Use of Noninvasive Ventilation in Patients with Acute Respiratory Failure, 2000–2009

A Population-Based Study

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Abstract

Rationale: Although evidence supporting use of noninvasive ventilation (NIV) during acute exacerbations of chronic obstructive pulmonary disease (COPD) is strong, evidence varies widely for other causes of acute respiratory failure.

Objectives: To compare utilization trends and outcomes associated with NIV in patients with and without COPD.

Methods: We identified 11,659,668 cases of acute respiratory failure from the Nationwide Inpatient Sample during years 2000 to 2009 and compared NIV utilization trends and failure rates for cases with or without a diagnosis of COPD.

Measurements and Main Results: The proportion of patients with COPD who received NIV increased from 3.5% in 2000 to 12.3% in 2009 (250% increase), and the proportion of patients without COPD who received NIV increased from 1.2% in 2000 to 6.0% in 2009 (400% increase). The rate of increase in the use of NIV was significantly greater for patients without COPD (18.1% annual change) than for patients with COPD (14.3% annual change; $P = 0.02$). Patients without COPD were more likely to have failure of NIV requiring endotracheal intubation (adjusted odds ratio, 1.19; 95% confidence interval, 1.15–1.22; $P < 0.0001$). Patients in whom NIV failed had higher hospital mortality than patients receiving mechanical ventilation without a preceding trial of NIV (adjusted odds ratio, 1.14; 95% confidence interval, 1.11–1.17; $P < 0.0001$).

Conclusion: The use of NIV during acute respiratory failure has increased at a similar rate for all diagnoses, regardless of supporting evidence. However, NIV is more likely to fail in patients without COPD, and NIV failure is associated with increased mortality.

Keywords: respiratory insufficiency; noninvasive ventilation, positive-pressure; research, health services; outcome study

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Physicians report wide use of noninvasive ventilation (NIV) for a variety of clinical indications (1–4). NIV may be particularly attractive to clinicians because it potentially offers an "easier," less invasive form of respiratory support for patients with acute respiratory failure than traditional mechanical ventilation (MV) implemented through an endotracheal tube. However, the ease of use of NIV may not translate into improved clinical outcomes. Indeed, the strength of evidence supporting use of NIV for acute respiratory failure varies according to the etiology of respiratory failure. Randomized trials consistently support improvements in mortality and reduction in endotracheal intubation rates with the use of NIV during acute exacerbations of chronic obstructive pulmonary disease (COPD) (5). Findings supporting NIV for acute cardiogenic pulmonary edema are mixed (6), although the weight of evidence favors a reduction in mortality and endotracheal intubation

(7). Little evidence supports the use of NIV for other causes of acute respiratory failure, such as asthma (8) or pneumonia (9, 10).

Clinical practice guidelines recommend the use of NIV in patients with acute exacerbations of COPD and cardiogenic pulmonary edema but generally do not recommend NIV for other causes of acute respiratory failure (11–14). In accordance with clinical practice guidelines, the use of NIV for acute exacerbations of COPD increased fourfold from 1998 to 2008 in the United States, with concomitant decreased endotracheal intubation and hospital mortality (15). Utilization patterns and outcomes associated with NIV use for other causes of acute respiratory failure outside of clinical trials remain unclear.

Given the enthusiasm reported by physicians for NIV in a variety of clinical presentations (1–4), we hypothesized that, despite little supporting evidence, the use of NIV in non-COPD causes of acute respiratory failure has increased at a similar rate to the use of NIV in COPD. Thus, we compared utilization trends and patient outcomes associated with NIV over the last decade in a nationwide, population-based sample of patients with acute respiratory failure associated with COPD and non-COPD diagnoses. Some of the results of this study have been previously reported in the form of an abstract (16).

