Published in final edited form as:
Ann Am Thorac Soc. 2013 February ; 10(1): 10–17. doi:10.1513/AnnalsATS.201206-034OC.

Utilization of Non-Invasive Ventilation in Patients with Acute Respiratory Failure 2000-2009: A Population-Based Study

Allan J. Walkey, MD, MSc and
The Pulmonary Center, Division of Pulmonary and Critical Care Medicine, Department of Medicine, Boston University School of Medicine, Boston, MA, USA

Renda Soylemez Wiener, MD, MPH
The Pulmonary Center, Division of Pulmonary and Critical Care Medicine, Boston University School of Medicine, Boston, MA USA. Center for Health Quality, Outcomes, & Economic Research, Edith Nourse Rogers Memorial VA Hospital, Bedford, MA, USA

Abstract

Rationale—Although evidence supporting use of non-invasive 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 2000-2009 and compared NIV utilization trends and failure rates for cases with or without a diagnosis of COPD.

Results and Measurements—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 compared with 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) as compared to 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% CI 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% CI 1.11-1.17), p<0.0001.

Conclusion—Utilization 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; non-Invasive Ventilation; Positive-Pressure; Research; health services; outcome study

Corresponding author: Allan J. Walkey, MD, MSc, Boston University School of Medicine, The Pulmonary Center, R-304, 715 Albany Street, Boston, MA 02118, Phone (617) 638-4860, Fax (617) 638-4896, alwalkey@bu.edu.

Contributions: concept, design, data analysis, interpretation, drafting of manuscript

Introduction

Physicians report wide use of non-invasive ventilation (NIV) for a variety of clinical indications.(1-4) NIV may be particularly attractive to clinicians as it potentially offers an "easier," less invasive form of respiratory support for patients with acute respiratory failure than traditional mechanical ventilation implemented through an endotracheal tube (MV). 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 use of NIV during acute exacerbations of chronic obstructive pulmonary disease (COPD).(5) Findings supporting NIV for acute cardiogenic pulmonary edema are mixed,(6) though 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 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, utilization of NIV for acute exacerbations of COPD increased 4-fold from 1998-2008 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, utilization 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).

Methods

Data Source

We examined hospitalizations for adults (age ≥18 years) using year 2000-2009 discharge data from the Nationwide Inpatient Sample (NIS), Healthcare Cost and Utilization Project, Agency for Healthcare Research and Quality.(17) The NIS is an approximate 20% stratified probability sample of all non-Federal acute care hospitals and contains de-identified information from approximately 5-8 million hospital discharges yearly. NIS sampling strata are based on hospital characteristics such as ownership/control, teaching status, urban/rural location, US region and bed size. The 2000 NIS contained data from 994 hospitals in 28 states and the 2009 NIS included data from 1050 hospitals in 44 states. Abstracted NIS elements include 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, in order 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 sub-classified 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 (Table E1, online data 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 prior to 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 mechanical ventilation (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 (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, Maryland) to calculate the relative annual percent change (APC) in ventilator utilization and to test for differences in NIV utilization trends between COPD- and non-COPD- associated acute respiratory failure hospitalizations. Our primary outcome measure was the relative change in NIV utilization. Because of the evidence in support of NIV for cardiogenic pulmonary edema, we performed a sensitivity analysis comparing NIV utilization trends in patients with COPD or cardiogenic pulmonary edema to 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 based upon COPD status. We used similar multivariable-adjusted logistic regression models (including above covariates, 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 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 alpha 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 2000-2009, 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 (Figure E1, online data supplement). From years 2000-2009 the incidence of acute respiratory failure-coded hospitalizations/increased from 165 to 257/100,000 US residents (56% increase) for patients with COPD and increased from 238 to 463/100,000 (95% increase) in patients without COPD. (Figure E2, online data supplement).

