Association of Diagnostic Coding With Trends in Hospitalizations and Mortality of Patients With Pneumonia, 2003-2009

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Context Recent reports suggest that the mortality rate of patients hospitalized with pneumonia has steadily declined. While this may be the result of advances in clinical care or improvements in quality, it may also represent an artifact of changes in diagnostic coding.

Objective To compare estimates of trends in hospitalizations and inpatient mortality among patients with pneumonia using 2 approaches to case definition: one limited to patients with a principal diagnosis of pneumonia, and another that includes patients with a secondary diagnosis of pneumonia if the principal diagnosis is sepsis or respiratory failure.

Design, Setting, and Participants Trends study using data from the 2003-2009 releases of the Nationwide Inpatient Sample.

Main Outcome Measures Change in the annual hospitalization rate and change in inpatient mortality over time.

Results From 2003 to 2009, the annual hospitalization rate for patients with a principal diagnosis of pneumonia declined 27.4%, from 5.5 to 4.0 per 1000, while the age- and sex-adjusted mortality decreased from 5.8% to 4.2% (absolute risk reduction [ARR], 1.6%; 95% CI, 1.4%-1.9%; relative risk reduction [RRR], 28.2%; 95% CI, 25.2%-31.2%). Over the same period, hospitalization rates of patients with a principal diagnosis of sepsis and a secondary diagnosis of pneumonia increased 177.6% from 0.4 to 1.1 per 1000, while inpatient mortality decreased from 25.1% to 22.2% (ARR, 3.0%; 95% CI, 1.6%-4.4%; RRR, 12%; 95% CI, 7.5%-16.1%); hospitalization rates for patients with a principal diagnosis of respiratory failure and a secondary diagnosis of pneumonia increased 9.3% from 0.44 to 0.48 per 1000 and mortality declined from 25.1% to 19.2% (ARR, 6.0%; 95% CI, 4.6%-7.3%; RRR, 23.7%; 95% CI, 19.7%-27.8%). However, when the 3 groups were combined, the hospitalization rate declined only 12.5%, from 6.3 to 5.6 per 1000, while the age- and sex-adjusted inpatient mortality rate increased from 8.3% to 8.8% (AR increase, 0.5%; 95% CI, 0.1%-0.9%; RR increase, 6.0%; 95% CI, 3.3%-8.8%). Over this same time frame, the age-, sex-, and comorbidity-adjusted mortality rate declined from 8.3% to 7.8% (ARR, 0.5%; 95% CI, 0.2%-0.9%; RRR, 6.3%; 95% CI, 3.8%-8.8%).

Conclusions From 2003 to 2009, hospitalization and inpatient mortality rates for patients with a principal diagnosis of pneumonia decreased substantially, whereas hospitalizations with a principal diagnosis of sepsis or respiratory failure accompanied by a secondary diagnosis of pneumonia increased and mortality declined. However, when the 3 pneumonia diagnoses were combined, the decline in the hospitalization rate was attenuated and inpatient mortality was little changed, suggesting an association of these results with temporal trends in diagnostic coding.

JAMA. 2012;307(13):1405-1413 www.jama.com

PNEUMONIA IS A LEADING CAUSE of morbidity and mortality among US adults, resulting in more than 1 million annual hospital admissions and accounting for more than $10.5 billion in aggregate costs.[1,2] Given its public health significance, pneumonia has been the target of quality improvement activities for nearly 2 decades. This began with the publication of clinical practice guidelines in the early 1990s,[3] was followed by a series of statewide and national quality improvement initiatives,[4] and more recently has included public reporting and pay-for-performance programs led by the Joint Commission and the Centers for Medicare & Medicaid Services (CMS) and other payers.[5,6]

These efforts have been associated with favorable trends in adherence to recommended processes of care,[7-10] including the choice and timely administration of antibiotics. At the same time, several epidemiologic analyses have reported that survival among pneumonia patients appears to be improving, suggesting that clinical advances, improvements in health care quality, or both are having beneficial effects.[11-14] Although the decline in pneumonia mortality may reflect real improvements in clinical outcomes, in the absence of any

For editorial comment see p 1433.

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care-transforming technologies, other explanations should also be considered. One possibility is that the decreasing mortality rate may be an artifact of secular changes in documentation and coding in which the most severe cases of pneumonia are, over time, increasingly receiving alternative principal diagnoses.

To test this hypothesis, we analyzed trends in hospital admissions and outcomes for patients with pneumonia, sepsis, and respiratory failure. We compared results using alternative approaches for defining pneumonia: one that depends on the principal diagnosis of pneumonia and another that also includes patients with the principal diagnoses of sepsis or respiratory failure when combined with a secondary diagnosis of pneumonia.[15,16] We also evaluated changes in hospitalization and mortality rates among patients with a set of conditions we hypothesized would be less susceptible to changes in coding.

METHODS

We conducted a temporal trends study using data from the 2003-2009 releases of the Nationwide Inpatient Sample (NIS), the largest all-payer, publicly available, national hospital database.[2] The NIS contains a 20% stratified sample of all short-term, nonfederal, nonrehabilitation hospitals, representing between 5 and 8 million discharges per year. It was developed as part of the Healthcare Cost and Utilization Project, sponsored by the Agency for Healthcare Research and Quality. Hospitals are sampled according to characteristics such as geographic region, ownership, location (urban/rural), teaching status, and number of beds. The NIS is widely used to study trends in hospital care and has been validated against the National Hospital Discharge Survey. All discharges from sampled hospitals are included in the database.

Cases

We included patients who were 18 years or older and discharged during the study period with a principal *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) diagnosis of pneumonia (481, 482, 483, 485, 486). We did not include patients with a diagnosis of viral pneumonia (480), because we hypothesized that they would be at lower risk of assignment to an alternative principal diagnosis, or those with influenza pneumonia (487.0), because the annual hospitalization and mortality rates exhibit marked changes from year to year. We also included patients with a principal diagnosis of sepsis (038, 995.92, 995.91, 785.52) or respiratory failure (518.81, 518.82, 518.84, 799.1) when accompanied by a secondary diagnosis of pneumonia, because these represent alternative diagnostic coding options in the face of severe disease.[17-19]

Additionally, we selected 3 control conditions that we hypothesized would be less susceptible to secular changes in the choice of an alternative principal diagnosis for patients with severe forms of disease. This included patients with the principal diagnoses of ischemic stroke (*ICD-9-CM* codes 433, 434, 436), ST-segment elevation myocardial infarction (*ICD-9-CM* codes 410.0-410.6 and 410.8), and ruptured thoracic or abdominal aortic aneurysm (*ICD-9-CM* codes 441.1 and 441.3).