Materials and Methods

Data Source

We examined hospitalizations for adults (age ⩾ 18 yr) using years 2000 to 2009 discharge data from the Nationwide Inpatient Sample (NIS), Healthcare Cost and Utilization Project, Agency for Healthcare Research and Quality (17). The NIS is an approximately 20% stratified probability sample of all non-Federal acute care hospitals and contains deidentified information from approximately 5 to 8 million hospital discharges yearly. NIS sampling strata are based on hospital characteristics such as ownership/control, teaching status, urban/rural location, region within the United States, and bed size. The 2000 NIS contained data from 994 hospitals in 28 states, and the 2009 NIS included data from 1,050 hospitals in 44 states. Abstracted NIS elements include

Table 1. Characteristics of patients with acute respiratory failure by year*

Patient Characteristics	2000†	2009‡
Age, yr; mean (95% CI)	67.2 (67.2–67.4)	66.1 (66.0–66.1)
Sex, female	443,664 (52.7)	862,026 (51.5)
Race/ethnicity		
White	501,047 (59.5)	1,029,353 (61.5)
Black	83,558 (9.9)	178,961 (10.7)
Hispanic	44,103 (5.2)	108,623 (6.5)
Asian or Pacific Islander	11,103 (1.3)	30,284 (1.8)
Native American	1350 (0.2)	8179 (0.5)
Other or missing	200,656 (23.8)	318,232 (19.0)
Comorbidities		
Total number of comorbidities, mean (95% CI)	0.94 (0.93–0.94)	1.38 (1.37–1.38)
Hypertension	293,339 (34.8)	853,575 (51.0)
Diabetes mellitus	176,759 (21.0)	451,823 (27.0)
Chronic kidney disease	81,609 (9.7)	330,300 (19.7)
Dementia	48,630 (5.8)	131,816 (7.9)
Metastatic or hematologic malignancy	58,182 (6.9)	121,099 (7.2)
Chronic liver disease	19,490 (2.3)	50,907 (3.0)
Obesity	40,786 (4.8)	155,666 (9.3)
Myocardial infarction	29,470 (3.5)	68,455 (4.1)
Paralysis/paraplegia	18,672 (2.2)	53,832 (3.2)
Neutropenia	14,668 (1.7)	75,641 (4.5)
HIV	8281 (1.0)	12,958 (0.77)
Acute nonrespiratory organ failures		
Total number of acute organ failures, mean (95% CI)	0.38 (0.38–0.38)	0.72 (0.72–0.72)
Renal failure	98,412 (11.7)	462,110 (27.6)
Circulatory failure	92,283 (11.0)	323,539 (19.3)
Hematologic failure	48,796 (5.8)	126,588 (7.6)
Metabolic failure (acidosis)	66,598 (7.9)	235,601 (14.0)
Hepatic failure	12,471 (1.5)	57,306 (3.4)
Electrolyte abnormality	279,547 (33.2)	745,286 (44.5)
Procedures		
Dialysis	38,667 (4.6)	114,711 (6.9)
Peripheral arterial catheter	33,106 (3.9)	85,063 (5.1)
Central venous catheter	139,065 (16.5)	446,933 (26.7)
Acute respiratory failure-associated diagnosis		
COPD	344,707 (40.9)	597,022 (35.7)
Cardiogenic pulmonary edema	155,396 (18.5)	293,862 (17.6)
Asthma	12,067 (1.4)	54,877 (3.3)
Pneumonia	121,682 (14.5)	314,339 (18.8)
Sepsis	24,763 (2.9)	79,744 (4.8)
Neurological condition	35,463 (4.3)	91,995 (5.5)
Other/unknown	146,777 (17.4)	241,634 (14.4)
United States geographic region		
Northeast	169,616 (20.1)	277,172 (16.6)
Midwest	174,886 (20.8)	394,585 (23.6)
South	354,270 (42.1)	704,122 (42.1)
West	143,082 (17.0)	297,758 (17.8)
Hospital bed size		
Small	89,164 (10.6)	189,115 (11.5)
Medium	239,147 (28.5)	383,392 (23.3)
Large	512,071 (60.9)	1,070,949 (64.2)
Hospital location: urban	716,130 (85.2)	1,452,340 (88.4)
Teaching hospital	325,444 (38.7)	704,711 (42.9)
Payer		
Medicare	540,255 (64.4)	1,053,827 (63.1)
Medicaid	76,487 (9.1)	173,509 (10.4)
Private Insurance	176,422 (21.0)	324,163 (19.4)
Self-pay	27,118 (3.2)	71,970 (4.3)
Other	18,262 (2.2)	46,858 (2.8)

Definition of abbreviations: CI = confidence interval; COPD = chronic obstructive pulmonary disease.
*Values are weighted n (%) unless otherwise specified.
†Unweighted n = 172,629; weighted n = 841,817.
‡Unweighted n = 331,573; weighted n = 1,673,631.

demographics, admission and discharge status, length of stay, International Classification of Diseases Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis and procedure codes, and hospital characteristics (geographic region, bed size, teaching status, urban/rural location). Although 25 ICD-9-CM codes were available in 2009, to avoid potential bias from an increased number of available diagnoses in 2009, only the first 15 diagnoses were abstracted for all years. Study procedures were deemed exempt by the Boston University Medical Campus Institutional Review Board.

