CLINICAL RESEARCH STUDY

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# Marked Reduction in 30-Day Mortality Among Elderly Patients with Community-acquired Pneumonia

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## ABSTRACT

**BACKGROUND:** Community-acquired pneumonia is the most common infectious cause of death in the US. Over the last 2 decades, patient characteristics and clinical care have changed. To understand the impact of these changes, we quantified incidence and mortality trends among elderly adults.

**METHODS:** We used Medicare claims to identify episodes of pneumonia, based on a validated combination of diagnosis codes. Comorbidities were ascertained using the diagnosis codes located on a 1-year look back. Trends in patient characteristics and site of care were compared. The association between year of pneumonia episode and 30-day mortality was then evaluated by logistic regression, with adjustment for age, sex, and comorbidities.

**RESULTS:** We identified 2,654,955 cases of pneumonia from 1987-2005. During this period, the proportion treated as inpatients decreased, the proportion aged ≥80 years increased, and the frequency of many comorbidities rose. Adjusted incidence increased to 3096 episodes per 100,000 population in 1999, with some decrease thereafter. Age/sex-adjusted mortality decreased from 13.5% to 9.7%, a relative reduction of 28.1%. Compared with 1987, the risk of mortality decreased through 2005 (adjusted odds ratio, 0.46; 95% confidence interval, 0.44-0.47). This result was robust to a restriction on comorbid diagnoses assessing for the results' sensitivity to increased coding.

**CONCLUSIONS:** These findings show a marked mortality reduction over time in community-acquired pneumonia patients. We hypothesize that increased pneumococcal and influenza vaccination rates as well as wider use of guideline-concordant antibiotics explain a large portion of this trend. 
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**KEYWORDS:** Community-acquired pneumonia; Mortality; Trends

Community-acquired pneumonia is the most common infectious cause of death in the US. Despite the development of a prediction rule to identify low-risk patients who may safely be treated as outpatients,[1] hospitalization rates have increased in both the US and England.[2,3] Some of this increase is attributable to demographic changes and an increase in comorbid illnesses.[2,3] Improved survivorship among patients with acute and chronic diseases, especially cardiac disease, may be a driving factor.[4] In addition to impacting incidence, comorbid illnesses, such as diabetes mellitus, are associated with a poor prognosis in pneumonia patients.[5]

Clinicians, health services researchers, and the health care quality community have been engaged in a concerted effort to improve the care of pneumonia patients.[6] The National Hospital Quality Measures established by the Centers for Medicare & Medicaid Services and the Joint Commission have encouraged hospitals to meet performance goals. These goals are focused on process measures that include patient testing (oxygenation assessment and obtaining blood cultures) and treatment (timing and choice of antibiotics), as well as preventive interventions (pneumo-

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**Conflict of Interest:** The authors confirm the absence of potential conflicts of interest, financial or otherwise.

**Authorship:** All authors had access to the data and a role in writing the manuscript. Dr. Ruhnke had full access to all 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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coccal vaccination [PV] and influenza vaccination [IV]). These interventions have been shown, either individually or in combination, to improve the outcomes of community-acquired pneumonia patients.[7-12] The implementation of clinical pathways also has been shown to improve outcomes.[13] In addition to encouraging the above interventions, pathways guide other clinical decisions, such as the timing of discharge and the switch to oral antibiotics.

The aggregate impact of these epidemiologic and clinical trends on the survival of pneumonia patients is of great importance to clinicians and policymakers, but has not been studied. As physicians are asked to meet performance measures, it is essential for them to understand their impact on outcomes. As health care costs increase, it also is important to examine mortality trends as a measure of the health benefits of increased resource allocation. Our objective was to quantify 30-day mortality trends in elderly Medicare patients diagnosed with community-acquired pneumonia.

**CLINICAL SIGNIFICANCE**

- The incidence of community-acquired pneumonia has increased, while the proportion of patients aged ≥80 years has increased, as has the frequency of comorbidities.
- Among elderly pneumonia patients, we demonstrate a markedly reduced 30-day mortality over 2 decades that is particularly evident after adjustment for comorbidities.
- Vaccinations and guideline-concordant antibiotics have been shown to reduce mortality. Their greatly increased use rates may explain a large portion of the mortality trend.

## METHODS

### Data Source and Study Subjects

Our analyses used all claims (1987-2005) for a random 20% sample of Medicare patients aged ≥65 years from the Centers for Medicare & Medicaid Services Research Identifiable Files. Cases of community-acquired pneumonia were identified by the *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9 CM)[14] code combinations as either: a principal diagnosis of pneumonia (codes 481-487) or a principal diagnosis of respiratory distress (code 786) or respiratory failure (code 518), with pneumonia as a secondary diagnosis. These code combinations have been shown to have a diagnostic sensitivity and specificity of 84% and 86%, respectively.[15] Medicare denominator files were used to establish enrollees' demographic characteristics and vital status.

The date of pneumonia diagnosis was defined as the day of admission for inpatients and the first date of an administrative pneumonia claim for outpatients. Outpatient claims or hospital admissions within 30 days of an initial outpatient pneumonia diagnosis or within 30 days after discharge from a hospital admission for pneumonia were not considered new community-acquired pneumonia episodes. Thirty-day mortality was defined as death within 30 days subsequent to the date of diagnosis. This study was approved by the Partners Human Research Committee.