For each discharge, we recorded age, sex, principal and secondary diagnoses (up to 15 diagnoses total for 2003-2008, 25 diagnoses total for 2009), discharge disposition, and whether the patient died of any cause during the hospitalization. For patients with a principal diagnosis of pneumonia or sepsis, we noted the microbiologic etiology of the infection when possible. The NIS does not contain unique patient identifiers; each discharge is viewed independently, even if it might represent a repeat hospitalization for a patient.

Outcomes

The primary outcomes were temporal changes in the annual hospitalization rate between 2003 and 2009 and the age- and sex-adjusted inpatient mortality rate. We also considered change over time in discharge disposition, including discharge to hospice, as a secondary outcome because increasing referral to inpatient nursing and rehabilitation facilities and hospice might allow sicker patients to be discharged rather than retained in the hospital. Additionally, we analyzed changes in hospitalization rates associated with specific microbial pathogens in order to provide greater insight about the larger trends.

Analyses

We derived estimates of the number of US hospitalizations by weighting the patient-level discharge data in the NIS files using weights provided. Population rates of hospitalization for each diagnostic category were then calculated from the projected number of hospitalizations and US census estimates of the adult population for each year, 2003 through 2009.

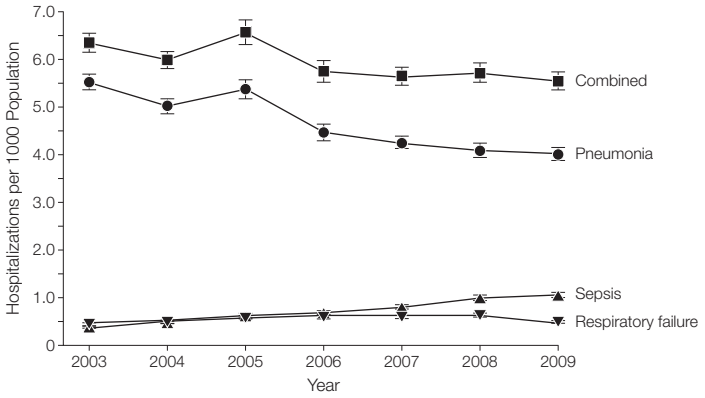
The in-hospital mortality rate was defined as the number of deaths divided by the total number of hospitalizations. We used indirect standardization to adjust in-hospital mortality rates for age and sex, using logistic regression models from 2003 to predict in-hospital mortality for 2004 to 2009 for all 3 diagnosis groups and the combined group. To isolate the effects of the choice of principal diagnosis from other coding trends, our primary analyses did not adjust for other secondary diagnoses that could represent comorbidities. We assessed trends over time using simple linear regression, accounting for discharge weighting in variance estimation, and considered P values less than .05 to be statistically significant; all tests were 2-sided. In a sensitivity analysis, we repeated these analyses while adjusting for the presence of up to 29 unique comorbidities. Comorbidities were assessed using software provided by the Agency for Healthcare Research and Quality based on methods developed by Elixhauser et al.[20]

To further test our hypothesis that changing patterns in the choice of principal diagnosis might account for the

decline in the number of observed cases with a principal diagnosis of pneumonia and the concomitant reduction in mortality, we first estimated the average mortality among patients whose principal diagnosis had potentially shifted (ie, those lost from the principal diagnosis of pneumonia group), assuming that the change in mortality we observed was entirely explained by shifting of the sickest patients. We then compared the age- and sex-adjusted 2009 mortality for sepsis and respiratory failure patients to a projected mortality computed as the weighted average of the adjusted 2003 mortality of sepsis and respiratory failure and the estimated mortality of the "shifted" patients.

All analyses were carried out using SAS statistical software version 9.2 (SAS Institute). The Baystate Medical Center institutional review board examined the study protocol and deemed this study "not human subjects research" that was exempt from further review.

Figure 1. Annual Rate of Hospitalization for Patients With a Principal Diagnosis of Pneumonia, Sepsis With Pneumonia, Respiratory Failure With Pneumonia, and the Combination of the 3 Diagnoses



Error bars indicate 95% confidence intervals.

RESULTS

Hospitalization Trends

Over the study period, the number of cases in the NIS data set ranged from 7.81 million (in 2009) to 8.16 million (in 2008). From 2003 to 2009 the hospitalization rate of patients with a principal diagnosis of pneumonia decreased from 5.5 to 4.0 per 1000, an overall decline of 27.4% (FIGURE 1). Over this same period, the hospitalization rate for patients with a principal diagnosis of sepsis and a secondary diagnosis of pneumonia increased 177.6% from 0.4 to 1.1 per 1000. The hospitalization rate of patients with a principal diagnosis of respiratory failure and secondary diagnosis of pneumonia rose 9.3%, from 0.44 to 0.48 per 1000. When the 3 diagnosis groups were combined to reduce the potential effect of changes in coding practices, the annual hospitalization rate decreased 12.5%, from 6.3 to 5.6 per 1000.

Similar trends were observed in men and women for all 3 of the groups (TABLE 1). Among patients with the principal diagnosis of pneumonia, the hospitalization rate declined for patients in each age group (<65, 65-84, ≥85 years) with the largest absolute decrease occurring in those 85 years or older. There were increases in the hospitalization rate of patients with a principal diagnosis of sepsis and a secondary diagnosis of pneumonia in all 3 age groups, with the largest absolute increase observed among patients 85 years or older.