Diagnosis and Procedure Classification

We selected our analysis cohort from hospitalizations with an ICD-9-CM code representing acute respiratory failure (518.81, 518.82, 518.84, 786.09, 799.1) (15). Patients with COPD were identified via ICD-9-CM codes for chronic bronchitis and emphysema (490–492, 495, 496) (15). We also performed a sensitivity analysis using an alternative definition of COPD that included the above codes as well as ICD-9-CM 493.22 (acute exacerbation of chronic obstructive asthma) (18). Patients without a COPD-associated ICD-9-CM code were classified as "non-COPD" patients. As an exploratory analysis, we subclassified non-COPD patients via a mutually exclusive algorithm according to the presence of a diagnosis of heart failure or cardiogenic pulmonary edema, asthma, pneumonia, sepsis, acute neurological disease, or other/unspecified etiology associated with acute respiratory failure (*see* Table E1 in the online supplement). In our algorithm, patients were assigned a diagnosis of COPD if any COPD diagnosis code was present. If no COPD code was found, then diagnosis codes were searched for a heart failure diagnosis; if no heart failure diagnosis was present, then an asthma diagnosis was searched, etc. Our algorithm was conservative in that patients were first assessed for diagnoses with a higher level of evidence for NIV before moving on to an alternative diagnosis with a lower level of NIV evidence. We selected comorbid conditions through enhanced Charlson and Elixhauser ICD-9-CM codes (19) for myocardial infarction, obesity, hypertension, diabetes mellitus, dementia, human immunodeficiency virus infection, paralysis, chronic liver disease, chronic kidney disease, neutropenia, and metastatic or hematologic malignancy. Acute factors were assessed through ICD-9-CM codes for type of acute organ dysfunction diagnoses (20, 21), electrolyte abnormalities, critical care procedures (arterial catheterization, central venous catheterization, dialysis), and hospital strata characteristics (Table E1). Patients receiving NIV were identified with ICD-9-CM procedure code 93.90, and MV via endotracheal route was identified with a procedure code for mechanical ventilation (96.7) or endotracheal intubation (96.04) (15). Prior studies have shown that ICD-9-CM codes for MV (kappa 0.9) (22) and NIV (sensitivity 78%; specificity 100%) (23) are reliable. In patients with both NIV and MV procedure codes, patients were defined as having "NIV failure" if the NIV procedure day preceded or matched the procedure day of MV. In the NIS, procedures codes are identified by the hospital day on which they were performed, whereas diagnosis codes lack temporal markers.

Statistical Analyses

We derived population estimates from the NIS using hospital weights with SAS version 9.1.3 (SAS, Cary, NC) surveyfreq, surveymeans, and surveylogistic procedures. We used the glimmix procedure to calculate yearly age-adjusted rates of NIV use in patients with COPD and patients without COPD. We then used Joinpoint version 3.5.2 (Statistical Research and Applications Branch, National Cancer Institute, Bethesda, MD) to calculate the relative annual percent change (APC) in ventilator use and to test for differences in NIV use trends between COPD-associated and non–COPD-associated acute respiratory failure hospitalizations. Our primary outcome measure was the relative change in NIV use. Because of the evidence in support of NIV for cardiogenic pulmonary edema, we performed a sensitivity analysis comparing NIV use trends in patients with COPD or cardiogenic pulmonary edema with those without one of these diagnoses. We used logistic regression models (adjusted for patient demographics, comorbid conditions, acute organ failures, procedures, hospital characteristics, and year) to calculate odds ratios (OR) for NIV failure on the basis of COPD status. We used similar multivariable-adjusted logistic regression models (including the covariates listed above as well as the potential etiology of acute respiratory failure) to assess the association between NIV failure and hospital mortality. Because patients with sleep apnea may receive NIV for an indication other than acute respiratory