The pneumonia Patient Outcomes Research Team derived a prediction tool for hospitalization decisions.[1] Subsequent studies have shown that physician behavior changes slowly in the absence of moderate/high-intensity implementation strategies.[16] Despite this, there may be a slow substitution of inpatient with outpatient treatment for low-risk patients. Because such a trend would make both groups appear to become sicker over time separately, we combined inpatients and outpatients. Patients from nursing homes were eliminated due to limited comorbidity information.

The 29 comorbidities were coded by mapping ICD-9 CM codes according to the Agency for Healthcare Research and Quality Elixhauser Comorbidity Software.[17] Diagnostic codes were included if they appeared at least once during the year before the pneumonia diagnosis. Including this look back, the patient sample is based on 19 years of data. To assess for validity of the coding, 29 univariate logistic regressions were performed, regressing mortality on a single comorbidity. Four of the comorbidity variables predicted a lower mortality risk. This likely reflects a tendency toward coding these conditions in patients without more significant comorbidities.[18] Hypertension, hypothyroidism, obesity, and depression were therefore excluded from subsequent multivariate analyses.

### Outcomes and Statistical Analysis

Patient characteristics, site of care, and mortality rates over time were compared using the Mantel-Haenszel chi-square test for trend. For comparative purposes, summary statistics were calculated for the periods 1987-1989 and 2003-2005, based on the combined samples of the 3 years that comprise each period. Age- and sex-adjusted mortality rates were then calculated based on their distribution in the year 2000.

To examine outcomes, 3 logistic regressions were performed with 30-day mortality as the dependent variable. We used the following independent variables: binary categorical variables for each year (1987 as the referent), age by 5-year category interacted with sex, and 25 comorbidity variables. The regression was first performed on the entire sample of community-acquired pneumonia patients. Second, we estimated the model on the subset of patients with no comorbidities, to isolate changes due solely to the care of pneumonia, independent of any effect due to treatment of comorbid conditions. Third, we repeated the analysis in patients with complicated diabetes mellitus to estimate

the effect of treatment of a major comorbidity on the mortality trends. For each of the 3 regressions, the primary result was the odds ratio (OR) of death in each year relative to 1987.

There have been several factors increasing the coding of comorbidities over time: a true increase in frequency; a change in diagnostic criteria over time (for example, diabetes mellitus); and an increase in the number of diagnostic fields available in the claims data. To assess the impact of these changes on the results of the logistic regression, we performed an additional regression on the total sample, restricting patients in all years to a maximum of 5 diagnoses.

All statistical analyses were performed using Statistical Analysis Software, version 9.1.3 (SAS Institute Inc., Cary, NC).

## RESULTS

### Characteristics of the Study Subjects and Incidence Trends

The total sample of 2,654,955 community-acquired pneumonia subjects included 1,130,919 outpatients and 1,524,036 inpatients. The Table shows the characteristics of the study subjects for the periods 1987-1989 and 2003-2005. From the early period to the recent period, the proportion of patients aged ≥80 years increased from 42.5% to 47.5% ($P$ <.001), while the proportion of subjects treated as inpatients decreased from 62.6% to 55.7% ($P$ <.001). Most of this shift in site of care had occurred by 1998. Mortality summary statistics show a decrease in the total sample, as well as a corresponding decrease within each age group.

Figure 1 exhibits the annual incidence of pneumonia for the combined sample as well as for men and women separately. Each trend is adjusted for age (and sex for the combined line). The incidence among both sexes and for the combined sample increased through 1999, declining somewhat thereafter. Figure 2 demonstrates the trend in several common comorbidities. Chronic lung disease, congestive heart failure, and uncomplicated diabetes mellitus were the most frequent, and each was increasing. The proportion of patients with chronic lung disease and congestive heart failure increased from 27.6% to 46.0% ($P$ <.001) and from 20.0% to 33.3% ($P$ <.001), respectively.

### Trends in 30-Day Mortality

Figure 3 shows the 30-day mortality trends. Overall mortality fell from 13.5% in 1987 to 9.7% in 2005, a 28.1% relative reduction.

The Appendix (available online) shows the logistic regression results for mortality in the total sample of patients. Figure 4 depicts the changes in multivariate-adjusted OR of 30-day mortality over the time period studied. A large proportion of the mortality decrease occurred during the