Microbiologic Trends

Over the study period, there were small and generally reciprocal changes in the documented etiology of pneumonia and sepsis (FIGURE 2 and the eTable, available at http://www.jama.com). For example, the hospitalization rate for the principal diagnosis of pneumococcal pneumonia declined by 33.6%, from 0.15 to 0.10 per 1000 population. Over the same period, the hospitalization rate for the principal diagnosis of pneumococcal sepsis with a secondary diagnosis of pneumonia increased by 119%, from 0.025 to 0.055 per 1000. Similarly, the hospitalization rate for the principal diagnosis of pneumonia due to *Pseudomonas* declined from 0.11 to 0.08 per 1000, while the rate for patients with sepsis due to *Pseudomonas* increased from 0.006 to 0.013 per 1000. Likewise, the hospitalization rate in which pneumonia due to *Staphylococcus aureus* (both methicillin sensitive and methicillin resistant) was listed as the principal diagnosis declined from 0.20 to 0.14 per 1000 while *Staphylococcal* sepsis with pneumonia as a secondary diagnosis increased from 0.041 to 0.074 per 1000.

Mortality and Discharge Disposition

The inpatient mortality rate decreased for each of the diagnosis groups between 2003 and 2009 (TABLE 2 and FIGURE 3). Among patients with a principal diagnosis of pneumonia, age- and sex-adjusted inpatient mortality declined from 5.8% in 2003 to 4.2% in 2009 ($P<.001$) (absolute risk reduction [ARR], 1.6%; 95% CI, 1.4%-1.9%; relative risk reduction [RRR], 28.2%; 95% CI, 25.2%-31.2%). For patients with a principal diagnosis of sepsis and a secondary diagnosis of pneumonia, the adjusted inpatient mortality decreased from 25.1% in 2003 to 22.2% in 2009 ($P<.001$) (ARR, 3.0%; 95% CI, 1.6%-4.4%; RRR, 12%; 95% CI, 7.5%-16.1%). Among patients with a principal diagnosis of respiratory failure, the adjusted inpatient mortality rate declined from 25.1% to 19.2% (ARR, 6.0%; 95% CI, 4.6%-7.3%; RRR, 23.7%; 95% CI, 19.7%-27.8%). However, within the combined group, the adjusted mortality increased from 8.3% in 2003 to 8.8% in 2009 ($P=.01$) (AR in-

crease, 0.5%; 95% CI, 0.1%-0.9%, RR increase, 6.0%; 95% CI, 3.3%-8.8%).

Over the study period, there was a small decline in the percentage of patients with a principal diagnosis of pneumonia discharged to non–acute care facilities, from 22.6% in 2003 to 21.7% in 2009 ($P = .03$). Among those with a principal diagnosis of sepsis, discharge to non–acute care facilities increased from 34.7% in 2003 to 35.7% in 2009 ($P < .001$), while for those with a principal diagnosis of respiratory failure, the proportion discharged to nursing facilities increased from 28.6% in 2003 to 33.4% in 2009 ($P < .001$). Discharges to nursing facilities in the combined group increased from 23.8% of cases in 2003 to 25.4% in 2009 ($P = .05$). Discharges to hospice (both home and facility-based hospice) increased for patients in each of the diagnostic groups, increasing from less than 1% in 2003 to more than 2% in 2009 among patients with a principal diagnosis of pneumonia. In the combined group, hospice discharges increased from 1.0% of cases in 2003 to 3.0% in 2009 (Table 2).

In a sensitivity analysis, adjustment for comorbidities resulted in larger ap-

Table 1. Hospitalization Rates for the Principal Diagnosis of Pneumonia, Sepsis With a Secondary Diagnosis of Pneumonia, Respiratory Failure With a Secondary Diagnosis of Pneumonia, and Combined, 2003-2009