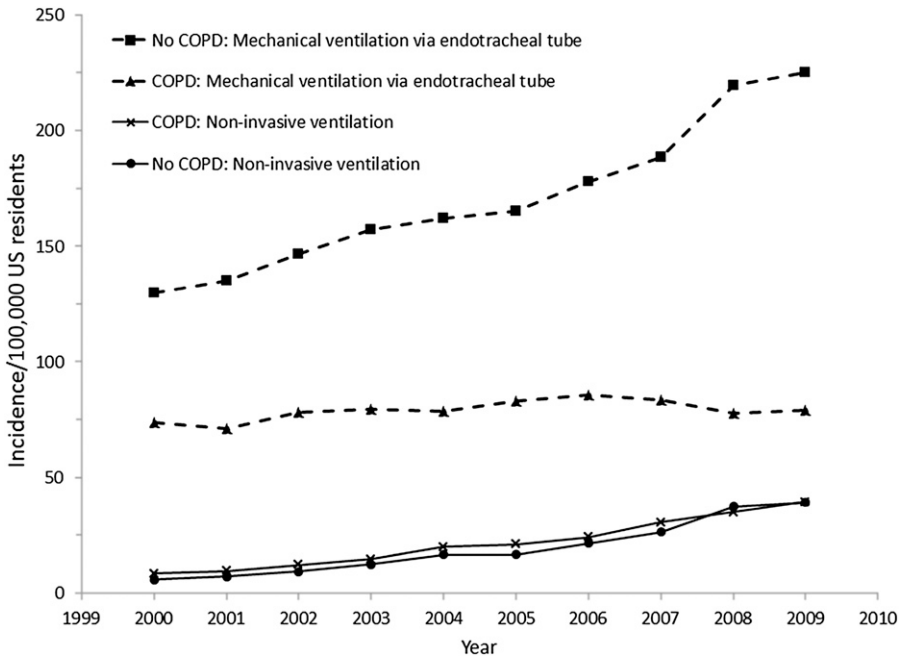

Figure 1. Population incidence of mechanical ventilation and noninvasive ventilation utilization among patients with an acute respiratory failure diagnosis in the United States, 2000 to 2009. COPD = chronic obstructive pulmonary disease.

