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Epidemiology and Outcomes of Acute Respiratory Failure in the United States, 2001 – 2009: A National Survey

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Abstract

Background—The objective of this study was to evaluate trends in hospitalization, cost, and short-term outcomes in acute respiratory failure (ARF) between 2001 and 2009 in the United States.

Methods—Using the Nationwide Inpatient Sample we identified cases of ARF based on *International Classification for Diseases, Ninth Revision, Clinical Modification* codes. We calculated weighted frequencies of ARF hospitalizations by year and estimated population adjusted incidence and mortality rates. We used logistic regression to examine hospital mortality rates over time while adjusting for changes in demographic characteristics and comorbidities of patients.

Results—The number of hospitalizations with a diagnosis of ARF rose from 1,007,549 in 2001 to 1,917,910 in 2009 with an associated increase in total hospital costs from 30.1 billion to 54.3 billion. During the same period we observed a decrease in hospital mortality from 27.6% in 2001 to 20.6% in 2009, a slight decline in average length of stay from 7.8 days to 7.1 days, and no

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Authors' contribution

Dr. Stefan had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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significant change in the mean cost per case (\$ 15, 900). Rates of mechanical ventilation (noninvasive, NIV or invasive mechanical ventilation, IMV) remained stable over the nine-year period and the use of NIV increased from 4% in 2001 to 10% in 2009.

Conclusions—Over the period of 2001–2009 there was a steady increase in the number of hospitalizations with a discharge diagnosis of ARF, with a decrease in inpatient mortality. There was a significant shift during this time toward the use of NIV, with a decrease in the rates of IMV use.

Keywords

respiratory insufficiency; case-fatality; incidence; mortality; mechanical ventilation

Background

Acute Respiratory Failure (ARF), a common and serious complication in hospitalized patients, may be caused by several conditions including pneumonia, COPD, adult respiratory distress syndrome (ARDS), and congestive heart failure (CHF). Although ARF is conventionally defined by an arterial oxygen tension of <60 mmHg, an arterial carbon dioxide tension of >45 mmHg, or both, these thresholds serve as a guide to be used in combination with history and clinical assessment of the patient.^{1, 2} Supplemental oxygen and treatment of the underlying cause is the mainstay of therapy for ARF, but in severe cases patients are treated with invasive mechanical ventilation (IMV) or noninvasive ventilation (NIV). ARF is the most frequent reason for admission to the intensive care unit (ICU)^{3, 4} and has an in-hospital mortality rate of 33–37% among those who require IMV.^{5, 6} The majority of epidemiologic studies of ARF have been limited to patients requiring mechanical ventilation or those admitted to the ICU and information about the characteristics and outcomes of patients across the full spectrum of severity is much more limited.^{5, 7–11} General improvements in the management of underlying conditions, implementation of more effective ventilation strategies,^{12, 13} and increasing use of NIV^{14, 15} may have led to better outcomes for patients with ARF, yet empirical evidence of a change in the adjusted mortality rate over time is lacking.

The objective of this study was to provide a broad characterization of the epidemiology of ARF among adults hospitalized in the US using a large, nationally representative database. We sought to evaluate whether incidence, mortality, cost, or ventilation practice associated with ARF in the U.S. changed over the period of 2001–2009.

Methods

Data source

We utilized data from the Nationwide Inpatient Sample (NIS) of the Health Care Cost and Utilization Project¹⁶, which is a 20% stratified probability sample of all US acute-care hospitals each year. This data is drawn from a sampling frame that contains close to 95% of all discharges in the US, with the hospital discharge record as the unit of analysis. The NIS has been used to study trends in many different diagnoses.^{17–19} The database contains demographic information, payer information, principal and secondary diagnoses, cost, discharge disposition, and death during hospitalization. It also contains information on hospital characteristics including ownership, size, teaching status, and geographic region.

Definitions

We included patients 18 years discharged between 2001 and 2009 with a primary or secondary diagnosis of ARF. We identified cases of ARF using diagnostic codes

(International Classification of Diseases, Ninth Revision, Clinical Modification, ICD-9-CM) previously used in studies of acute organ dysfunction in sepsis (518.81, 518.82, 518.84, 518.4, 799.1, 786.09).^{17, 20, 21} To define ARDS we relied on ICD-9-CM codes (518.4, 518.82, 518.5, 786.09) used in prior studies which showed good sensitivity and specificity.^{22,23} The use of ventilatory support was identified using the ICD-9-CM procedure codes²⁴ (93.90, 93.70, 93.71, 93.76). Comorbidities were classified using the AHRQ's HCUP Comorbidity Software, version 3.10–3.5.²⁵

Outcomes

The primary outcomes included the annual number of hospitalizations, population incidence, hospital mortality, and costs of care. Secondary outcomes included length of stay, most common diagnoses associated with ARF, disposition at discharge, and use and type of ventilatory support.