	Rate (95% CI)						
	2003	2004	2005	2006	2007	2008	2009
Principal Diagnosis Pneumonia							
Discharges in NIS, No.	233 737	216 792	232 435	211 283	203 422	200 948	192 792
Hospitalizations per 1000 population	5.5 (5.4-5.7)	5.0 (4.9-5.2)	5.4 (5.2-5.6)	4.5 (4.3-4.6)	4.3 (4.1-4.4)	4.1 (3.9-4.2)	4.0 (3.9-4.2)
Sex							
Male	5.1 (5.0-5.3)	4.7 (4.5-4.8)	5.0 (4.8-5.2)	4.3 (4.1-4.4)	4.0 (3.9-4.2)	3.9 (3.7-4.0)	3.8 (3.7-3.9)
Female	5.9 (5.7-6.1)	5.3 (5.2-5.5)	5.8 (5.5-6.0)	4.7 (4.5-4.9)	4.4 (4.3-4.6)	4.3 (4.1-4.4)	4.2 (4.0-4.4)
Age, y							
18-64	2.0 (1.9-2.1)	1.8 (1.7-1.9)	1.9 (1.8-2.0)	1.8 (1.7-1.8)	1.8 (1.7-1.8)	1.7 (1.6-1.8)	1.8 (1.7-1.9)
65-84	17.6 (17.0-18.2)	16.2 (15.7-16.8)	17.4 (16.7-18.1)	15.0 (14.4-15.6)	13.9 (13.4-14.4)	13.2 (12.7-13.7)	12.5 (12.1-13.0)
≥85	63.1 (60.7-65.4)	55.8 (53.7-58.0)	59.5 (57.1-61.9)	39.8 (38.2-41.5)	36.9 (35.5-38.4)	36.3 (34.9-37.7)	32.5 (31.2-33.8)
Principal Diagnosis Sepsis With Secondary Diagnosis Pneumonia							
Discharges in NIS, No.	16 094	20 489	26 994	33 179	38 870	49 562	51 849
Hospitalizations per 1000 population	0.4 (0.4-0.4)	0.5 (0.5-0.5)	0.6 (0.6-0.7)	0.7 (0.6-0.7)	0.8 (0.8-0.8)	1.0 (0.9-1.1)	1.1 (1.0-1.1)
Sex							
Male	0.4 (0.3-0.4)	0.5 (0.4-0.5)	0.6 (0.6-0.6)	0.7 (0.7-0.7)	0.8 (0.8-0.9)	1.0 (0.9-1.1)	1.1 (1.0-1.1)
Female	0.4 (0.4-0.4)	0.5 (0.5-0.5)	0.6 (0.6-0.7)	0.7 (0.6-0.7)	0.8 (0.7-0.8)	1.0 (0.9-1.1)	1.0 (1.0-1.1)
Age, y							
18-64	0.1 (0.1-0.1)	0.1 (0.1-0.2)	0.2 (0.2-0.2)	0.2 (0.2-0.3)	0.3 (0.3-0.3)	0.4 (0.4-0.4)	0.4 (0.4-0.5)
65-84	1.2 (1.2-1.3)	1.6 (1.5-1.7)	2.1 (1.9-2.2)	2.4 (2.3-2.6)	2.8 (2.6-2.9)	3.5 (3.2-3.7)	3.5 (3.3-3.7)
≥85	5.2 (4.8-5.5)	6.1 (5.7-6.5)	7.5 (6.9-8.1)	6.6 (6.1-7.1)	7.4 (6.8-8.0)	8.9 (8.3-9.5)	8.6 (8.1-9.2)
Principal Diagnosis Respiratory Failure With Secondary Diagnosis Pneumonia							
Discharges in NIS, No.	19 262	21 633	25 880	28 170	28 428	31 254	23 620
Hospitalizations per 1000 population	0.4 (0.4-0.5)	0.5 (0.5-0.5)	0.6 (0.5-0.6)	0.6 (0.6-0.6)	0.6 (0.6-0.6)	0.6 (0.6-0.7)	0.5 (0.5-0.5)
Sex							
Male	0.4 (0.4-0.5)	0.5 (0.4-0.5)	0.6 (0.5-0.6)	0.6 (0.5-0.6)	0.6 (0.5-0.6)	0.6 (0.6-0.6)	0.5 (0.4-0.5)
Female	0.5 (0.4-0.5)	0.5 (0.5-0.5)	0.6 (0.6-0.7)	0.6 (0.6-0.6)	0.6 (0.6-0.6)	0.7 (0.6-0.7)	0.5 (0.5-0.5)
Age, y							
18-64	0.2 (0.2-0.2)	0.2 (0.2-0.2)	0.2 (0.2-0.2)	0.2 (0.2-0.3)	0.2 (0.2-0.2)	0.3 (0.2-0.3)	0.2 (0.2-0.2)
65-84	1.6 (1.5-1.7)	1.8 (1.7-1.9)	2.1 (2.0-2.3)	2.2 (2.0-2.3)	2.2 (2.1-2.3)	2.4 (2.2-2.5)	1.7 (1.6-1.8)
≥85	3.4 (3.1-3.7)	3.6 (3.4-3.9)	4.5 (4.1-4.8)	3.5 (3.2-3.7)	3.6 (3.4-3.9)	3.8 (3.5-4.1)	2.4 (2.2-2.5)
Combined Pneumonias							
Discharges in NIS, No.	269 093	258 914	285 309	272 632	270 720	281 764	268 261
Hospitalizations per 1000 population	6.3 (6.1-6.6)	6.0 (5.8-6.2)	6.6 (6.3-6.8)	5.7 (5.5-6.0)	5.6 (5.5-5.8)	5.7 (5.5-5.9)	5.6 (5.4-5.7)
Sex							
Male	5.9 (5.7-6.1)	5.6 (5.4-5.8)	6.1 (5.9-6.4)	5.5 (5.3-5.7)	5.4 (5.3-5.6)	5.5 (5.3-5.7)	5.4 (5.2-5.5)
Female	6.8 (6.5-7.0)	6.3 (6.1-6.6)	7.0 (6.7-7.3)	6.0 (5.7-6.2)	5.8 (5.6-6.0)	5.9 (5.7-6.2)	5.7 (5.5-5.9)
Age, y							
18-64	2.3 (2.2-2.4)	2.1 (2.1-2.2)	2.4 (2.2-2.5)	2.2 (2.1-2.3)	2.3 (2.2-2.4)	2.3 (2.2-2.4)	2.5 (2.4-2.6)
65-84	20.4 (19.7-21.1)	19.6 (19.0-20.3)	21.6 (20.7-22.5)	19.6 (18.8-20.4)	18.8 (18.2-19.5)	19.0 (18.3-19.7)	17.7 (17.1-18.4)
≥85	71.6 (68.9-74.4)	65.6 (63.0-68.1)	71.5 (68.4-74.5)	49.9 (47.8-52.0)	48.0 (46.0-50.0)	49.0 (47.0-51.0)	43.5 (41.7-45.3)

Abbreviation: NIS, Nationwide Inpatient Sample.

parent reductions in the mortality rates for each of the 3 groups than had been observed after adjustment for age and sex alone (Table 2). Further, the combined group demonstrated a small decline in inpatient mortality (8.3% to 7.8%; ARR, 0.5%; 95% CI, 0.2%-0.9%; RRR, 6.3%; 95% CI, 3.8%-8.8%) instead of the modest increase observed without comorbidity adjustment.

Trends in Hospitalizations and Outcomes for Control Conditions

Over the period 2003 to 2009, there were significant reductions in the hospitalization rate for patients with the principal diagnosis of ischemic stroke (2.9 to 2.3 cases per 1000), ST segment elevation myocardial infarction (1.3 to 0.71 cases per 1000), and aneurysmal rupture of the thoracic or abdominal aorta (0.037 to 0.024 cases per 1000) (TABLE 3). Although inpatient mortality decreased for each of the 3 conditions, ranging from 8.5% for patients with ruptured aneurysms (48.6% to 44.5%; ARR, 4.2%; 95% CI, 0.3%-8.0%) to 17.4% for ischemic stroke (4.8% to 4.0%; ARR, 0.8%; 95% CI, 0.6%-1.1%), each of these changes was significantly smaller ($P < .001$) than the 28% observed for patients with a principal diagnosis of pneumonia.