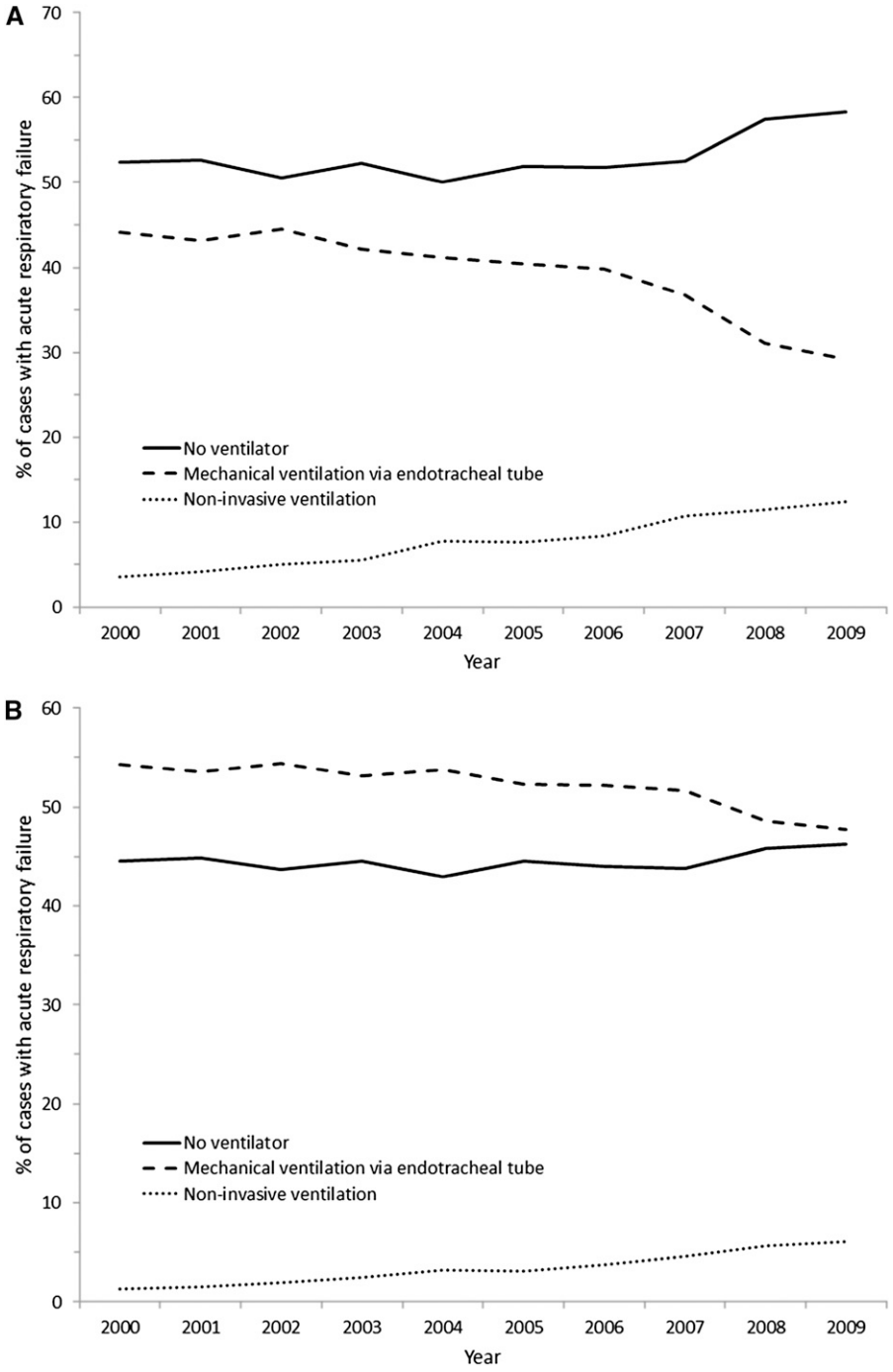

Figure 2. (*A*) United States trends in ventilator practice patterns during acute respiratory failure hospitalizations among patients with chronic obstructive pulmonary disease, 2000 to 2009. (*B*) United States trends in ventilator practice patterns during acute respiratory failure hospitalizations among patients without a diagnosis of chronic obstructive pulmonary disease, 2000 to 2009.

failure, we performed an additional sensitivity analysis excluding patients with a sleep apnea diagnosis (ICD-9-CM 372.2 or 780.57). A two-sided α level of 0.05 was selected for statistical significance.

Results

Trends in Acute Respiratory Failure

Of about 78 million (346 million population-weighted) discharges included in the NIS during years 2000 to 2009, we identified 2,380,632 (3%; 11,659,668 million population weighted) hospitalizations with an acute respiratory failure claim. Characteristics of patients with acute respiratory failure claims in years 2000 and 2009 are shown in Table 1. COPD was present in 900,750 (37%; 4.4 million population-weighted) cases with an acute respiratory failure code (*see* Figure E1 in the online supplement). From the years 2000 to 2009, the incidence of acute respiratory failure–coded hospitalizations increased from 165 to 257 per 100,000 United States residents (56% increase) for patients with COPD and increased from 238 to 463 per 100,000 (95% increase) in patients without COPD (Figure E2)

Trends in NIV and MV

Population-based use of NIV during a hospitalization with an acute respiratory failure claim increased in patients with COPD from 8.6 to 39 per 100,000 United States residents (360% increase), and NIV use in patients without COPD increased from 6 to 39 patients per 100,000 United States residents during the years 2000 to 2009 (560% increase); the use of MV increased by 73% for patients without COPD but remained relatively stable among patients with COPD (7% increase) (Figure 1).