**Table** Characteristics of Elderly Patients Diagnosed with Community-acquired Pneumonia

| | Inpatients* | | | Outpatients* | | |
|---|---|---|---|---|---|---|
| | 1987-1989 (n = 211,539) | 2003-2005 (n = 252,551) | *P*-Value | 1987-1989 (n = 126,263) | 2003-2005 (n = 200,915) | *P*-Value |
| Incidence per 100,000 by age group (years) | 1282 | 1421 | | 765 | 1131 | |
| 65-69 | 30,050 (14.2) | 33,342 (13.2) | <.001 | 27,092 (21.5) | 36,650 (18.2) | <.001 |
| 70-74 | 38,506 (18.2) | 38,545 (15.3) | | 28,474 (22.6) | 38,368 (19.1) | |
| 75-79 | 43,603 (20.6) | 49,031 (19.4) | | 26,666 (21.1) | 42,050 (20.9) | |
| 80-84 | 41,581 (19.7) | 53,579 (21.2) | | 21,177 (16.8) | 38,481 (19.2) | |
| ≥85 | 57,799 (27.3) | 78,054 (31.0) | | 22,854 (18.1) | 45,366 (22.6) | |
| Sex | | | | | | |
| Female | 111,216 (52.6) | 141,439 (56.0) | <.001 | 73,681 (58.4) | 113,936 (56.8) | <.001 |
| Male | 100,323 (47.4) | 111,112 (44.0) | | 52,582 (41.6) | 86,979 (43.3) | |
| Mean number of comorbid conditions† | 1.9 (1.3) | 4.0 (2.2) | <.001 | 0.7 (1.2) | 2.7 (2.3) | <.001 |
| Overall mortality | 38,518 (18.2) | 38,400 (15.2) | <.001 | 5728 (4.5) | 8257 (4.1) | <.001 |
| Mortality by age group (years) | | | | | | |
| 65-69 | 3517 (11.7) | 3030 (9.1) | <.001 | 519 (1.9) | 550 (1.5) | <.001 |
| 70-74 | 5189 (13.5) | 4065 (10.5) | | 746 (2.6) | 822 (2.1) | |
| 75-79 | 7099 (16.3) | 6386 (13.0) | | 1087 (4.1) | 1244 (3.0) | |
| 80-84 | 8126 (19.5) | 8412 (15.7) | | 1239 (5.9) | 1780 (4.6) | |
| ≥85 | 14,587 (25.2) | 16,507 (21.1) | | 2137 (9.4) | 3861 (8.5) | |

*Number (percentage) except incidence.
†Number (standard deviation).

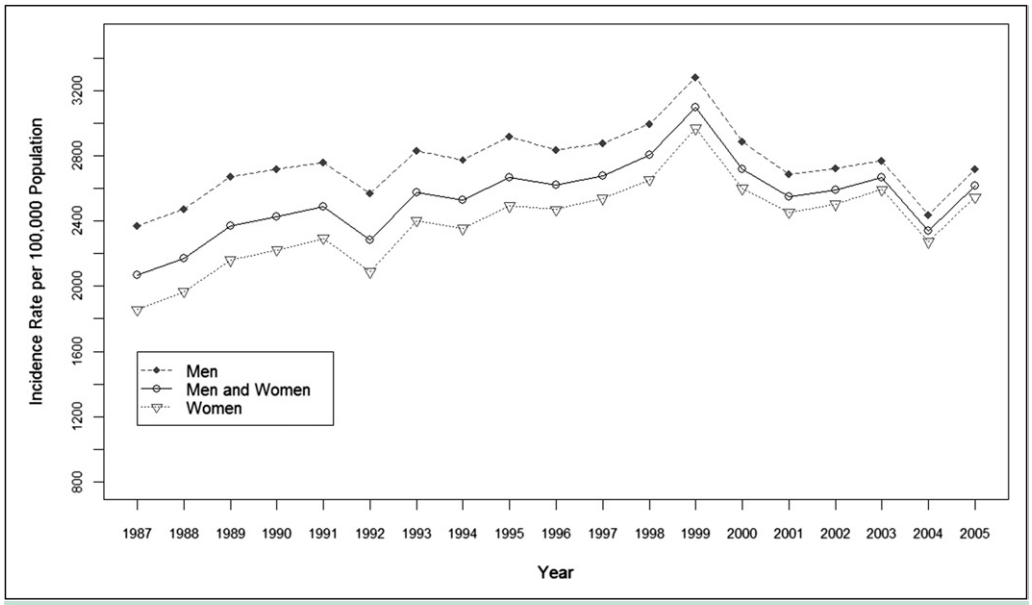


**Figure 1** Standardized incidence of community-acquired pneumonia among elderly adults. Trends for men and women are standardized for age. Trends for the combined sample are standardized to the sex and age distribution of the elderly Medicare population in the year 2000.

first half of the study period. Compared with 1987, the adjusted OR of death within 30 days of a pneumonia diagnosis had decreased to 0.61 (95% confidence interval [CI], 0.60 to 0.63) by 1998 and to 0.46 (95% CI, 0.44-0.47) by 2005. After restricting all patients to a maximum of 5 diagnoses, the OR in 2005 was 0.53 (95% CI, 0.52-0.54). For the no-comorbidity and complicated diabetes mellitus subgroups, the OR in 2005 was 0.44 (95% CI, 0.39-0.50) and 0.49 (95% CI, 0.44-0.55), respectively.

## DISCUSSION

Our findings reveal a substantial mortality reduction in elderly pneumonia patients from 1987 to 2005, over which