Trends in NIV and MV

Population-based utilization of NIV during a hospitalization with an acute respiratory failure claim increased in patients with COPD from 8.6 to 39/100,000 US residents (360% increase) and NIV utilization in patients without COPD increased from 6 to 39 patients/100,000 US residents during years 2000-2009 (560% increase); 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 2000-2009. 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, online data supplement). 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 to 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 2000-2009 [COPD: −4.1% APC (95% CI −2.4, −5.8%); No COPD: −1.4% APC (95% CI −0.8, −2.0%)].

The proportion of patients who received neither MV nor NIV increased among patients with COPD [1.3% APC (0.3, 2.4)] but did not significantly change among patients without COPD [0.4% APC (−0.1, 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 2000-2009 (p=0.09).

Trends in NIV-Associated Diagnoses

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

NIV Failure

A greater percentage of patients without a COPD diagnosis who received NIV subsequently required MV (i.e., failed NIV) [69,374/335717 (20.7%)] as compared to patients with COPD who received NIV [54,911/409,062 (13.4%)], multivariable-adjusted OR 1.19 (95% confidence intervals (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 prior to MV had greater hospital mortality, multivariable-adjusted OR 1.14 (95% CI 1.11-1.17), $p<0.0001$. 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 to with a COPD diagnosis [OR 1.20 (95% CI 1.16-1.24)]. Hospital mortality remained greater in patients who failed NIV than those that did not receive NIV prior to 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 to other etiologies, NIV utilization 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. Importantly, 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 utilization trends.(15, 24) Esteban et al. compared NIV utilization in 1998 with utilization in 2004 among critically ill patients who received MV through either an endotracheal tube or via NIV for at least 12 hours. Use of NIV was observed more frequently in 2004 [186/4968 ventilated patients (3.7%)] than in 1998 [61/5183 ventilated patients (1.1%)], with use increasing among both 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 et al. investigated NIV trends in patients hospitalized with COPD and found a 4-fold increase in NIV and a decrease in use of MV from 1998-2008. 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 et al.

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 to 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 utilization 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.

We recognize that 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 has lower sensitivity to identify diagnoses of interest, but high specificity, thus underestimating disease prevalence or incidence. Documentation in administrative data may reflect true trends in disease epidemiology or alternatively, may represent evolving documentation in response to changing reimbursement algorithms.(32) For example, over recent years hospitals may be increasingly likely to code "acute respiratory failure" when patients meet minimum criteria, in order 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 actually rose over time, suggesting a sicker population; 2) the proportion of patients with acute respiratory failure that received neither invasive nor non-invasive ventilation 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 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 utilization or outcomes in the immunocompromised. 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, 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 et al. 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 (ie, APACHE II and SAPS II). (34) Of note, the NIS data used for the present study does not reliably contain two data elements that were present in Lagu et al. (ie.,early use of intensive care and vasopressors), thus risk-adjustment using NIS is currently uncertain. Most importantly, we were able to observe trends in use of invasive and non-invasive ventilation over a decade among millions of patients with acute respiratory failure from a nationally representative sample of U.S. 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 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 three 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 utilization 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.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Support: R21HL112672 (AJW) K07 CA138772 (RSW) and the Department of Veterans Affairs (RSW). No funding organization had a role in the design or conduct of the study.