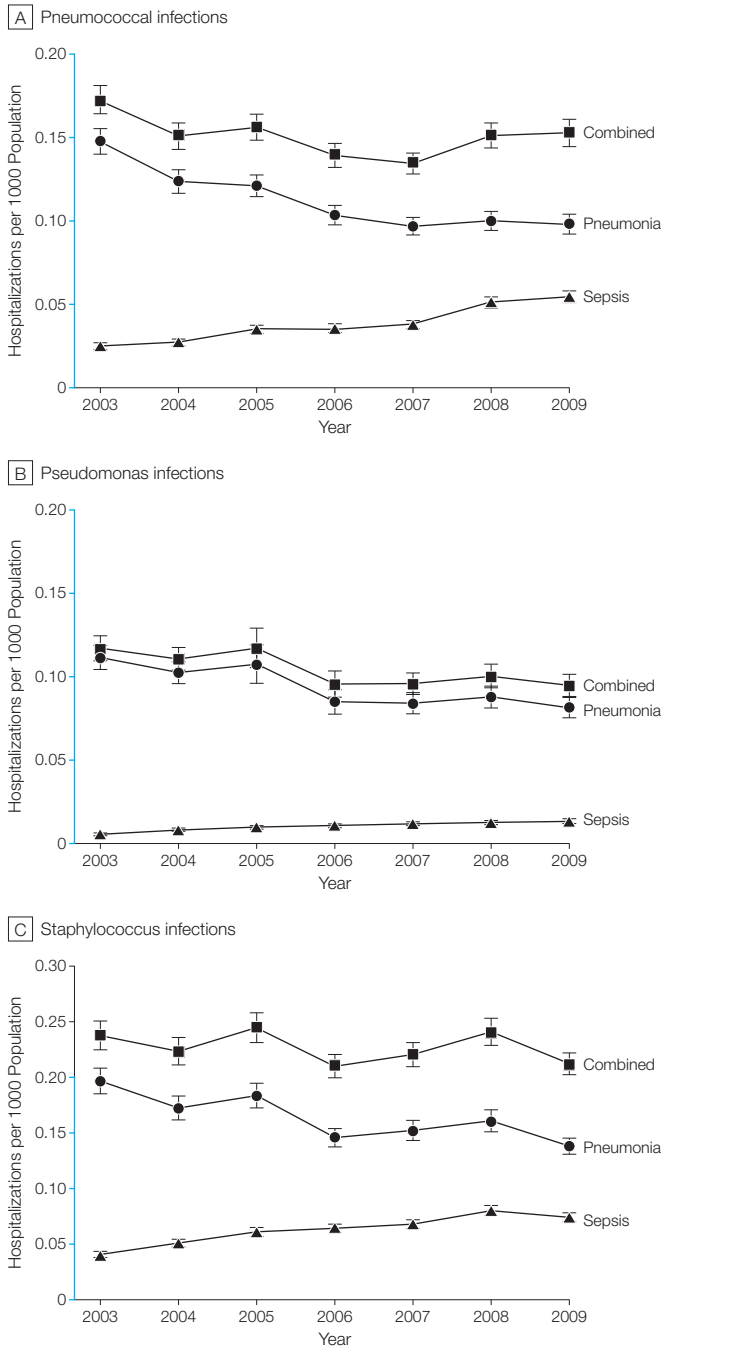
Modeling the Effects of Changes in Coding

Projecting to a national population estimate, 149 088 fewer patients received a principal diagnosis of pneumonia in 2009 than in 2003. Assuming that mortality among the remaining patients with a principal diagnosis of pneumonia did not change from 2003 to 2009, the age- and sex-adjusted mortality within the group of patients who hypothetically shifted from the principal diagnosis of pneumonia to the principal diagnoses of sepsis and respiratory failure was estimated to be 16.3%. Averaging the mortality of these shifted patients with the mortality of the sepsis and respiratory failure patients from 2003 produces an expected mortality for 2009 of 21.0%. By comparison, the adjusted mortality for sepsis and respiratory failure patients in 2009 was 21.3%.

COMMENT

Over the brief 7-year period 2003-2009, there was a 28% relative decline in the age- and sex-adjusted inpatient mortality of patients with a principal diagnosis of pneumonia, far greater than the mortality reduction seen in several conditions that may be less

Figure 2. Annual Rate of Hospitalization for Patients With a Principal Diagnosis of Pneumonia and Sepsis With Pneumonia due to *Streptococcus pneumoniae*, *Pseudomonas*, and *Staphylococcus aureus*



The y-axis in blue indicates range from 0 to 0.20 hospitalizations per 1000 population. Error bars indicate 95% confidence intervals.

Table 2. Adjusted Mortality Rates and Discharge Disposition Among Cases With a Principal Diagnosis of Pneumonia, Sepsis With a Secondary Diagnosis of Pneumonia, Respiratory Failure With a Secondary Diagnosis of Pneumonia, and Combined, 2003-2009

