes is challenging. On the one hand, a hospital level analysis is appealing because it seemingly overcomes serious concern about confounding by indication that arises in patient-level comparisons of individuals treated with invasive and noninvasive forms of ventilation. To invalidate the findings of a hospital level analysis, one would have to posit large and unobservable differences in the severity of illness of patients with COPD at some hospitals compared with others. On the other hand, hospital-level analyses could be subject to a stage migration problem whereby a reduction in the threshold to initiate NIV would reduce the average severity of illness of the ventilated cohort. Our observation of proportionately lower rates of IMV at hospitals with the strongest preference for NIV reduces this threat. In addition, our secondary analyses that included all patients with COPD, and was not limited to those undergoing ventilation, provides another check against this form of bias. In those analyses, we found smaller, though statistically significant, benefits associated with a preference for NIV.

Our study has a number of strengths. We included a large number of patients cared for within a geographically and structurally diverse set of U.S. hospitals. We used hierarchical modeling to estimate risk-standardized rates of IMV and NIV, as well as mortality, allowing us to make comparisons across hospitals that took into account differences in case mix and in hospital structural characteristics. We grouped hospitals according to the percentage of ventilator starts that were NIV, overcoming the bias that could be introduced at hospitals with low overall rates of ventilation but with a strong preference for NIV.

Although our results were striking, our findings should be interpreted in light of several limitations. First, we used ICD-9-CM codes to identify patients with COPD, and these codes do not have perfect accuracy (29). However, we took advantage of hospital pharmacy data to limit the analysis to patients with COPD who were treated with bronchodilators and systemic steroids. Second, although our analyses were adjusted for differences in patient demographics, comorbidities, and prior hospitalizations, including receipt of mechanical ventilation, we did not have direct physiologic measures to assess disease severity. Thus, some of the variation in risk-standardized rates across hospitals may reflect residual unmeasured factors. Third, although we adjusted for differences in patient and hospital characteristics across the hospitals, stratified by the percentage of ventilator starts that were noninvasive, our findings could reflect confounding by other hospital factors. Fourth, our analyses were not intended to define an optimal percentage of NIV starts, although when we stratified hospitals into quartiles on the basis of NIV use, higher rates were associated with better outcomes without increased rate of NIV failure. Fifth, our study was limited to outcomes occurring during hospitalization, and it is possible that longer-term hospital outcomes (such as 30-d mortality rate) may also relate to patterns of mechanical ventilation.

In conclusion, we found that use of NIV in the management of COPD varied widely across hospitals. Institutions with greater use of NIV used less IMV and generally achieved better patient outcomes. Future research should explore the contextual factors and strategies associated with successful implementation of NIV. ■

Author disclosures are available with the text of this article at www.atsjournals.org.

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