Among patients with acute respiratory failure codes, practice patterns involving the choice of initial ventilator interface changed similarly for patients with COPD (Figure 2A) and patients without COPD (Figure 2B) from 2000 to 2009. The proportion of patients with a COPD diagnosis who received NIV increased from 3.5% in 2000 to 12.3% in 2009 (250% increase), whereas 1.2% of patients without COPD received NIV in 2000 compared with 6.0% in 2009 (400% increase). These results represent a 14.3% APC (95% CI, 12.1–16.8) in NIV among patients with COPD and a 18.1% APC (95% CI, 15.9–20.7) among patients without COPD (P = 0.02) (Figure E3). Results did not change substantially in a sensitivity analysis using an alternative definition of COPD (COPD: 260% increase in NIV; no COPD: 360% increase in NIV) or in a sensitivity analysis where patients with COPD or cardiogenic pulmonary edema (300% increase in NIV) were compared with patients without COPD or cardiogenic pulmonary edema (340% increase in NIV). The proportion of

patients with COPD (Figure 2A) and without COPD (Figure 2B) who received MV showed a relative decline from 2000 to 2009 (COPD: −4.1% APC [95% CI, −2.4 to −5.8%]; no COPD: −1.4% APC [95% CI, −0.8 to −2.0%]).

The proportion of patients who received neither MV nor NIV increased among patients with COPD (1.3% APC; 95% CI, 0.3–2.4) but did not significantly change among patients without COPD (0.4% APC; 95% CI, −0.1 to 1.0). When patients with and without COPD were combined, the proportion of patients who did not receive MV or NIV did not change from 2000 to 2009 ($P = 0.09$).

Trends in NIV-Associated Diagnoses

Although COPD represented the most common diagnosis associated with use of NIV (52.6% of NIV use), among patients receiving NIV the proportion with a COPD diagnosis declined during the period from 2000 to 2009 (Figure 3).

NIV Failure

A greater percentage of patients without a COPD diagnosis who received NIV subsequently required MV (i.e., failed NIV) (69,374/335,717 [20.7%]) as compared with patients with COPD who received NIV (54,911/409,062 [13.4%]) (multivariable-adjusted OR, 1.19; 95% CI, 1.15–1.22; $P < 0.0001$). Table 2 demonstrates the other potential etiologies of acute respiratory failure that were associated with a greater risk of NIV failure than COPD. Among patients who received MV, those that experienced NIV failure before MV had greater hospital mortality (multivariable-adjusted OR, 1.14; 95% CI, 1.11–1.17; $P < 0.0001$). Our results did not appreciably differ in a sensitivity analysis using an alternative definition of COPD: the risk of NIV failure was greater in patients without COPD (OR, 1.19; 95% CI, 1.15–1.22), and patients with NIV failure had greater hospital mortality (OR, 1.13; 95% CI, 1.10–1.16).

Sensitivity Analysis Excluding Sleep Apnea

We identified 645,953 (5.5%) patients with acute respiratory failure who also had a sleep apnea diagnosis. A greater proportion of patients receiving NIV had sleep apnea (122,054/916,235 [13.3%]) than patients who did not receive NIV (523,899/10,219,350 [4.9%]). After excluding patients with sleep apnea, we found little change in our results. The proportion of patients with COPD who received NIV again increased from 3.2% in 2000 to 11.4% in 2009, and the proportion of patients without COPD receiving NIV increased from 1.1% in 2000 to 5.5% in 2009. The multivariable-associated risk of NIV failure was similarly higher in patients without a COPD diagnosis as compared with a COPD diagnosis (OR, 1.20; 95% CI, 1.16–1.24). Hospital mortality remained greater in patients who failed NIV than in those who did not receive NIV before MV (multivariable-adjusted OR, 1.16; 95% CI, 1.13–1.19).

Discussion

We investigated population-based trends in the use of NIV among patients with an acute respiratory failure diagnosis code in the United States. Despite substantial differences in the evidence base supporting use of NIV to treat acute respiratory failure from COPD or cardiogenic pulmonary edema as compared with other etiologies, NIV use increased at similar relative rates regardless of the potential etiology of respiratory failure. When NIV was used in situations with weaker supporting evidence, such as patients without a COPD diagnosis, NIV was more likely to fail. Patients who required MV after NIV failure were more likely to die in the hospital than patients who received MV via endotracheal tube without a preceding trial of NIV.