	% (95% CI)							Trend	
	2003	2004	2005	2006	2007	2008	2009	*P* Value	Slope
Principal Diagnosis Pneumonia									
Mortality									
Age and sex adjusted	5.8 (5.6-5.9)	5.4 (5.2-5.6)	4.6 (4.4-4.8)	4.2 (4.0-4.5)	4.1 (3.9-4.2)	4.2 (4.0-4.4)	4.2 (4.0-4.3)	<.001	–0.2764
Age, sex, and comorbidity adjusted	5.7 (5.6-5.9)	5.3 (5.1-5.5)	4.6 (4.4-4.8)	4.2 (4.0-4.4)	3.9 (3.7-4.1)	4.1 (3.9-4.3)	4.0 (3.8-4.2)	<.001	–0.3002
Discharge disposition									
Home	58.8 (58.1-59.6)	55.2 (54.5-55.9)	57.1 (56.4-57.8)	57.3 (56.6-58.0)	57.3 (56.6-58.1)	56.7 (56.0-57.4)	57.8 (57.2-58.5)	.94	0.0083
Home health care[a]	9.9 (9.5-10.4)	12.4 (11.9-12.8)	12.1 (11.7-12.6)	12.6 (12.1-13.0)	12.6 (12.2-13.1)	13.2 (12.8-13.7)	13.0 (12.6-13.5)	<.001	0.4145
Nursing facility[b]	22.6 (22.0-23.2)	24.2 (23.6-24.8)	23.3 (22.8-23.8)	23.0 (22.4-23.5)	22.9 (22.3-23.5)	22.6 (22.1-23.1)	21.7 (21.2-22.2)	.03	–0.2287
Transfer to acute care	1.9 (1.8-2.0)	2.0 (1.9-2.1)	1.9 (1.8-2.0)	2.0 (1.8-2.1)	2.0 (1.9-2.2)	2.3 (2.2-2.4)	2.3 (2.1-2.4)	.53	0.0654
Other[c]	0.9 (0.8-1.0)	0.9 (0.8-1.0)	0.9 (0.9-1.0)	1.0 (0.9-1.1)	1.1 (1.0-1.2)	1.0 (1.0-1.1)	1.2 (1.1-1.3)	.70	0.0405
Hospice[d]	0.8 (0.7-0.9)	1.2 (1.1-1.3)	1.3 (1.2-1.4)	1.5 (1.4-1.6)	1.7 (1.6-1.8)	2.1 (2.0-2.2)	2.2 (2.1-2.3)	<.001	0.3536
Principal Diagnosis Sepsis With Secondary Diagnosis Pneumonia									
Mortality									
Age and sex adjusted	25.1 (24.2-26.1)	25.5 (24.3-26.7)	24.8 (23.6-26.0)	24.3 (23.1-25.5)	23.5 (22.4-24.7)	22.8 (21.7-24)	22.2 (21.1-23.2)	.001	–0.553
Age, sex, and comorbidity adjusted	25.1 (24.2-26.1)	24.9 (23.7-26.1)	24.1 (22.9-25.3)	23.4 (22.2-24.6)	22.2 (21.1-23.3)	22.5 (21.3-23.7)	21.7 (20.6-22.8)	.001	–0.6013
Discharge disposition									
Home	27.0 (25.8-28.1)	23.2 (22.1-24.2)	23.8 (22.8-24.8)	23.9 (22.8-25.0)	23.6 (22.4-24.8)	24.6 (23.5-25.7)	26.5 (25.6-27.5)	.72	0.0498
Home health care[a]	9.6 (9.0-10.2)	10.3 (9.8-10.9)	10.6 (10.1-11.1)	11.5 (11.0-12.1)	11.2 (10.7-11.8)	12.5 (12.0-13.0)	12.4 (11.9-12.9)	<.001	0.4848
Nursing facility[b]	34.7 (33.6-35.7)	37.4 (36.1-38.7)	37.5 (36.4-38.6)	37.0 (36.0-38.1)	38.1 (37.0-39.2)	36.9 (35.9-38.0)	35.7 (34.8-36.6)	.45	0.1037
Transfer to acute care	3.2 (2.9-3.5)	3.1 (2.9-3.4)	3.2 (2.9-3.5)	3.3 (3.0-3.7)	3.7 (3.3-4.1)	3.5 (3.2-3.8)	3.8 (3.4-4.2)	.44	0.1069
Other[c]	0.5 (0.4-0.6)	0.7 (0.5-1.0)	0.6 (0.5-0.8)	0.6 (0.5-0.7)	0.8 (0.7-0.9)	0.7 (0.6-0.8)	0.8 (0.7-0.9)	.79	0.0361
Hospice[d]	2.0 (1.6-2.3)	2.7 (2.3-3.1)	3.8 (3.4-4.2)	4.5 (4.1-4.9)	4.7 (4.3-5.2)	5.5 (5.1-5.9)	5.3 (4.9-5.7)	<.001	0.2235
Principal Diagnosis Respiratory Failure With Secondary Diagnosis Pneumonia									
Mortality									
Age and sex adjusted	25.1 (24.2-26.0)	22.2 (21.0-23.3)	21.5 (20.4-22.6)	20.9 (19.8-22.1)	18.4 (17.4-19.3)	17.5 (16.6-18.5)	19.2 (18.1-20.2)	<.001	–1.0819
Age, sex, and comorbidity adjusted	25.1 (24.2-26.0)	22.3 (21.1-23.4)	21.3 (20.2-22.4)	20.4 (19.3-21.6)	17.9 (17.0-18.9)	17.9 (16.7-19.0)	19.0 (18.0-20.0)	<.001	–1.0884
Discharge disposition									
Home	29.8 (28.3-31.2)	27.2 (26.0-28.4)	27.4 (26.2-28.6)	27.4 (26.1-28.7)	29.3 (28.1-30.5)	29.7 (28.3-31.0)	26.5 (25.3-27.6)	.46	–0.107
Home health care[a]	11.4 (10.6-12.2)	14.0 (13.3-14.7)	13.5 (12.9-14.2)	14.2 (13.6-14.8)	14.7 (14.0-15.3)	15.3 (14.7-15.8)	15.0 (14.3-15.6)	<.001	0.5132
Nursing facility[b]	28.6 (27.5-29.7)	31.9 (30.9-32.9)	32.3 (31.3-33.3)	32.0 (31.0-33.0)	32.2 (31.3-33.2)	32.0 (31.0-33.0)	33.4 (32.5-34.4)	<.001	0.5173
Transfer to acute care	4.4 (4.0-4.8)	4.2 (3.8-4.6)	4.6 (4.2-4.9)	4.9 (4.4-5.4)	4.7 (4.3-5.0)	4.8 (4.3-5.3)	5.7 (5.2-6.2)	.21	0.1817
Other[c]	0.7 (0.5-0.8)	0.7 (0.5-0.8)	0.7 (0.6-0.9)	0.8 (0.7-0.9)	0.9 (0.8-1.0)	0.9 (0.8-1.1)	1.1 (0.9-1.3)	.61	0.0744
Hospice[d]	1.9 (1.6-2.2)	2.9 (2.5-3.3)	3.6 (3.2-3.9)	4.1 (3.8-4.5)	4.4 (4.0-4.8)	5.2 (4.8-5.5)	5.1 (4.7-5.5)	<.001	0.5916
Combined Pneumonias									
Mortality									
Age and sex adjusted	8.3 (8.1-8.5)	8.3 (8.1-8.6)	8.0 (7.7-8.3)	8.3 (8.0-8.6)	8.3 (8.0-8.6)	8.9 (8.5-9.2)	8.8 (8.5-9.1)	.01	0.1016
Age, sex, and comorbidity adjusted	8.3 (8.1-8.5)	8.1 (7.8-8.4)	7.8 (7.5-8.0)	7.8 (7.5-8.0)	7.5 (7.2-7.7)	8.0 (7.7-8.3)	7.8 (7.5-8.1)	.06	–0.0747
Discharge disposition									
Home	54.9 (54.1-55.7)	50.3 (49.6-51.0)	51.3 (50.6-52.0)	50.2 (49.5-50.9)	49.6 (48.8-50.3)	48.0 (47.4-48.7)	49.1 (48.4-49.8)	<.001	–0.8449
Home health care[a]	10.0 (9.6-10.4)	12.3 (11.9-12.8)	12.1 (11.7-12.5)	12.6 (12.2-13.1)	12.6 (12.2-13.1)	13.3 (12.9-13.7)	13.1 (12.7-13.5)	<.001	0.4209
Nursing facility[b]	23.8 (23.2-24.4)	25.9 (25.3-26.5)	25.5 (24.9-26.0)	25.6 (25.0-26.1)	26.1 (25.5-26.7)	26.2 (25.6-26.7)	25.4 (24.9-25.9)	.047	0.2177
Transfer to acute care	2.2 (2.1-2.3)	2.2 (2.1-2.4)	2.3 (2.1-2.4)	2.4 (2.3-2.6)	2.6 (2.4-2.7)	2.8 (2.6-2.9)	2.9 (2.7-3.1)	.27	0.1217
Other[c]	0.9 (0.8-0.9)	0.9 (0.8-1.0)	0.9 (0.8-1.0)	0.9 (0.9-1.0)	1.0 (0.9-1.1)	1.0 (0.9-1.0)	1.1 (1.0-1.2)	.76	0.034
Hospice[d]	1.0 (0.9-1.1)	1.4 (1.3-1.6)	1.7 (1.6-1.8)	2.1 (2.0-2.3)	2.4 (2.2-2.6)	3.0 (2.8-3.2)	3.0 (2.8-3.2)	<.001	0.5307