Analysis

We estimated the number of hospitalizations with a diagnosis of ARF/year and we calculated the weighted frequencies following HCUP-NIS recommendations using SAS/STAT SURVEY procedures. Using population estimates for years 2001 to 2009 from the US Census Bureau, we employed direct standardization to calculate age-, gender- and race-adjusted population incidence and mortality rates of ARF per 100,000 population. Hospital mortality was defined as the ratio of ARF hospitalizations ending in death divided by total number of ARF hospitalizations. Mechanical ventilation rates and rates of selected comorbidities were similarly defined.

We employed indirect standardization to adjust hospital mortality rates for age, sex, race/ethnicity, comorbidities, and hospital characteristics using logistic regression models from 2001 to predict hospital mortality for 2002 to 2009. We used linear regression models to test whether the slope of year was significant for trends in outcomes overtime. Costs were calculated using hospital-specific cost-to-charge ratios when available and a weighted group average at the state level for remaining hospitals. We converted all costs to 2009 US dollars using the Consumer Price Index. Costs and lengths of stay were not normally distributed, so we calculated weighted geometric means (the average of all logarithmic values), then converted back to a base-ten number. Using a Taylor series expansion, we then calculated standard errors. All analyses were performed using SAS version 9.2 (SAS Institute, Inc., Cary, NC).

The Baystate Medical Center IRB determined that the project did not constitute human subjects research.

Results

Hospitalization trends

The number of hospitalizations with an ARF diagnosis code increased at an average annual rate of 11.3% from 1,007,549 (SD=19,268) in 2001 to 1,917,910 (SD=47,558) in 2009. More than two-thirds of ARF admissions were associated with medical, rather than surgical, conditions (69.5% in 2001 and 71.2% in 2009). The median age, racial make-up and gender did not change significantly. Over the study period we observed an increase in ARF-related hospitalizations in large, urban, teaching hospitals and in hospitals located in the Midwest (Table 1).

After adjusting for age and sex, the population incidence of ARF increased from 502 (SE=10) cases per 100,000 in 2001 to 784 (SE=19) cases per 100,000 in 2009 (a 56%

increase, $p < 0.0001$). Hispanics had the lowest rates of ARF with both black and white groups having similar rates (Table 2).

The most common etiologies of ARF among medical patients were pneumonia, CHF, ARDS, COPD exacerbation, and sepsis. Over the nine-year study, the proportion of cases secondary to pneumonia and sepsis rose significantly: from 39% to 46% and 13% to 21% respectively. (Figure 1)

Mortality and other outcomes

The number of in-hospital deaths related to ARF increased from 277,407 deaths in 2001 to 381,155 in 2009 (a 37% increase; $p < .001$). Standardized to the population, deaths increased from 140 in 2001 to 154 cases per 100,000 in 2009 (a 10% increase $p = 0.027$). Despite slightly increasing mortality rates at a population level, adjusted in-hospital mortality improved from 27.6% in 2001 to 20.6% in 2009 ($p < 0.001$). Mortality declined for both invasive (IMV) and non-invasive (NIV) ventilated patients from 35.3% in 2001 to 30.2% in 2009 and from 23.5% to 19% respectively, but increased for those who required both NIV and IMV (from 26.9% in 2001 to 28% in 2009).

Adjusted hospital length of stay decreased from 7.8 days per patient in 2001 to 7.1 days in 2009 ($p < .001$), with a concomitant increase in discharges to nursing facilities, from 24% in 2001 to 29% in 2009. There was no linear trend in adjusted cost per case, with \$15,818 in 2001 and \$15,987 in 2009 (in 2009 US dollars) (Table 1).

Ventilation practices

Overall, 50.9% patients received ventilatory support (NIV or IMV or both) in 2001 and 49.7% in 2009 ($p = 0.25$). The use of NIV increased from 3.8% to 10.1% ($p < .001$), a 169% increase, while the utilization of IMV decreased from 48.5% in 2001 to 42.1% in 2009 (p for trend $< .0001$), a 13% decrease. Uses of both NIV and IMV during hospitalization were seen in 1.4% of cases in 2001 and 2.5% of cases in 2009.