References

1. Hess DR, Pang JM, Camargo CA Jr. A survey of the use of noninvasive ventilation in academic emergency departments in the United States. Respir Care. 2009; 54:1306–1312. [PubMed: 19796409]
2. Burns KE, Sinuff T, Adhikari NK, Meade MO, Heels-Ansdell D, Martin CM, Cook DJ. Bilevel noninvasive positive pressure ventilation for acute respiratory failure: survey of Ontario practice. Crit Care Med. 2005; 33:1477–1483. [PubMed: 16003051]
3. Crimi C, Noto A, Princi P, Esquinas A, Nava S. A European survey of noninvasive ventilation practices. Eur Respir J. 2010; 36:362–369. [PubMed: 20075052]
4. Bierer GB, Soo Hoo GW. Noninvasive ventilation for acute respiratory failure: a national survey of Veterans Affairs hospitals. Respir Care. 2009; 54:1313–1320. [PubMed: 19796410]
5. Ram FS, Picot J, Lightowler J, Wedzicha JA. Non-invasive positive pressure ventilation for treatment of respiratory failure due to exacerbations of chronic obstructive pulmonary disease. Cochrane Database Syst Rev. 2004; (3):CD004104.
6. Gray A, Goodacre S, Newby DE, Masson M, Sampson F, Nicholl J. 3CPO Trialists. Noninvasive ventilation in acute cardiogenic pulmonary edema. N Engl J Med. 2008; 359:142–151. [PubMed: 18614781]
7. Weng CL, Zhao YT, Liu QH, Fu CJ, Sun F, Ma YL, Chen YW, He QY. Meta-analysis: Noninvasive ventilation in acute cardiogenic pulmonary edema. Ann Intern Med. 2010; 152:590–600. [PubMed: 20439577]

8. Ram FS, Wellington S, Rowe BH, Wedzicha JA. Non-invasive positive pressure ventilation for treatment of respiratory failure due to severe acute exacerbations of asthma. Cochrane Database Syst Rev. 2005; (1):CD004360.

9. Wysocki M, Tric L, Wolff MA, Millet H, Herman B. Noninvasive pressure support ventilation in patients with acute respiratory failure. A randomized comparison with conventional therapy. Chest. 1995; 107:761–768. [PubMed: 7874950]

10. Confalonieri M, Potena A, Carbone G, Porta RD, Tolley EA, Umberto Meduri G. Acute respiratory failure in patients with severe community-acquired pneumonia. A prospective randomized evaluation of noninvasive ventilation. Am J Respir Crit Care Med. 1999; 160:1585–1591. [PubMed: 10556125]

11. British Thoracic Society Standards of Care Committee. Non-invasive ventilation in acute respiratory failure. Thorax. 2002; 57:192–211. [PubMed: 11867822]

12. Organized jointly by the American Thoracic Society, the European Respiratory Society, the European Society of Intensive Care Medicine, and the Societe de Reanimation de Langue Francaise, and approved by ATS Board of Directors, December 2000. International Consensus Conferences in Intensive Care Medicine: noninvasive positive pressure ventilation in acute Respiratory failure. Am J Respir Crit Care Med. 2001; (163):283–291. [PubMed: 11208659]

13. Keenan SP, Sinuff T, Burns KE, Muscedere J, Kutsogiannis J, Mehta S, Cook DJ, Ayas N, Adhikari NK, Hand L, Scales DC, Pagnotta R, Lazosky L, Rocker G, Dial S, Laupland K, Sanders K, Dodek P. Canadian Critical Care Trials Group/Canadian Critical Care Society Noninvasive Ventilation Guidelines Group. Clinical practice guidelines for the use of noninvasive positive-pressure ventilation and noninvasive continuous positive airway pressure in the acute care setting. CMAJ. 2011; 183:E195–214. [PubMed: 21324867]

14. Schonhofer B, Kuhlen R, Neumann P, Westhoff M, Berndt C, Sitter H. Clinical practice guideline: non-invasive mechanical ventilation as treatment of acute respiratory failure. Dtsch Arztebl Int. 2008; 105:424–433. [PubMed: 19626185]

15. Chandra D, Stamm JA, Taylor B, Ramos RM, Satterwhite L, Krishnan JA, Mannino D, Sciurba FC, Holguin F. Outcomes of noninvasive ventilation for acute exacerbations of chronic obstructive pulmonary disease in the United States, 1998-2008. Am J Respir Crit Care Med. 2012; 185:152–159. [PubMed: 22016446]

16. Walkey AJ, Wiener RS. Utilization Of Non-Invasive Ventilation In Patients With Acute Respiratory Failure From 2000-2009: A Population-Based Study [abstract]. Am J Respir Crit Care Med. 2012; 185:A6488.