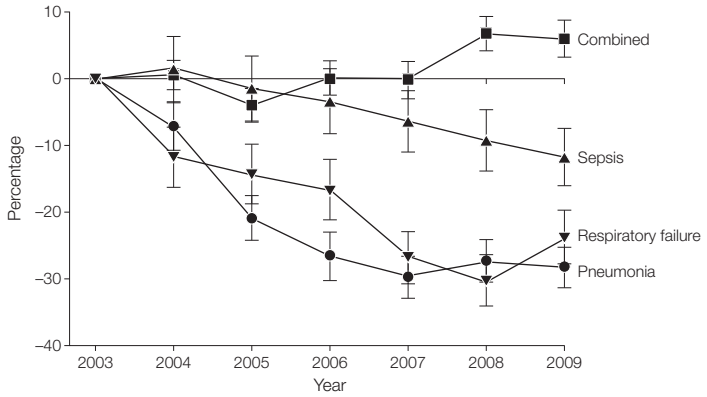
[a] Includes home hospice.
[b] Includes skilled nursing facility, intermediate care facility, rehabilitation facility, hospice, and long-term care.
[c] Includes against medical advice and unknown.
[d] Hospice data based on UB-92 coding 2003-2006 and UB-04 coding 2007-2009 with 2.4%-3.6% missing data varying by year.

susceptible to secular trends in the choice of principal diagnosis. This change in outcome was accompanied by a 27% relative reduction in the annual hospitalization rate, reversing a well-documented, decades-long trend toward increasing hospitalization. Over the same period, there was a near tripling in the hospitalization rates of patients with the principal diagnosis of sepsis and the secondary diagnosis of pneumonia and a smaller increase in cases of respiratory failure. These groups also demonstrated substantial reductions in mortality. However, when the 3 groups were combined, the annual pneumonia hospitalization rate showed a more modest decline, and there was little change in the inpatient mortality rate, varying from a small increase to a small decline depending on the approach to risk adjustment. These results suggest that secular trends in documentation and coding, rather than improvements in actual outcomes, may explain much of the observed change in this and other studies.

A number of studies have described trends in hospitalizations and outcomes of patients with pneumonia. However, to our knowledge, this is the first to compare estimates derived from more than 1 approach to case definition. Combining patients with a principal diagnosis of pneumonia as well as those with the principal diagnoses of sepsis or respiratory failure, a study by Metersky et al[11] found that between 1991 and 1997, there was a 20% increase in the hospitalization rate of Medicare beneficiaries admitted to Connecticut hospitals, and that age-, sex-, and comorbidity-adjusted inpatient mortality rates declined from 14.2% to 12%. In our analysis of the NIS approximately 12 years later, there was a declining rather than increasing hospitalization rate (which may be due to growth in the outpatient management of pneumonia) and a lower inpatient mortality rate (which may reflect improvements in hospital care, the younger patient population found in an all-payer data set like NIS, or both). However, our analyses also suggest that the reduction in mortality reported by Metersky et al may be reaching a plateau.

Using a more contemporary national cohort limited to patients with a principal diagnosis of pneumonia, a study by Fry et al[12] reported that over the period 1988 to 2002, the hospitalization rate increased by 20% among elderly patients, suggesting that the declining hospitalization rate among patients with a principal diagnosis of pneumonia between 2003 and 2009 is a recent occurrence. Using the NIS, a study by Rothberg et al[13] reported that

Figure 3. Age- and Sex-Adjusted Mortality Relative to 2003 Among Patients Discharged With a Principal Diagnosis of Pneumonia, Sepsis With Pneumonia, Respiratory Failure With Pneumonia, and the Combination of the 3 Diagnoses



Error bars indicate 95% confidence intervals.

Table 3. Hospitalization Rates and Adjusted Mortality for Cases With a Principal Diagnosis of Ischemic Stroke, ST-Segment Elevation Myocardial Infarction, or Ruptured Thoracic and Abdominal Aortic Aneurysm, 2003-2009