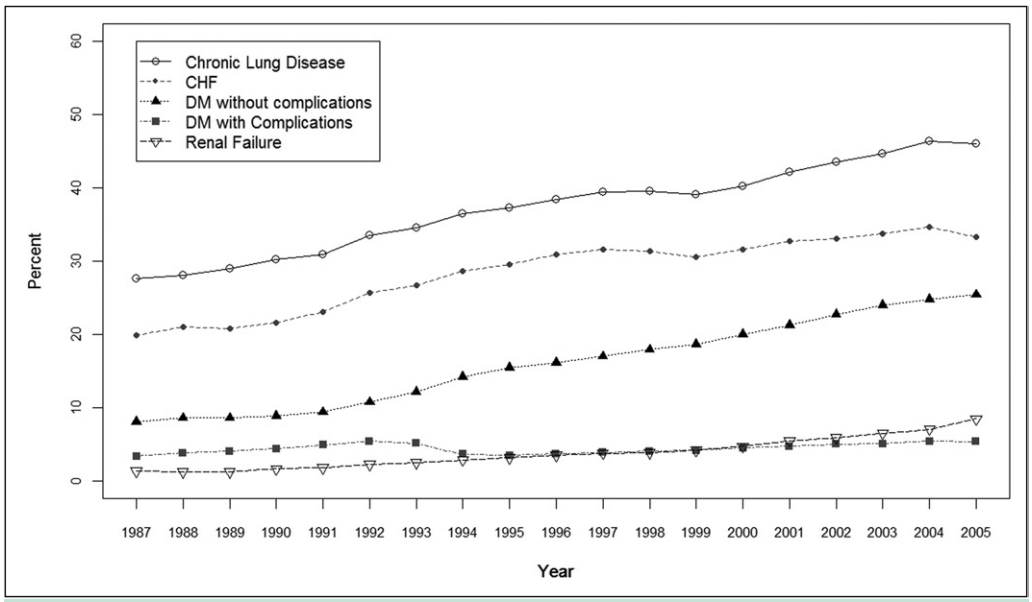


**Figure 2** Trends in the frequency of selected comorbid conditions among inpatients and outpatients diagnosed with community-acquired pneumonia. CHF = congestive heart failure; DM = diabetes mellitus.

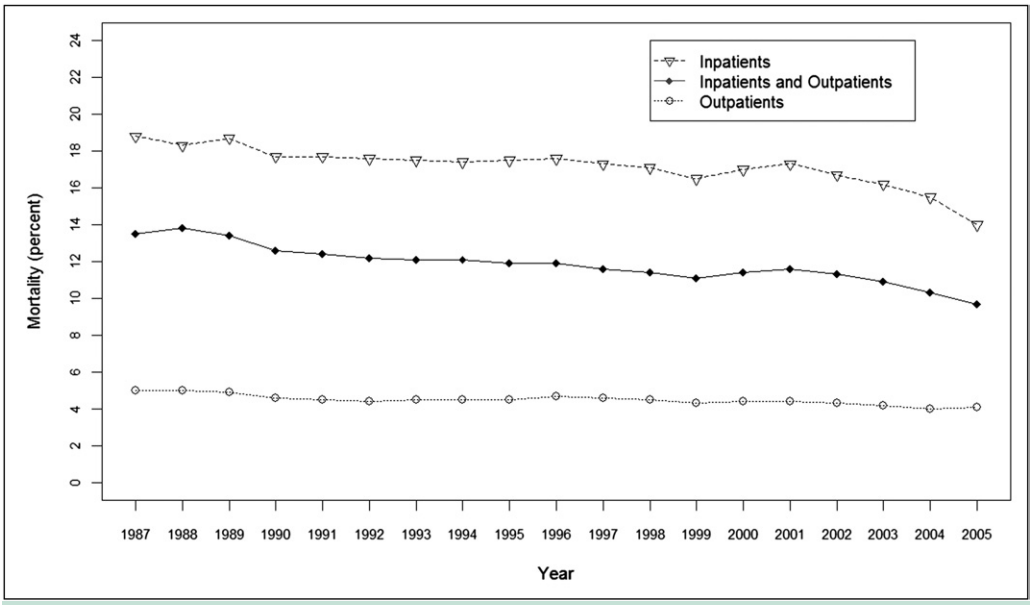


**Figure 3** Adjusted 30-day mortality rates among elderly patients diagnosed with community-acquired pneumonia. Mortality rates are standardized to the sex and age distribution of year 2000.

time the relative risk of mortality fell by 28%, and, after comorbidity adjustment, 54%. Our data demonstrate a 13.5% mortality rate in 1987 that decreased markedly over the period studied. However, even this initial mortality rate reflects a decrease during the 1980s. A *Lancet* report studying community-acquired pneumonia patients with a mean age of 51 years in 1980 and 1981 showed an in-hospital mortality rate of 15%.[19] Especially given the relatively young age of their subjects, this suggests important improvements were already occurring during the 1980s. Similarly, a prospective study conducted from 1981 to 1987 showed a mortality rate of 28.6% in patients over age 60 years admitted for pneumonia.[20] Our data suggest that mortality due to pneumonia has indeed decreased. We believe that inclusion of outpatients is a strength of our study. Especially as patient care shifts to the outpatient setting, it is crucial for evidence to incorporate these patients.