17. HCUP Nationwide Inpatient Sample (NIS). Healthcare Cost and Utilization Project (HCUP). Agency for Healthcare Research and Quality. Rockville, MD: 1998-2009.

18. Stein BD, Bautista A, Schumock GT, Lee TA, Charbeneau JT, Lauderdale DS, Naureckas ET, Meltzer DO, Krishnan JA. The validity of International Classification of Diseases, Ninth Revision, Clinical Modification diagnosis codes for identifying patients hospitalized for COPD exacerbations. Chest. 2012; 141:87–93. [PubMed: 21757568]

19. Quan H, Sundararajan V, Halfon P, Fong A, Burnand B, Luthi JC, Saunders LD, Beck CA, Feasby TE, Ghali WA. Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data. Med Care. 2005; 43:1130–1139. [PubMed: 16224307]

20. Martin GS, Mannino DM, Eaton S, Moss M. The epidemiology of sepsis in the United States from 1979 through 2000. N Engl J Med. 2003; 348:1546–1554. [PubMed: 12700374]

21. Angus DC, Linde-Zwirble WT, Lidicker J, Clermont G, Carcillo J, Pinsky MR. Epidemiology of severe sepsis in the United States: analysis of incidence, outcome, and associated costs of care. Crit Care Med. 2001; 29:1303–1310. [PubMed: 11445675]

22. Quan H, Parsons GA, Ghali WA. Validity of procedure codes in International Classification of Diseases, 9th revision, clinical modification administrative data. Med Care. 2004; 42:801–809. [PubMed: 15258482]

23. Chio A, Ciccone G, Calvo A, Vercellino M, Di Vito N, Ghiglione P, Mutani R. Piemonte and Valle d'Aosta Register for ALS. Validity of hospital morbidity records for amyotrophic lateral sclerosis. A population-based study J Clin Epidemiol. 2002; 55:723–727.