2009 data analysis

In 2009 the 1,917,910 hospitalizations with ARF resulted in 381,155 (SD= 8,965) deaths and a total inpatient cost of \$54 billion. The most common etiologies in patients over 65 years were pneumonia, CHF, COPD, ARDS, and sepsis. In patients younger than 45 years the most frequent diagnoses were: pneumonia, ARDS, sepsis, asthma, drug ingestion and trauma. Stratified analysis by gender and by age groups showed that mortality rates among men were higher than for women and were highest in patients older than 85 years (Table 3).

When we examined ventilation practices among medical patients we found that patients older than 85 years, when compared to patients younger than 45 years, were less likely to be treated with IMV (25% vs. 55%) and more likely to be treated with NIV (12.7% vs. 7%). At the same time, the average cost per case was lowest among patients 85 years and older, and hospital costs per case fell sharply after age 70. Costs were considerably higher for those who did not survive during hospitalization, particularly for patients younger than 45 years. Figure 2

Discussion

In this large population-based study we found that the number of hospitalizations associated with a diagnosis of ARF almost doubled over a nine year period. In 2009 there were nearly 2 million hospitalizations with ARF in the US resulting in approximately 380,000 deaths and inpatient costs of over \$54 billion. The population-adjusted ARF-hospitalization rates

increased in all age groups and patients 85 years and older had the highest age-specific hospitalization rate. While overall rates of mechanical ventilation (NIV or IMV) remained stable over the nine-year period, there was an important shift away from IMV (which decreased from 48% in 2001 to 42% in 2009) towards NIV (which increased from 4% in 2001 to 10% in 2009). Overall, there was a significant increase in the number of total deaths despite a decline in adjusted in-hospital mortality rates. In-hospital mortality rates decreased for all cases of ARF regardless of ventilation choice.

The findings of this study mirror results of others which have shown that while the incidence of critical care illnesses like sepsis^{17, 20, 21, 26} and acute renal failure²⁷ has increased over the last decade, in-hospital mortality rates have decreased.^{20, 21, 28} Our results also compliment the results of a recent study that looked at hospitalizations for noncardiogenic ARF which observed a 3.7 fold increase in the number of cases and a steady decline in case fatality.¹¹

Most prior studies addressing the incidence of ARF have included only patients receiving mechanical ventilation. In 1994 the estimated number of cases of ARF requiring IMV was 329,766⁹ which increased to 790,257 in 2005.¹⁰ In our study we found that in 2009 the number of patients with ARF hospitalizations with IMV increased to 806,538. The increase in the overall number of cases with ARF was mainly driven by a surge in cases of sepsis and pneumonia. Our findings are consistent with national trends over time in noncardiogenic ARF¹¹ and in conditions that predispose patients to ARF such as sepsis^{17, 20, 28} and acute renal failure.²⁷ As the number of claims for ARF doubled and the number of deaths increased, we found that adjusted hospital mortality improved from 27.6% in 2001 to 20.6% in 2009. This decline in hospital mortality was observed among all patients groups, regardless of ventilation choice. The decline in overall case fatality is consistent with prior findings in noncardiogenic ARF,¹¹ sepsis,^{17, 28} and CHF.²⁹

There are a number of potential explanations for the reduction in mortality observed over the study period, including improvements in hospital management of the underlying conditions leading to ARF, an increase in the proportion of patients being treated with NIV,³⁰ and advances in the care of critically ill patients like the use of low-tidal volume ventilation.^{31, 32} Another contributor may be an increase in the proportion of discharges to nursing facilities, although this change in discharge disposition cannot fully explain our findings. For example, from 2007 to 2009 mortality decreased by 2 percentage points and nursing home discharges increased by only 0.4 percentage points. Growth and aging of the US population only partially explain the increase we observed in the incidence of ARF, as age- and sex-adjusted population rates increased by 56% from 2001 to 2009. In addition, NIS captures data on hospital discharges and not individual patients; thus, a patient may have had multiple admissions. Over the last decade adoption of a more intensive practice style has been associated with improved in-hospital mortality^{33, 34} and while these patients may be living longer they may have multiple readmissions.^{35, 36}