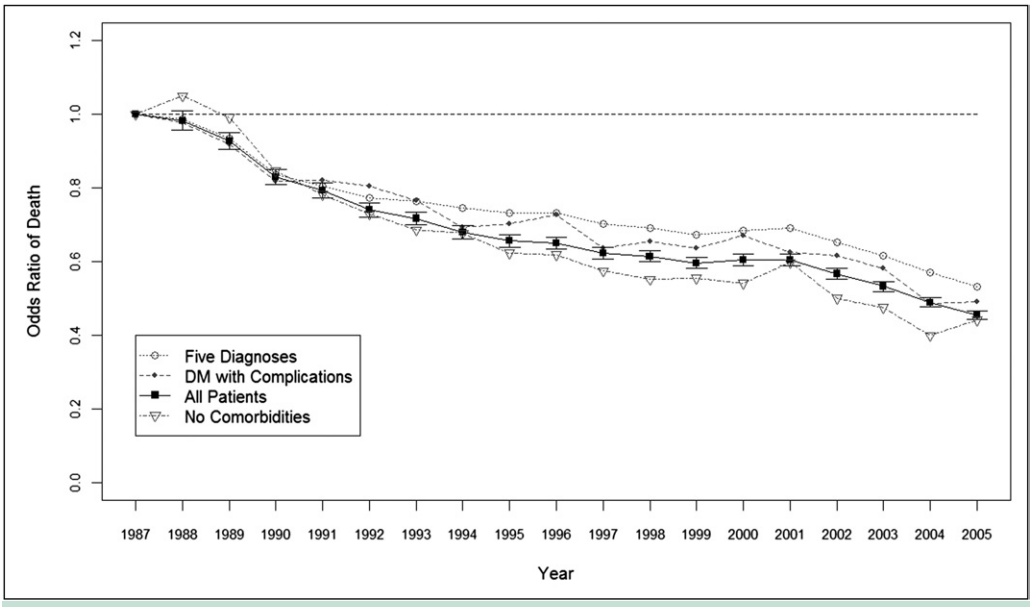


**Figure 4** Multivariate-adjusted mortality trends. This figure shows the odds ratio of death 30 days after a diagnosis of community-acquired pneumonia in each year relative to reference year 1987. DM = diabetes mellitus.

It is important to explain the reduction in mortality. Although our data do not allow us to know with certainty why mortality has decreased, we review the evidence for the likely possibilities. A good part of the improvement may be due to an increase in the use of PV and IV, as well as guideline-concordant antibiotics. Two large studies have shown that PV does little to prevent pneumonia, but markedly reduces the risk of bacteremia and invasive pneumococcal disease, both of which greatly increase mortality risk.[21,22] One of these studies demonstrated a multivariable-adjusted hazard ratio of death due to pneumonia of 0.41 in patients who received PV.[22] Among 17,393 hospitalized community-acquired pneumonia patients, receipt of IV was associated with a 39% lower mortality, after adjusting for receipt of PV.[23] Use of the 23-valent pneumococcal polysaccharide vaccine, which replaced the 14-valent vaccine in 1983, increased sharply after the vaccination recommendations of the Centers for Disease Control and Prevention were published in the *Morbidity and Mortality Weekly Report* in 1989.[24-26] From 1989 to 1993, distribution of PV tripled, while distribution of IV doubled.[27] According to the United States Immunization Survey, 10.7% and 23.0% of elderly adults in 1985 had received PV and IV, respectively. In 1989, the National Health Interview Survey showed that 14.7% and 32.9% of elderly adults received PV and IV, respectively. We use the means of these rates to establish estimated reference year 1987 PV and IV rates of 12.7% and 28.0%, respectively. More recently, the Behavioral Risk Factor Surveillance System estimated that, in 2005, 65.7% and 65.5% of elderly adults received PV and IV, respectively. There is little controversy about the mortality benefit of IV in pneumonia. However, we recognize that there is varied opinion about the benefit of PV. Although we reference high-quality studies that showed a mortality benefit of PV, a Cochrane Review did conclude that the evidence for a mortality benefit was not compelling.[28]

Recommendations for combination antibiotic therapy were published in 1987, and are part of the 1993 American Thoracic Society guidelines for community-acquired pneumonia management.[29,30] Such combination, guideline-concordant antibiotics[31] have been shown to achieve large mortality reductions.[7-9,32-34] For example, among community-dwelling hospitalized elderly pneumonia patients, 3 guideline-concordant antibiotic regimens reduced 30-day mortality with hazard ratios of 0.64-0.78, compared with monotherapy.[34] One study based on 1992 data demonstrated that only 54% of pneumonia patients received such antibiotics.[35] More recent data have shown a guideline-concordant antibiotics use rate of 88%.[9] We believe that the exponential increases in influenza, and possibly pneumococcal, vaccination, as well as greater use of guideline-concordant antibiotics explain a sizable portion of the mortality reduction we demonstrate. The referenced studies examined largely inpatients, and therefore must be used cautiously in explaining trends in a combined sample including outpatients. Still, they merit further exploration. Early administration of antibiotics and obtaining blood cultures are probably beneficial, but the literature suggests a less substantial impact.[10] There also is a burgeoning literature on the infection-related mortality reduction associated with statin use.[36-38] Although causality has not yet been established in controlled trials,[39] the remarkable increase in statin use may be decreasing pneumonia mortality.

Even as mortality from pneumonia fell, the incidence increased from 1987 to 1999. We believe this is largely due to an increase in the frequency of comorbidities that predispose patients to developing pneumonia. The decrease we find after 1999 is consistent with other published data.[2] Although we cannot perfectly explain this reduced incidence, several factors are likely at work: the modest effect of higher PV rates on the risk of pneumonia; reductions in smoking; and better treatment of the comorbid conditions that are risk factors for pneumonia. Reduced use of oral and inhaled corticosteroids in patients with chronic lung disease also may be playing a role,[40] as may increased use of statins.[38] Finally the increase in influenza vaccination in recent years and corresponding reduction in risk for bacterial pneumonia is probably decreasing incidence. For the mild seasons of 2000-2003, the Centers for Disease Control and Prevention reported a relatively low incidence of influenza compared with the previous 2. The 2003-2004 season was more severe, but began early and peaked in 2003. We believe that the low incidence in 2004 is partially explained by this, as well as a February 2005 peak during the 2004-2005 season.[41]

There are limitations to this investigation. We identified pneumonia patients based on an administrative dataset rather than clinical chart review. It is possible that we excluded cases of community-acquired pneumonia and that some of our patient sample had nosocomial pneumonia. However, our patient identification methods were validated in a study showing a 93% positive predictive value. Moreover, any imperfections in the inclusion process should have been constant over time. For these reasons, we believe the small number of patients incorrectly included or excluded would not appreciably impact our results. Our conclusions also are limited by our inability to explain with confidence the reasons for the mortality decrease.