24. Esteban A, Ferguson ND, Meade MO, Frutos-Vivar F, Apezteguia C, Brochard L, Raymondos K, Nin N, Hurtado J, Tomicic V, Gonzalez M, Elizalde J, Nightingale P, Abroug F, Pelosi P, Arabi Y, Moreno R, Jibaja M, D'Empaire G, Sandi F, Matamis D, Montanez AM, Anzueto A. Evolution of mechanical ventilation in response to clinical research. Am J Respir Crit Care Med. 2008; 177:170–7. [PubMed: 17962636]
25. Delclaux C, L'Her E, Alberti C, Mancebo J, Abroug F, Conti G, Guerin C, Schortgen F, Lefort Y, Antonelli M, Lepage E, Lemaire F, Brochard L. Treatment of acute hypoxemic nonhypercapnic respiratory insufficiency with continuous positive airway pressure delivered by a face mask: A randomized controlled trial. JAMA. 2000; 284:2352–2360. [PubMed: 11066186]
26. Kramer N, Meyer TJ, Meharg J, Cece RD, Hill NS. Randomized, prospective trial of noninvasive positive pressure ventilation in acute respiratory failure. Am J Respir Crit Care Med. 1995; 151:1799–1806. [PubMed: 7767523]
27. Phua J, Kong K, Lee KH, Shen L, Lim TK. Noninvasive ventilation in hypercapnic acute respiratory failure due to chronic obstructive pulmonary disease vs. other conditions: effectiveness and predictors of failure. Intensive Care Med. 2005; 31:533–539. [PubMed: 15742175]
28. Carrillo A, Gonzalez-Diaz G, Ferrer M, Martinez-Quintana ME, Lopez-Martinez A, Llamas N, Alcazar M, Torres A. Non-invasive ventilation in community-acquired pneumonia and severe acute respiratory failure. Intensive Care Med. 2012; 38:458–466. [PubMed: 22318634]
29. Keenan SP, Sinuff T, Cook DJ, Hill NS. Does noninvasive positive pressure ventilation improve outcome in acute hypoxemic respiratory failure? A systematic review. Crit Care Med. 2004; 32:2516–2523. [PubMed: 15599160]
30. Birman-Deych E, Waterman AD, Yan Y, Nilasena DS, Radford MJ, Gage BF. Accuracy of ICD-9-CM codes for identifying cardiovascular and stroke risk factors. Med Care. 2005; 43:480–485. [PubMed: 15838413]
31. Walkey AJ, Wiener RS, Ghobrial JM, Curtis LH, Benjamin EJ. Incident stroke and mortality associated with new-onset atrial fibrillation in patients hospitalized with severe sepsis. JAMA. 2011; 306:2248–2254. [PubMed: 22081378]
32. Lindenauer PK, Lagu T, Shieh M, Pekow PS, Rothberg MB. Association of Diagnostic Coding With Trends in Hospitalizations and Mortality of Patients With Pneumonia, 2003-2009. JAMA: The Journal of the American Medical Association. 2012; 307:1405–1413. [PubMed: 22474204]
33. Hilbert G, Gruson D, Vargas F, Valentino R, Gbikpi-Benissan G, Dupon M, Reiffers J, Cardinaud JP. Noninvasive ventilation in immunosuppressed patients with pulmonary infiltrates, fever, and acute respiratory failure. N Engl J Med. 2001; 344:481–487. [PubMed: 11172189]
34. Lagu T, Lindenauer PK, Rothberg MB, Nathanson BH, Pekow PS, Steingrub JS, Higgins TL. Development and validation of a model that uses enhanced administrative data to predict mortality in patients with sepsis. Crit Care Med. 2011; 39:2425–2430. [PubMed: 22005222]
35. Beohar N, Davidson CJ, Kip KE, Goodreau L, Vlachos HA, Meyers SN, Benzuly KH, Flaherty JD, Ricciardi MJ, Bennett CL, Williams DO. Outcomes and complications associated with off-label and untested use of drug-eluting stents. JAMA. 2007; 297:1992–2000. [PubMed: 17488964]
36. Win HK, Caldera AE, Maresh K, Lopez J, Rihal CS, Parikh MA, Granada JF, Marulkar S, Nassif D, Cohen DJ, Kleiman NS. EVENT Registry Investigators. Clinical outcomes and stent thrombosis following off-label use of drug-eluting stents. JAMA. 2007; 297:2001–2009. [PubMed: 17488965]
37. King SB 3rd, Smith SC Jr, Hirshfeld JW Jr, Jacobs AK, Morrison DA, Williams DO, 2005 WRITING COMMITTEE MEMBERS. Feldman TE, Kern MJ, O'Neill WW, Schaff HV, Whitlow PL, Adams CD, Anderson JL, Buller CE, Creager MA, Ettinger SM, Halperin JL, Hunt SA, Krumholz HM, Kushner FG, Lytle BW, Nishimura R, Page RL, Riegel B, Tarkington LG, Yancy CW. 2007 Focused Update of the ACC/AHA/SCAI 2005 Guideline Update for Percutaneous Coronary Intervention: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines: 2007 Writing Group to Review New Evidence and Update the ACC/AHA/SCAI 2005 Guideline Update for Percutaneous Coronary Intervention, Writing on Behalf of the 2005 Writing Committee. Circulation. 2008; 117:261–295. [PubMed: 18079354]
38. Farb A, Boam AB. Stent thrombosis redux--the FDA perspective. N Engl J Med. 2007; 356:984–987. [PubMed: 17296827]