We also observed that older patients were less likely to be treated with IMV, had a higher mortality rate and less expensive care. These results are consistent with other studies and suggest that the intensity of treatment decreases with increasing age and decisions to withhold or withdraw life-supporting treatments are more frequent in the elderly.^{26, 37} Prior research has shown that severity of illness is more important than age on patients' prognosis^{38, 39} and aggressive treatment strategies are not less cost-effective when provided to older patients.⁴⁰

Another important finding of this study is the marked increase in the use of NIV paired with a modest reduction in the use of IMV in the treatment of patients with ARF. This finding

adds to evidence from other studies which have similarly reported a dramatic increase in the use of NIV and a decrease in the use of IMV in patients with COPD as well as in ARF of other etiologies.^{30, 41}

Our work has several limitations. First, we identified ARF based on ICD-9-CM codes and therefore cannot exclude disease misclassification. We did not find any studies in the literature addressing the accuracy and the completeness of ARF coding. However, we employed the same codes used to define ARF as has been used to define organ dysfunction in studies of severe sepsis^{17, 20} and the ICD-9-CM codes that we used to identify cases of ARDS have been used in prior studies.^{11, 22, 23} Another limitation is that it is not clear to what extent the trends we observed may be due to changes in over time in documentation and coding practices. While this should be considered given the additional reimbursement associated with the diagnosis of ARF, our observation that rates of assisted ventilation have remained almost flat over the nine-year period of the study suggest that would not wholly account for the rise in ARF. Second, because we did not have access to physiological data such as results of blood gas testing we could not determine whether the threshold for applying the diagnosis of ARF or for delivering ventilatory support has changed over time. Third, for the purpose of this study we employed a broad definition of ARF, not limiting cases to those requiring mechanical ventilation, and this led to a more heterogeneous cohort including less severe cases of ARF. However, this is not dissimilar to the heterogeneity in disease severity observed among patients who receive a diagnosis of heart failure or acute renal failure. Fourth, survivors of ARF remain at high risk of death in the months after hospitalization⁴² but we assessed only in-hospital mortality. It is possible that while in-hospital mortality has improved, 30-day mortality remained stable. Finally, as NIS contains only discharge-level data we could not distinguish between patients admitted for ARF from those who developed ARF (potentially iatrogenic) after admission.

In summary, over the period of 2001–2009 there was a large increase in the number of patients given a diagnosis of ARF and a concomitant reduction in inpatient mortality. While rates of mechanical ventilation remained relatively constant, there was a significant shift towards greater use of NIV at the expense of IMV.

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References

1. Goldman, L.; Schaffer, A. Goldman's Cecil Medicine. 24th ed. Elsevier Inc.; 2012.
2. Murray, JF.; Nadel, JA. Textbook of respiratory Medicine. 5th ed. Philadelphia, PA: Saunders; 2010.
3. Vincent JL, Sakr Y, Ranieri VM. Epidemiology and outcome of acute respiratory failure in intensive care unit patients. Crit Care Med. 2003 Apr; 31(4 Suppl):S296–S299. [PubMed: 12682455]
4. Cartin-Ceba R, Kojicic M, Li G, et al. Epidemiology of critical care syndromes, organ failures, and life-support interventions in a suburban US community. Chest. Dec; 140(6):1447–1455. [PubMed: 21998258]