Also, the increase in frequency of comorbidities over time reflects, to some extent, changes in coding practices and disease definitions rather than a true change in physiologically comparable prevalence. However, many of these diseases have in fact increased in prevalence over time, and 2 recent studies of pneumonia patients also have documented their increasing frequency.[2,3] Additionally, restricting all patients to 5 diagnoses changed the results only a small amount—not enough to change the overall conclusions or implications of our study. Rather, it supports the primary conclusion that care of pneumonia patients has indeed improved. Our study also is limited by the absence of laboratory data and physiologic variables. We were therefore unable to perform risk adjustment as accurately as the pneumonia severity index would have. However, because age and comorbidities contribute a great deal to the pneu-

monia severity index, it is probable that its incorporation would not have a large impact on the identified trends. Some portion of the incidence trend and the substantial reduction in mortality we demonstrate could be due to a change in coding practices. For example, if patients with bronchitis were increasingly likely to be coded as pneumonia, this would explain some of the mortality reduction. Similarly, if patients in recent years with sepsis due to pneumonia were coded with a principal diagnosis of sepsis at a higher rate than in the early years, this might artifactually reduce mortality because our validated diagnostic code algorithm would not capture this trend. Although experienced professional coders at the Massachusetts General Hospital with whom we consulted did not believe such a trend has occurred, we think it important to recognize this as a potential influence on mortality trends examined using administrative data.

In summary, we found significant improvements in survival among a large sample of community-acquired pneumonia patients from 1987 to 2005. The few other studies of mortality trends in pneumonia[2,42] have had limitations, which our study addresses. This is the first study to use 2 decades of data to examine 30-day, adjusted mortality trends, including comorbid conditions, in a combined sample of noninstitutionalized inpatients and outpatients. Improved survival is consistent with data showing increased use of guideline-concordant combination antibiotic therapy, as well as vaccination, which may collectively explain a large proportion of the mortality decrease we found. Additional efforts to get all providers to use these measures might reduce mortality from pneumonia even further.