39. Roe MT, Chen AY, Cannon CP, Rao S, Rumsfeld J, Magid DJ, Brindis R, Klein LW, Gibler WB, Ohman EM, Peterson ED. CRUSADE and ACTION-GWTG Registry Participants. Temporal changes in the use of drug-eluting stents for patients with non-ST-Segment-elevation myocardial infarction undergoing percutaneous coronary intervention from 2006 to 2008: results from the can rapid risk stratification of unstable angina patients supress ADverse outcomes with early implementation of the ACC/AHA guidelines (CRUSADE) and acute coronary treatment and intervention outcomes network-get with the guidelines (ACTION-GWTG) registries. Circ Cardiovasc Qual Outcomes. 2009; 2:414–420. [PubMed: 20031871]

Abbreviations

APC	annual percent change
CI	Confidence Interval
COPD	Chronic obstructive pulmonary disease
ICD-9-CM	*International Classification of Disease, 9th Revision, Clinical Modification*
MV	Mechanical ventilation through endotracheal tube
NIV	Non-invasive ventilation
NIS	Nationwide Inpatient Sample
OR	odds ratio

At a Glance Commentary

Scientific Knowledge on the Subject: Utilization of non-invasive ventilation during exacerbations of chronic obstructive pulmonary disease has increased in association with strong evidence demonstrating clinical outcome benefits. Population-based utilization and outcomes of non-invasive ventilation for indications with weaker supporting evidence are unclear.

What This Study Adds to the Field: Utilization of non-invasive ventilation during acute respiratory failure has increased similarly for patients with and without chronic obstructive lung disease. Patients without chronic obstructive pulmonary disease are more likely to experience failure of non-invasive ventilation, and those who fail NIV experience higher in-hospital mortality.

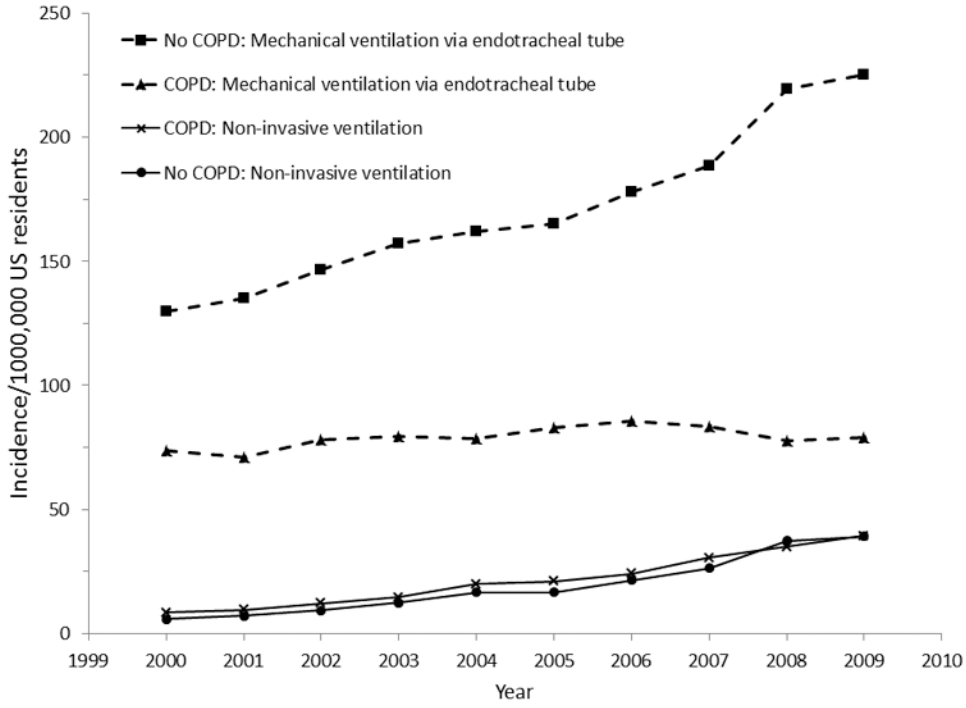

Figure 1.
Population incidence of mechanical ventilation and non-invasive ventilation utilization among patients with an acute respiratory failure diagnosis in the United States, 2000-2009.