5. Carson SS, Cox CE, Holmes GM, Howard A, Carey TS. The changing epidemiology of mechanical ventilation: a population-based study. *J Intensive Care Med.* 2006 May-Jun;21(3):173–182. [PubMed: 16672639]
6. Needham DM, Bronskill SE, Sibbald WJ, Pronovost PJ, Laupacis A. Mechanical ventilation in Ontario, 1992–2000: incidence, survival, and hospital bed utilization of noncardiac surgery adult patients. *Crit Care Med.* 2004 Jul; 32(7):1504–1509. [PubMed: 15241095]
7. Lewandowski K. Contributions to the epidemiology of acute respiratory failure. *Crit Care.* 2003 Aug; 7(4):288–290. [PubMed: 12930552]
8. Lewandowski K, Metz J, Deutschmann C, et al. Incidence, severity, and mortality of acute respiratory failure in Berlin, Germany. *Am J Respir Crit Care Med.* 1995 Apr; 151(4):1121–1125. [PubMed: 7697241]
9. Behrendt CE. Acute respiratory failure in the United States: incidence and 31-day survival. *Chest.* 2000 Oct; 118(4):1100–1105. [PubMed: 11035684]
10. Wunsch H, Linde-Zwirble WT, Angus DC, Hartman ME, Milbrandt EB, Kahn JM. The epidemiology of mechanical ventilation use in the United States. *Crit Care Med.* 2010 Oct; 38(10):1947–1953. [PubMed: 20639743]
11. Cooke CR, Erickson SE, Eisner MD, Martin GS. Trends in the incidence of noncardiogenic acute respiratory failure: the role of race. *Crit Care Med.* 2012 May; 40(5):1532–1538. [PubMed: 22511134]
12. Girou E, Brun-Buisson C, Taille S, Lemaire F, Brochard L. Secular trends in nosocomial infections and mortality associated with noninvasive ventilation in patients with exacerbation of COPD and pulmonary edema. *JAMA.* 2003 Dec 10; 290(22):2985–2991. [PubMed: 14665660]
13. Girou E, Schortgen F, Delclaux C, et al. Association of noninvasive ventilation with nosocomial infections and survival in critically ill patients. *JAMA.* 2000 Nov 8; 284(18):2361–2367. [PubMed: 11066187]
14. Carlucci A, Richard JC, Wysocki M, Lepage E, Brochard L. Noninvasive versus conventional mechanical ventilation. An epidemiologic survey. *Am J Respir Crit Care Med.* 2001 Mar; 163(4):874–880. [PubMed: 11282759]
15. Nouridine K, Combes P, Carton MJ, Beuret P, Cannamela A, Ducreux JC. Does noninvasive ventilation reduce the ICU nosocomial infection risk? A prospective clinical survey. *Intensive Care Med.* 1999 Jun; 25(6):567–573. [PubMed: 10416907]
16. Healthcare Cost and Utilization Project (HCUP). [Accessed December, 6, 2011] Overview of the Nationwide Inpatient Sample. <http://www.hcup-us.ahrq.gov/nisoverview.jsp>.
17. Lagu T, Rothberg MB, Shieh MS, Pekow PS, Steingrub JS, Lindenauer PK. Hospitalizations, costs, and outcomes of severe sepsis in the United States 2003 to 2007. *Crit Care Med.* 2011 Mar; 40(3):754–761. [PubMed: 21963582]
18. Lindenauer PK, Lagu T, Shieh MS, Pekow PS, Rothberg MB. Association of diagnostic coding with trends in hospitalizations and mortality of patients with pneumonia 2003–2009. *JAMA.* Apr 4; 307(13):1405–1413. [PubMed: 22474204]
19. Rothberg MB, Cohen J, Lindenauer P, Maselli J, Auerbach A. Little evidence of correlation between growth in health care spending and reduced mortality. *Health Aff (Millwood).* 2010 Aug; 29(8):1523–1531. [PubMed: 20679657]
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 Apr 17; 348(16):1546–1554. [PubMed: 12700374]
21. Dombrovskiy VY, Martin AA, Sunderram J, Paz HL. Rapid increase in hospitalization and mortality rates for severe sepsis in the United States: a trend analysis from 1993 to 2003. *Crit Care Med.* 2007 May; 35(5):1244–1250. [PubMed: 17414736]
22. TenHoor T, Mannino DM, Moss M. Risk factors for ARDS in the United States: analysis of the 1993 National Mortality Followback Study. *Chest.* 2001 Apr; 119(4):1179–1184. [PubMed: 11296187]
23. Reynolds HN, McCunn M, Borg U, Habashi N, Cottingham C, Bar-Lavi Y. Acute respiratory distress syndrome: estimated incidence and mortality rate in a 5 million-person population base. *Crit Care.* 1998; 2(1):29–34. [PubMed: 11056707]