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## References

1. Fine MJ, Auble TE, Yealy DM, et al. A prediction rule to identify low-risk patients with community-acquired pneumonia. *N Engl J Med*. 1997;336(4):243-250.
2. Fry AM, Shay DK, Holman RC, Curns AT, Anderson LJ. Trends in hospitalizations for pneumonia among persons aged 65 years or older in the United States, 1988-2002. *JAMA*. 2005;294(21):2712-2719.
3. Trotter CL, Stuart JM, George R, Miller E. Increasing hospital admissions for pneumonia, England. *Emerg Infect Dis*. 2008;14(5):727-733.
4. Vaccarino V, Parsons L, Peterson ED, Rogers WJ, Kiefe CI, Canto J. Sex differences in mortality after acute myocardial infarction: changes from 1994 to 2006. *Arch Intern Med*. 2009;169(19):1767-1774.
5. Kornum JB, Thomsen RW, Riis A, Lervang HH, Schonheyder HC, Sorensen HT. Type 2 diabetes and pneumonia outcomes: a population-based cohort study. *Diabetes Care*. 2007;30(9):2251-2257.
6. Seymann GB. Community-acquired pneumonia: defining quality care. *J Hosp Med*. 2006;1(6):344-353.
7. Baddour LM, Yu VL, Klugman KP, et al. Combination antibiotic therapy lowers mortality among severely ill patients with pneumococcal bacteremia. *Am J Respir Crit Care Med*. 2004;170(4):440-444.
8. Waterer GW, Somes GW, Wunderink RG. Monotherapy may be suboptimal for severe bacteremic pneumococcal pneumonia. *Arch Intern Med*. 2001;161(15):1837-1842.
9. Ramirez JA. Processes of care for community-acquired pneumonia. *Infect Dis Clin North Am*. 2004;18(4):843-859.
10. Meehan TP, Fine MJ, Krumholz HM, et al. Quality of care, process, and outcomes in elderly patients with pneumonia. *JAMA*. 1997; 278(23):2080-2084.
11. Fine MJ, Stone RA, Singer DE, et al. Processes and outcomes of care for patients with community-acquired pneumonia: results from the Pneumonia Patient Outcomes Research Team (PORT) cohort study. *Arch Intern Med*. 1999;159(9):970-980.
12. Fine JM, Fine MJ, Galusha D, Petrillo M, Meehan TP. Patient and hospital characteristics associated with recommended processes of care for elderly patients hospitalized with pneumonia: results from the medicare quality indicator system pneumonia module. *Arch Intern Med*. 2002;162(7):827-833.
13. Meehan TP, Weingarten SR, Holmboe ES, et al. A statewide initiative to improve the care of hospitalized pneumonia patients: the Connecticut Pneumonia Pathway Project. *Am J Med*. 2001;111(3):203-210.
14. Centers for Disease Control and Prevention, US Department of Health and Human Services. *International Classification of Diseases, Ninth Revision, Clinical Modification*. Washington, DC: US Department of Health and Human Services; 2009.
15. Whittle J, Fine MJ, Joyce DZ, et al. Community-acquired pneumonia: can it be defined with claims data? *Am J Med Qual*. 1997;12(4):187-193.
16. Yealy DM, Auble TE, Stone RA, et al. Effect of increasing the intensity of implementing pneumonia guidelines: a randomized, controlled trial. *Ann Intern Med*. 2005;143(12):881-894.
17. Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. *Med Care*. 1998;36(1):8-27.
18. Iezzoni LI, Foley SM, Daley J, Hughes J, Fisher ES, Heeren T. Comorbidities, complications, and coding bias. Does the number of diagnosis codes matter in predicting in-hospital mortality? *JAMA*. 1992;267(16):2197-2203.
19. Macfarlane JT, Finch RG, Ward MJ, Macrae AD. Hospital study of adult community-acquired pneumonia. *Lancet*. 1982;2(8292):255-258.
20. Marrie TJ, Durant H, Yates L. Community-acquired pneumonia requiring hospitalization: 5-year prospective study. *Rev Infect Dis*. 1989; 11(4):586-599.
21. Jackson LA, Neuzil KM, Yu O, et al. Effectiveness of pneumococcal polysaccharide vaccine in older adults. *N Engl J Med*. 2003;348(18): 1747-1755.
22. Vila-Corcoles A, Ochoa-Gondar O, Hospital I, et al. Protective effects of the 23-valent pneumococcal polysaccharide vaccine in the elderly population: the EVAN-65 study. *Clin Infect Dis*. 2006;43(7):860-868.
23. Spaude KA, Abrutyn E, Kirchner C, Kim A, Daley J, Fisman DN. Influenza vaccination and risk of mortality among adults hospitalized with community-acquired pneumonia. *Arch Intern Med*. 2007;167(1): 53-59.
24. Centers for Disease Control. Pneumococcal polysaccharide vaccine. *MMWR Morb Mortal Wkly Rep*. 1989;38(5):64-68, 73-76.
25. Fedson DS. Pneumococcal vaccination in the United States and 20 other developed countries, 1981-1996. *Clin Infect Dis*. 1998;26(5): 1117-1123.
26. Influenza and pneumococcal vaccination coverage levels among persons aged > or = 65 years—United States, 1973-1993. *MMWR Morb Mortal Wkly Rep*. 1995;44(27):506-507, 513-515.
27. Fedson DS. Influenza and pneumococcal vaccination in Canada and the United States, 1980-1993: what can the two countries learn from each other? *Clin Infect Dis*. 1995;20(5):1371-1376.
28. Moberley SA, Holden J, Tatham DP, Andrews RM. Vaccines for preventing pneumococcal infection in adults. *Cochrane Database Syst Rev*. 2008(1):CD000422.
29. Macfarlane JT. Treatment of lower respiratory infections. *Lancet*. 1987;2(8573):1446-1449.

30. Niederman MS, Bass JB Jr, Campbell GD, et al. Guidelines for the initial management of adults with community-acquired pneumonia: diagnosis, assessment of severity, and initial antimicrobial therapy. American Thoracic Society. Medical Section of the American Lung Association. *Am Rev Respir Dis*. 1993;148(5):1418-1426.
31. Mandell LA, Wunderink RG, Anzueto A, et al. Infectious Diseases Society of America/American Thoracic Society consensus guidelines on the management of community-acquired pneumonia in adults. *Clin Infect Dis*. 2007;44(Suppl 2):S27-S72.
32. Frei CR, Restrepo MI, Mortensen EM, Burgess DS. Impact of guideline-concordant empiric antibiotic therapy in community-acquired pneumonia. *Am J Med*. 2006;119(10):865-871.
33. Garcia Vazquez E, Mensa J, Martinez JA, et al. Lower mortality among patients with community-acquired pneumonia treated with a macrolide plus a beta-lactam agent versus a beta-lactam agent alone. *Eur J Clin Microbiol Infect Dis*. 2005;24(3):190-195.
34. Gleason PP, Meehan TP, Fine JM, Galusha DH, Fine MJ. Associations between initial antimicrobial therapy and medical outcomes for hospitalized elderly patients with pneumonia. *Arch Intern Med*. 1999; 159(21):2562-2572.
35. Hueston WJ, Schiaffino MA. Antibiotic choice and patient outcomes in community-acquired pneumonia. *J Am Board Fam Pract*. 1994; 7(2):95-99.
36. Thomsen RW, Riis A, Kornum JB, Christensen S, Johnsen SP, Sorensen HT. Preadmission use of statins and outcomes after hospitalization with pneumonia: population-based cohort study of 29,900 patients. *Arch Intern Med*. 2008;168(19):2081-2087.
37. Chopra V, Flanders SA. Does statin use improve pneumonia outcomes? *Chest*. 2009;136(5):1381-1388.
38. Tleyjeh IM, Kashour T, Hakim FA, et al. Statins for the prevention and treatment of infections: a systematic review and meta-analysis. *Arch Intern Med*. 2009;169(18):1658-1667.
39. Viasus D, Garcia-Vidal C, Gudiol F, Carratala J. Statins for community-acquired pneumonia: current state of the science. *Eur J Clin Microbiol Infect Dis*. 2010;29(2):143-152.
40. Suh DC, Lau H, Pokras SM, Choi IS, Valiyeva E. Sex differences in ambulatory visits for chronic obstructive pulmonary disease, based on the National Ambulatory Medical Care Survey and the National Hospital Ambulatory Medical Care Survey from 1995 to 2004. *Respir Care*. 2008;53(11):1461-1469.
41. Centers for Disease Control and Prevention. Seasonal influenza (flu): flu activity & surveillance. Available at: http://www.cdc.gov/flu/weekly/fluactivity.htm. Last accessed April 15, 2010.
42. Metersky ML, Tate JP, Fine MJ, Petrillo MK, Meehan TP. Temporal trends in outcomes of older patients with pneumonia. *Arch Intern Med*. 2000;160(22):3385-3391.