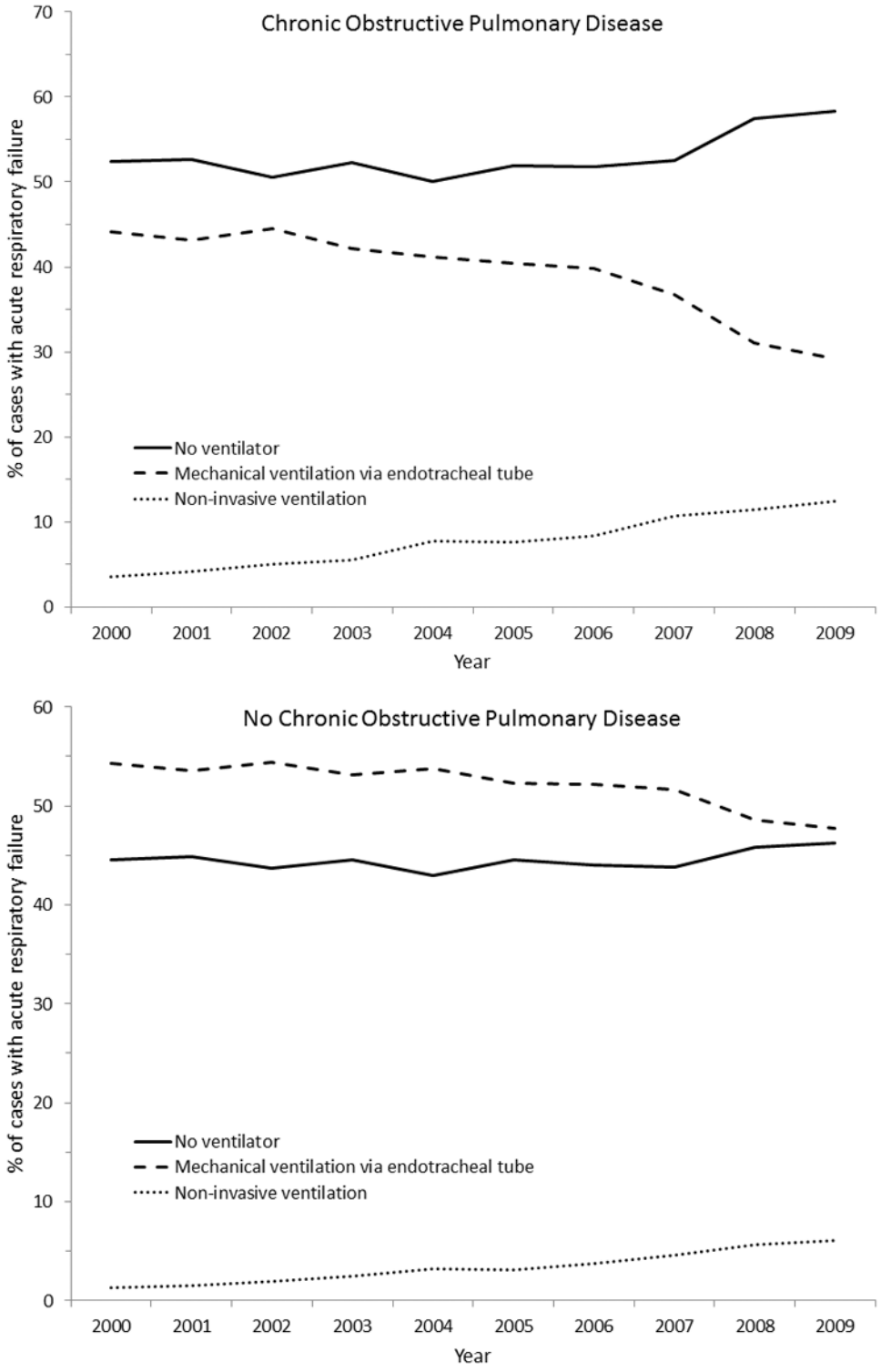

Figure 2.