Our results expand upon two prior studies investigating NIV use trends (15, 24). Esteban and colleagues compared NIV use in 1998 with NIV use in 2004 among critically ill patients who received MV through an endotracheal tube or via NIV for at least 12 hours. The use of NIV was observed more frequently in 2004 (186/4,968 ventilated patients [3.7%]) than in 1998 (61/5,183 ventilated patients [1.1%]), with use increasing among patients with COPD (17% in 1998 vs. 44% in 2004) and patients with acute respiratory failure from other etiologies (4% in 1998 vs. 10% in 2004). Chandra and colleagues (15) investigated NIV trends in patients hospitalized with COPD and found a 4-fold increase in NIV and a decrease in use of MV from 1998 to 2008. Although the proportion of patients with COPD who received NIV was approximately 3 times greater in our study, most likely because our cohort was required to have an acute respiratory failure diagnosis code in addition to a COPD diagnosis, we observed similar NIV and MV trends among patients with COPD as Chandra and colleagues (15).

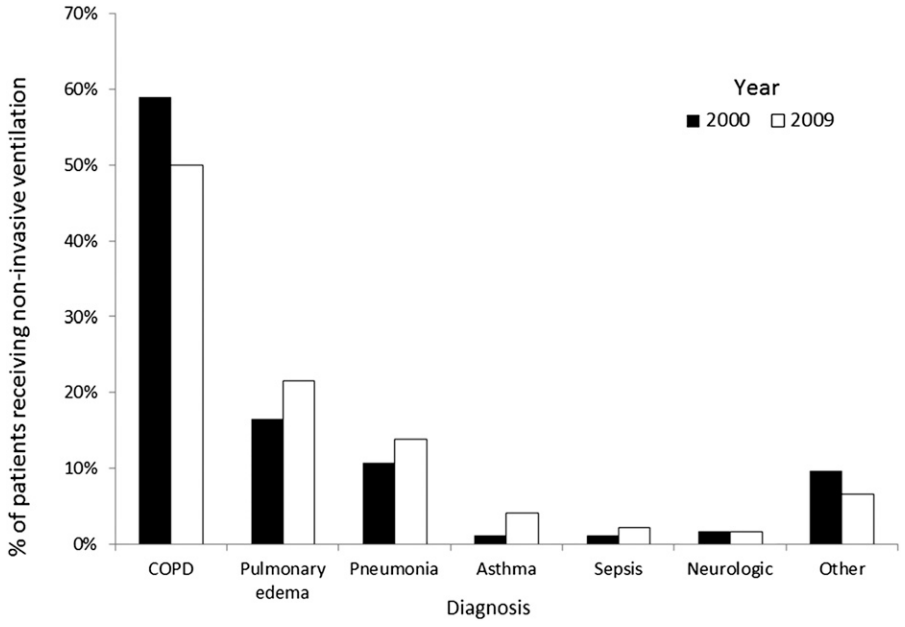

Figure 3. Changing etiologies of acute respiratory failure among patients receiving noninvasive ventilation, 2000 versus 2009.

Table 2. Failure of noninvasive ventilation among patients without chronic obstructive pulmonary disease compared with patients with chronic obstructive pulmonary disease

Acute respiratory failure etiology	Adjusted odds ratio (95% confidence interval) for failure of noninvasive ventilation
Chronic obstructive pulmonary disease (n = 409,062)*	Reference
Sepsis (n = 12,962)	1.07 (0.97–1.19)
Heart failure (n = 153,489)	1.08 (1.04–1.13)
Asthma (n = 24,438)	1.18 (1.09–1.28)
Pneumonia (n = 78,162)	1.56 (1.48–1.63)
Neurological diagnosis (n = 9,075)	1.70 (1.51–1.93)
Other/unknown diagnosis (n = 55,591)	0.95 (0.89–1.01)

*Weighted n.

Our findings of higher rates of NIV failure among patients without COPD are supported by findings of previous randomized trials (25, 26) and single-center observational studies (27, 28) A systemic review of randomized trials comparing NIV with standard care for acute hypoxemic respiratory failure showed marked heterogeneity in outcomes; no mortality benefit was observed in patients without COPD or cardiogenic pulmonary edema (29). Our results are also supported by previous studies that show an increase risk of death in patients with acute respiratory failure (28) or acute exacerbations of COPD (15) who fail NIV. The strength of our findings regarding use and outcomes associated with NIV during acute respiratory lies in the "real world" population-based data in which management was not controlled by clinical trial protocols or limited to a single center's experience.