24. Quan H, Parsons GA, Ghali WA. Validity of procedure codes in International Classification of Diseases 9th revision, clinical modification administrative data. *Med Care*. 2004 Aug; 42(8):801–809. [PubMed: 15258482]
25. Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. *Med Care*. 1998 Jan; 36(1):8–27. [PubMed: 9431328]
26. Angus DC, Wax RS. Epidemiology of sepsis: an update. *Crit Care Med*. 2001 Jul; 29(7 Suppl):S109–S116. [PubMed: 11445744]
27. Liangos O, Wald R, O'Bell JW, Price L, Pereira BJ, Jaber BL. Epidemiology and outcomes of acute renal failure in hospitalized patients: a national survey. *Clin J Am Soc Nephrol*. 2006 Jan; 1(1):43–51. [PubMed: 17699189]
28. Dombrovskiy VY, Martin AA, Sunderram J, Paz HL. Facing the challenge: decreasing case fatality rates in severe sepsis despite increasing hospitalizations. *Crit Care Med*. 2005 Nov; 33(11):2555–2562. [PubMed: 16276180]
29. Chen J, Normand SL, Wang Y, Krumholz HM. National and regional trends in heart failure hospitalization and mortality rates for Medicare beneficiaries 1998–2008. *JAMA*. 2011 Oct; 306(15):1669–1678. [PubMed: 22009099]
30. Chandra D, Stamm JA, Taylor B, et al. Outcomes of noninvasive ventilation for acute exacerbations of chronic obstructive pulmonary disease in the United States 1998–2008. *Am J Respir Crit Care Med*. 2011 Jan 15; 185(2):152–159. [PubMed: 22016446]
31. Gattinoni L, Brazzi L, Pelosi P, et al. A trial of goal-oriented hemodynamic therapy in critically ill patients. SvO2 Collaborative Group. *N Engl J Med*. 1995 Oct 19; 333(16):1025–1032. [PubMed: 7675044]
32. Oba Y, Salzman GA. Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury. *N Engl J Med*. 2000 Sep 14; 343(11):813. author reply 813–814. [PubMed: 10991706]
33. Kaufmann PA, Smolle KH, Krejs GJ. Short- and long-term survival of nonsurgical intensive care patients and its relation to diagnosis, severity of disease, age and comorbidities. *Curr Aging Sci*. 2009 Dec; 2(3):240–248. [PubMed: 20021418]
34. Stefan MS, Bannuru RR, Lessard D, Gore JM, Lindenauer PK, Goldberg RJ. The Impact of COPD on Management and Outcomes of Patients Hospitalized with Acute Myocardial Infarction - A Ten-Year Retrospective Observational Study. *Chest*. Dec 29.
35. Barsky AJ. The paradox of health. *N Engl J Med*. 1988 Feb 18; 318(7):414–418. [PubMed: 3340120]
36. Jencks SF, Williams MV, Coleman EA. Rehospitalizations among patients in the Medicare fee-for-service program. *N Engl J Med*. 2009 Apr 2; 360(14):1418–1428. [PubMed: 19339721]
37. Hamel MB, Phillips RS, Davis RB, et al. Outcomes and cost-effectiveness of ventilator support and aggressive care for patients with acute respiratory failure due to pneumonia or acute respiratory distress syndrome. *Am J Med*. 2000 Dec 1; 109(8):614–620. [PubMed: 11099680]
38. Hamel MB, Davis RB, Teno JM, et al. Older age aggressiveness of care, and survival for seriously ill hospitalized adults. SUPPORT Investigators. Study to Understand Prognoses and Preferences for Outcomes and Risks of Treatments. *Ann Intern Med*. 1999 Nov 16; 131(10):721–728. [PubMed: 10577294]
39. Hamel MB, Teno JM, Goldman L, et al. Patient age and decisions to withhold life-sustaining treatments from seriously ill hospitalized adults. SUPPORT Investigators. Study to Understand Prognoses and Preferences for Outcomes and Risks of Treatment. *Ann Intern Med*. 1999 Jan 19; 130(2):116–125. [PubMed: 10068357]
40. Hamel MB, Phillips RS, Davis RB, et al. Are aggressive treatment strategies less cost-effective for older patients? The case of ventilator support and aggressive care for patients with acute respiratory failure. *J Am Geriatr Soc*. 2001 Apr; 49(4):382–390. [PubMed: 11347780]
41. Walkey AJ, Wiener RS. Utilization of non-Invasive ventilation in patients with acute respiratory failure from 2000–2009: a population-based study. *Am J Respir Crit Care Med*. 2012; 185:A6488.
42. Herridge MS, Cheung AM, Tansey CM, et al. One-year outcomes in survivors of the acute respiratory distress syndrome. *N Engl J Med*. 2003 Feb 20; 348(8):683–693. [PubMed: 12594312]

Figure 1.