2A: United States trends in ventilator practice patterns during acute respiratory failure hospitalizations among patients with chronic obstructive pulmonary disease, 2000-2009.

2B: United States trends in ventilator practice patterns during acute respiratory failure hospitalizations among patients without a diagnosis of chronic obstructive pulmonary disease, 2000-2009.

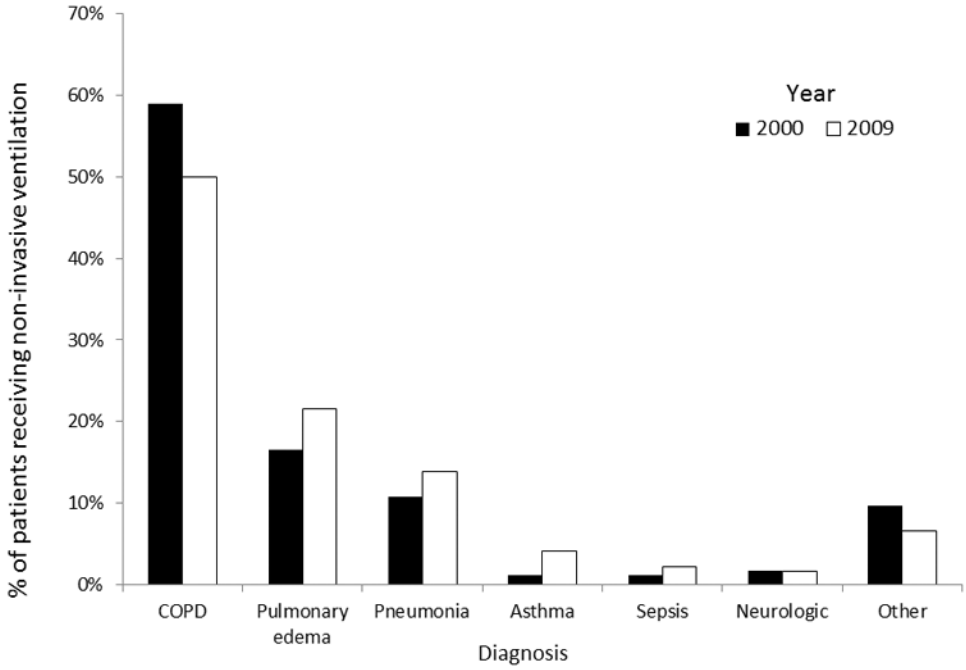

Figure 3.
Changing etiologies of acute respiratory failure among patients receiving non-invasive ventilation, 2000 vs. 2009.

Table 1
Characteristics of patients with acute respiratory failure by year

Weighted N (%) unless otherwise specified	2000 Unweighted n=172,629 Weighted n=841,817	2009 Unweighted n=331,573 Weighted n=1,673,631
Age, years, 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/plegia	18,672 (2.2)	53,832 (3.2)
Neutropenia	14,668 (1.7)	75,641 (4.5)
Human immunodeficiency virus	8281 (1.0)	12,958 (0.77)
Acute non-respiratory organ failures		
Total # 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)

Weighted N (%) unless otherwise specified	2000 Unweighted n=172,629 Weighted n=841,817	2009 Unweighted n=331,573 Weighted n=1,673,631
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)
US 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)	1053827 (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)

Table 2

Failure of non-invasive ventilation among patients without COPD compared to patients with COPD

Acute respiratory failure etiology Weighted N	Adjusted odds ratio (95% CI) for failure of Non-invasive ventilation
COPD 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=9075	1.70 (1.51-1.93)
Other/unknown diagnosis N=55,59	0.95 (0.89-1.01)