Our study has limitations, most of which relate to our reliance on administrative data prepared for purposes of billing rather than clinical care or research. The ICD-9-CM codes used for our analyses depend on reliable healthcare provider identification and documentation of disease. Most ICD-9-CM validation studies (18, 23, 30, 31) demonstrate that claims data generally have lower sensitivity to identify diagnoses of interest but have high specificity, thus underestimating disease prevalence or incidence. Documentation in administrative data may reflect true trends in disease epidemiology or may represent evolving documentation in response to changing reimbursement algorithms (32). For example, hospitals may be increasingly likely to code "acute respiratory failure" when patients meet minimum criteria to garner the higher reimbursement associated with codes assigned a higher disease severity level. Such "upcoding" may explain our finding of a decreasing proportion of patients with acute respiratory failure codes receiving invasive mechanical ventilation in later study years. However, two observations argue against this: *1*) disease severity (as measured by number of organ failures) of patients with acute respiratory failure rose over time, suggesting a sicker population, and *2*) the proportion of patients with acute respiratory failure that received neither invasive ventilation nor NIV did not change over time, suggesting that the decreasing proportion of acute respiratory failure patients treated with invasive mechanical ventilation represents an increasing tendency to substitute NIV for treatment of respiratory failure. Using ICD-9-CM diagnosis codes, we could not ascertain with certainty the cause of acute respiratory failure, the indication for ventilatory support, disease severity, mitigating circumstances to clinical decision making (e.g., do not resuscitate status), or the temporality of diagnoses. In addition, we could not ascertain the location of care or setting in which NIV was implemented. Although some evidence supports the use of NIV in severely immunocompromised patients with hypoxemic respiratory failure (33), assessment of immunocompromised status was limited with administrative data alone; thus, we could not assess use or outcomes in immunocompromised patients. Given the observational study design, we could not establish a causal relationship between NIV failure or acute respiratory failure etiology and outcomes such as mortality.

Despite these limitations, the use of administrative data has a number of unique strengths. We were able to ascertain temporality between NIV and MV and procedure codes occurring on different hospital days; procedure codes for MV and NIV have previously been shown to be reliable (22, 23). In addition, Lagu and colleagues demonstrated that mortality risk adjustment using administrative data in critically ill patients with sepsis may be a "viable alternative" to severity of illness scores obtained from direct chart review (i.e., APACHE II and SAPS II) (34). The NIS data used for the present study do not reliably contain two data elements that were present in Lagu and colleagues (i.e., early use of intensive care and vasopressors); thus, risk adjustment using NIS is uncertain. Most importantly, we were able to observe trends in use of invasive ventilation and NIV over a decade among millions of patients with acute respiratory failure from a nationally representative sample of United States hospitals. Use of a national database such as the NIS provides a "real-world" view of provider practice patterns that are unlikely affected by potential "Hawthorne effects" and are more generalizable than limited patient or medical center characteristics of prospective cohorts, providing valuable information that allow for benchmarking of clinical practice and estimates of clinical effectiveness.

Our findings are consistent with prior surveys in which physicians expressed enthusiasm for the use of NIV in clinical indications with little supporting evidence (e.g., asthma, pneumonia) (1–4). This type of "spill-over" of medical technology from an indication with proven efficacy to other indications has occurred in other areas as well. As healthcare providers become more comfortable with a medical technology and witness "success stories" associated with its use, we may seek to find broader application for the technology for untested indications. One recent example of this phenomenon is the use of drug-eluting coronary artery stents. During the first 3 years after FDA approval of drug-eluting stents, approximately 50% of patients received a drug-eluting stent for an "off-label" or "untested" indication. (35, 36) Off-label use of drug-eluting stents was associated with worse outcomes than "on-label" use (35, 36), a finding that led an FDA advisory panel (37, 38) and revised societal guidelines

(37) to recommend greater caution when considering off-label or untested use of drug-eluting stents. After release of the FDA advisory panel recommendations, off-label use of drug-eluting stents declined by approximately 66% (39). Our findings of increasing use and worse outcomes associated with NIV use "outside of the evidence" are similar to those of drug-eluting stents. Unless further trial data emerge, we recommend similar caution and increased vigilance when selecting NIV for indications without strong supporting evidence. ■

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

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