Proportion of patients with acute respiratory failure with the 5 most common medical conditions from 2001 to 2009

Figure 2.
Age-specific hospital cost per patient (geometric mean) stratified by surviving status

Table 1
Hospitalizations with acute respiratory failure in US, 2001 to 2009 by patient and hospital characteristics

	2001	2003	2005	2007	2009
Patient Characteristics					
All; N, (SD)	1007549 (19268)	1184928 (25542)	1288594 (30493)	1480270 (32002)	1917910 (47558)
Age; Mean, (SE)	66.6 (0.2)	66.0 (0.2)	66.1 (0.2)	65.8 (0.2)	65.8 (0.2)
Age group	%	%	%	%	%
18–44	11.5	12.0	11.5	11.6	10.9
45–64**	26.7	28.9	29.6	30.7	31.7
65–84**	50.2	47.8	47.0	45.7	45.3
85+	11.5	11.4	11.9	12.0	12.1
Male**	48.1	48.2	48.6	49.3	49.2
Race					
White	75.8	71.9	76.5	71.8	73.4
Black	12.7	13.6	11.2	14.2	12.5
Hispanic	7.2	9.8	7.7	8.5	7.8
Other	4.2	4.7	4.7	5.5	6.3
Primary ARF	20.7	20.9	25.9	26.1	19.9
Secondary ARF	79.3	79.1	74.1	73.9	80.1
Medical**	69.5	69.1	69.9	70.2	71.2
Surgical**	30.5	30.8	30.1	29.8	28.8
Hospital Characteristics					
	%	%	%	%	%
Number of beds					
Small	10.0	10.1	10.5	10.8	11.3
Medium*	25.2	25.3	24.6	24.0	22.7
Large	64.7	64.6	64.9	65.2	66.0
Region					
South**	18.5	18.5	17.6	17.0	16.3
Midwest	21.4	22.0	23.6	23.2	23.5

	2001	2003	2005	2007	2009
Northeast	42.6	41.7	41.4	42.2	42.1
West **	17.5	17.8	17.3	17.6	18.1
Hospital type					
Rural	13.6	13.0	11.8	11.0	10.8
Urban non-teaching	45.5	44.5	50.1	45.3	45.7
Urban teaching	40.9	42.5	38.1	43.7	43.6
Patient Outcomes					
Ventilation strategy					
IMV **	48.5	48.4	47.5	46.5	42.1
NIV **	3.8	5.3	6.9	9.4	10.1
IMV or NIV	50.9	51.7	52.1	52.9	49.7
Disposition					
Home/home health care **	42.1	43.8	42.8	43.4	45.7
Transfer to acute care	5.2	4.7	4.6	4.6	4.4
Nursing facility *	24.4	24.9	27.4	28.6	29.0
Other	0.7	0.8	0.9	0.9	1.0
Adjusted mortality **† % (SE)	27.6 (0.3)	26.4 (0.4)	24.9 (0.4)	22.7 (0.4)	20.6 (0.3)
Adjusted mean† LOS/case (days, SE) **†	7.8 (0.1)	7.9 (0.1)	7.7 (0.1)	7.5 (0.1)	7.1 (0.1)
Adjusted mean† cost/case (‘09 USD, SE) †	15818 (251)	16981 (419)	17236 (411)	16941 (436)	15987 (402)

* p-value for trend <0.01, including all years 2001–2009

** p-value for trend <0.0001, including all years 2001–2009

† adjusted for sex, age, race, hospital characteristics and comorbidities

‡ Geometric mean reported; standard errors from Taylor series expansion

LOS=Length of stay; USD=United States Dollars

Table 2

Cases of acute respiratory failure per 100 000 population

	2001	2003	2005	2007	2009
	Per 100,000 population* (SE)				
All [†]	502 (10)	569 (12)	595 (14)	627 (14)	784 (19)
Age group					
18–44 [†]	107 (3)	130 (4)	137 (4)	153 (5)	189 (6)
45–64 [†]	422 (9)	500 (12)	521 (13)	580 (14)	739 (19)
65–84 [†]	1697 (35)	1863 (42)	1950 (50)	2066 (46)	2578 (69)
85+	3449 (86)	3792 (106)	3981 (120)	3429 (97)	4163 (123)
Sex					
Male [†]	491 (10)	553 (13)	582 (14)	629 (14)	782 (20)
Female [†]	512 (10)	583 (12)	607 (15)	625 (13)	786 (19)
Race/ethnicity					
White [†]	491 (10)	553 (13)	582 (14)	629 (14)	782 (20)
Black [†]	512 (10)	583 (12)	607 (15)	625 (13)	786 (19)
Hispanic [†]	247 (24)	381 (42)	307 (27)	353 (34)	478 (42)
Other [†]	268 (20)	342 (29)	347 (26)	424 (29)	713 (77)
In-hospital mortality	140 (3)	148 (3)	146 (3)	140 (3)	154 (4)