**Appendix (online)** Multivariate Logistic Regression Results

Odds Ratio Estimates

| Effect | Point Estimate | 95% Wald Confidence Limits | |
|---|---|---|---|
| Year (relative to 1987) | | | |
| 1988 | 0.98 | 0.96 | 1.01 |
| 1989 | 0.93 | 0.90 | 0.95 |
| 1990 | 0.83 | 0.81 | 0.85 |
| 1991 | 0.79 | 0.77 | 0.81 |
| 1992 | 0.74 | 0.72 | 0.76 |
| 1993 | 0.72 | 0.70 | 0.74 |
| 1994 | 0.68 | 0.66 | 0.70 |
| 1995 | 0.66 | 0.64 | 0.67 |
| 1996 | 0.65 | 0.63 | 0.67 |
| 1997 | 0.62 | 0.61 | 0.64 |
| 1998 | 0.61 | 0.60 | 0.63 |
| 1999 | 0.60 | 0.58 | 0.61 |
| 2000 | 0.60 | 0.59 | 0.62 |
| 2001 | 0.60 | 0.59 | 0.62 |
| 2002 | 0.57 | 0.55 | 0.58 |
| 2003 | 0.53 | 0.52 | 0.55 |
| 2004 | 0.49 | 0.48 | 0.50 |
| 2005 | 0.46 | 0.44 | 0.47 |
| Men age 70-74 vs 65-69 | 1.20 | 1.17 | 1.23 |
| Men age 75-79 vs 65-69 | 1.50 | 1.47 | 1.53 |
| Men age 80-84 vs 65-69 | 1.92 | 1.88 | 1.96 |
| Men age 85-89 vs 65-69 | 2.43 | 2.38 | 2.48 |
| Men age 90-94 vs 65-69 | 3.16 | 3.08 | 3.24 |
| Men age 95+ vs 65-69 | 4.11 | 3.97 | 4.27 |
| Women age 70-74 vs 65-69 | 1.29 | 1.26 | 1.33 |
| Women age 75-79 vs 65-69 | 1.72 | 1.68 | 1.76 |
| Women age 80-84 vs 65-69 | 2.29 | 2.24 | 2.35 |
| Women age 85-89 vs 65-69 | 3.06 | 2.99 | 3.14 |
| Women age 90-94 vs 65-69 | 4.05 | 3.95 | 4.16 |
| Women age 95+ vs 65-69 | 5.49 | 5.33 | 5.65 |
| Congestive heart failure | 1.66 | 1.64 | 1.67 |
| Valvular disease | 0.95 | 0.93 | 0.96 |
| Pulmonary circulation disorders | 1.28 | 1.24 | 1.31 |
| Peripheral vascular disorders | 1.32 | 1.29 | 1.34 |
| Paralysis | 1.32 | 1.29 | 1.34 |
| Neurological disorders | 1.51 | 1.50 | 1.53 |
| Chronic lung disease | 0.99 | 0.98 | 0.99 |
| Diabetes mellitus | 1.00 | 0.99 | 1.01 |
| Diabetes mellitus with complications | 1.08 | 1.06 | 1.10 |
| Renal failure | 1.68 | 1.65 | 1.71 |
| Liver disease | 1.57 | 1.52 | 1.63 |
| Peptic ulcer disease | 0.82 | 0.75 | 0.89 |
| AIDS | 1.43 | 1.06 | 1.93 |
| Lymphoma | 1.70 | 1.65 | 1.75 |
| Metastatic cancer | 3.88 | 3.81 | 3.95 |
| Cancer without metastases | 1.54 | 1.52 | 1.56 |
| Collagen vascular disease | 1.11 | 1.09 | 1.14 |
| Coagulopathy | 1.57 | 1.54 | 1.60 |
| Weight loss | 1.78 | 1.76 | 1.81 |
| Electrolyte disorders | 2.01 | 2.00 | 2.03 |
| Blood loss anemia | 1.01 | 0.99 | 1.04 |
| Deficiency anemias | 0.88 | 0.87 | 0.89 |
| Alcohol abuse | 1.19 | 1.15 | 1.23 |
| Drug abuse | 0.90 | 0.84 | 0.97 |
| Psychosis | 1.08 | 1.06 | 1.10 |