* Standardized to 2000 US Census population

[†] p-value for trend <0.0001, including all years 2001–2009

Table 3
Characteristics of hospitalizations by etiology (medical, surgical, comorbidities, procedures) in 2009[#]

Disease	Total	Age < 45	45-65	65-84	85+	Male	Female
Medical							
Total ^{*/†} ; N (%)	1364624 (71.2)	144715 (10.6)	416922 (30.6)	615009 (45.1)	187977 (13.8)	647894 (47.5)	716635 (52.5)
	%	%	%	%	%	%	%
Pneumonia ^{*/†}	46.1	41.7	42.8	46.9	54.3	48.8	43.7
CHF ^{*/†}	36.6	10.4	27.3	43.6	54.8	35.0	38.1
ARDS ^{*/†}	16.1	22.9	16.2	14.5	15.9	15.5	16.7
Sepsis ^{*/†}	21.2	18.1	21.3	21.3	23.1	22.8	19.8
COPD [*]	25.4	4.2	25.6	32.3	18.3	25.0	25.7
AMI ^{*/†}	9.0	2.6	7.1	10.5	13.3	9.3	8.8
Asthma ^{*/†}	9.2	18.1	11.6	6.7	5.4	6.2	12.0
Stroke [*]	4.8	2.3	4.1	5.5	6.0	5.0	4.7
Trauma or Burns ^{*/†}	3.4	5.4	2.9	3.0	4.1	4.3	2.5
Cardio respiratory arrest ^{*/†}	4.1	3.9	4.4	4.1	3.8	4.6	3.7
Drug [*]	3.7	16.6	5.1	0.8	0.3	3.8	3.6
IMV ^{*/†}	37.7	54.6	43.7	33.5	24.8	41.1	34.5
NIV ^{*/†}	11.9	7.1	11.5	13.0	12.7	11.4	12.3
In-hospital mortality, (CI)	22 (21.3,22.7)	12.9 (11.9,13.9)	18.5 (17.6,19.4)	23.9 (23.0,24.9)	31.8 (30.6,33.1)	24.2 (23.3,25.1)	20.9 (20.1,21.7)
Surgical							
Total ^{*/†} ; N (%)	552971 (28.8)	64983 (11.8)	190225 (34.4)	254336 (46)	43426 (7.9)	295660 (53.5)	257287 (46.5)
	%	%	%	%	%	%	%
Pneumonia ^{*/†}	34.9	33.0	34.0	35.0	40.5	37.1	32.2
CHF [*]	27.2	8.9	21.7	33.3	42.6	26.7	27.7
ARDS [*]	45.5	51.5	45.2	44.7	42.7	45.0	46.1
Sepsis [*]	25.1	22.8	25.4	25.2	26.1	25.4	24.7

Disease	Total	Age < 45	45-65	65-84	85+	Male	Female
COPD *	8.2	1.1	7.4	10.8	7.5	8.3	8.1
AMI **†	16.9	4.9	17.0	19.8	17.9	19.1	14.4
Asthma **†	6.1	7.6	7.2	5.4	3.6	4.1	8.5
Stroke *	8.9	6.6	9.2	9.4	7.2	8.9	8.8
Trauma or Burns **†	12.2	26.5	9.6	9.2	20.3	13.8	10.4
Cardio respiratory arrest **†	5.5	4.4	6.0	5.4	5.2	6.1	4.7
Drug **†	0.5	1.3	0.7	0.2	0.2	0.4	0.6
IMV **†	52.9	57.1	54.3	51.3	50.0	54.5	51
NIV *	5.8	3.5	5.5	6.4	6.4	5.6	6.0
In-hospital mortality, (CI)	18.6 (17.8,19.5)	10.7 (9.3,12.0)	15.5 (14.2,16.8)	20.8 (19.8,21.9)	29.4 (27.8,31.1)	19.0 (18.2,19.8)	18.3 (17.3,19.2)

* p-value <0.0001 for age group

† p-value <0.0001 for gender

**The p-values are from Rao-Scott chi-square test

One patient can have more than one diagnosis