	2003	2004	2005	2006	2007	2008	2009
Ischemic stroke							
Discharges in NIS, No.	123 756	116 864	112 852	114 146	111 513	118 853	111 205
Hospitalizations per 1000, rate (95% CI)[a]	2.9 (2.8-3.0)	2.7 (2.6-2.8)	2.6 (2.5-2.7)	2.4 (2.3-2.5)	2.3 (2.2-2.4)	2.4 (2.3-2.5)	2.3 (2.2-2.4)
Mortality, % (95% CI)[a]	4.8 (4.7-5.0)	4.8 (4.6-5.0)	4.5 (4.3-4.7)	4.4 (4.2-4.7)	4.1 (3.9-4.4)	4.4 (4.1-4.6)	4.0 (3.8-4.2)
ST-elevation MI							
Discharges in NIS, No.	59 038	49 835	45 130	46 580	39 299	39 155	35 496
Hospitalizations per 1000, rate (95% CI)[a]	1.3 (1.2-1.4)	1.1 (1.0-1.2)	1.0 (0.9-1.1)	0.96 (0.89-1.02)	0.8 (0.75-0.86)	0.78 (0.72-0.84)	0.71 (0.66-0.76)
Mortality, % (95% CI)[a]	8.2 (7.9-8.5)	7.9 (7.5-8.4)	7.8 (7.3-8.2)	7.3 (6.9-7.6)	7.6 (7.2-8.0)	7.5 (7.1-7.9)	7.2 (6.8-7.6)
Ruptured thoracic and abdominal aortic aneurysm							
Discharges in NIS, No.	1590	1454	1369	1388	1215	1448	1173
Hospitalizations per 1000, rate (95% CI)[a]	0.037 (0.034-0.04)	0.034 (0.031-0.037)	0.031 (0.029-0.034)	0.029 (0.027-0.032)	0.025 (0.023-0.027)	0.029 (0.026-0.032)	0.024 (0.022-0.026)
Mortality, % (95% CI)	48.6 (46.0-51.2)	47.8 (45.1-50.6)	49.9 (47.2-52.6)	46.7 (44.1-49.3)	44.8 (42.1-47.4)	42.2 (39.6-44.9)	44.5 (41.6-47.3)

Abbreviations: MI, myocardial infarction; NIS, Nationwide Inpatient Sample.
[a]Age- and sex-adjusted rates.

adjusted mortality rates of patients with pneumonia decreased by 20% between 2000 and 2004, similar to the trend seen in this study. However, the analysis did not consider other diagnostic code possibilities. A study by Ruhnke et al[14] reported that the incidence of pneumonia among Medicare beneficiaries increased between 1987 and 2005, while the odds of 30-day mortality decreased by 54%. In addition to reporting on an earlier time period, the analysis included patients with a principal diagnosis of respiratory failure when paired with a secondary diagnosis of pneumonia, but not those with the principal diagnosis of sepsis. Our analyses suggest that this latter group may have accounted for the majority of any changes in coding. Several recent studies have reported very rapid growth in the rate of hospitalizations of patients with sepsis and severe sepsis, suggesting that the phenomenon in this study may not be limited to pneumonia. This may have implications for the evaluation of trends in the outcomes of patients with other infectious diseases in which sepsis can be chosen as the principal diagnosis.[21-23]

In 1985, a study by Feinstein et al[24] used the term "the Will Rogers phenomenon" when describing apparent temporal improvements in survival among 3 subgroups of cancer patients that were, in reality, a result of stage migration due to enhanced diagnostic techniques. Feinstein et al recognized that many cancer patients who had previously been classified as early stage were now being assigned to a later stage. Because the prognosis of those who migrated was better than the average prognosis of those in the late-stage group, and at the same time worse than those in the early-stage group, survival rates in both groups improved without any changes in individual patient outcomes. Yet when the groups were considered together, the apparent improvement disappeared. Our analysis of data from the NIS suggests that a similar phenomenon may be taking place in hospitalizations for pneumonia.

This hypothesis was also supported by several secondary analyses, including those focused on bacterial etiology, discharge disposition, and control conditions that may be less susceptible to temporal trends in the choice of principal diagnosis. Although the percentage of cases in which specific pathogens were identified was small, there were reductions in the hospitalization rate for pneumococcal, pseudomonas, and staphylococcal pneumonia that were matched by an increasing rate of sepsis due to those organisms, in which pneumonia was considered the secondary diagnosis. Furthermore, at a time when the mortality rate of patients with a principal diagnosis of pneumonia was declining, the proportion of patients discharged to nursing facilities also declined, arguing against discharge of sicker patients. Referrals to home hospice and facility-based hospice increased over the period; however, this was not sufficient to explain the changes seen in the mortality rate among those with a principal diagnosis of pneumonia. Although the control conditions analyzed also demonstrated declining hospitalization rates over time, these rates may have been influenced by improved risk factor management, an interpretation that has been suggested by other investigators.[25] More importantly, even in the face of national programs focused on improving evidence-based treatment in stroke and myocardial infarction, the reductions in inpatient mortality observed over the period were smaller than those seen among patients with a principal diagnosis of pneumonia.

Although our study was not designed to identify the cause of changes in the choice of principal diagnosis for patients with pneumonia, increased documentation and coding of sepsis (and, to a lesser extent, respiratory failure) may have been driven by guidelines that defined a broader set of sepsis signs and symptoms,[26] a national campaign focused on the early recognition and treatment of sepsis, and the higher hospital reimbursement rates associated with sepsis and respiratory failure.[27] Although it may be appealing to attribute better pneumonia outcomes to changes brought about by gains in quality,[9,11] research has cast doubt on the extent to which modest improvements in antibiotic timing and selection might lead to reductions in mortality.[28] Moreover, other possible explanations for a marked decline in inpatient mortality rates, such as a shift toward less severely ill patients being hospitalized or the introduction of transformational care management strategies, seem unlikely.

These findings have important implications. They suggest that attempts to measure the outcomes of patients with pneumonia by studying only those who receive a principal diagnosis of pneumonia will be biased toward increasingly less severe cases. This is especially problematic in the context of longitudinal studies that are subject to the effects of temporal trends in coding practice. Furthermore, ongoing efforts to measure and compare the performance of hospitals, such as those currently being carried out by the CMS, may also be biased if there is variation across hospitals in their use of the sepsis and respiratory failure codes.[29,30]

Our study has a number of limitations. First, the analysis was based on hospital claims, not medical record review, and in the setting of a principal diagnosis of respiratory failure or sepsis, pneumonia can represent a complication of hospitalization rather than a condition present at the time of admission. These 2 possibilities could not be distinguished because present-on-admission coding was only introduced in 2008 and because the NIS has not yet incorporated these new indicators. Nevertheless, had the growth in the number of cases with the principal diagnosis of respiratory failure or sepsis been due to an increase in cases of pneumonia arising as a complication of care, the mortality rate in those cohorts would be expected to have increased over time, not decreased.[31,32] Future efforts to assess outcomes in pneumonia will be able to take advantage of this advance in coding. Second, our analyses were limited to hos-

pitalized patients. Although our findings suggest that outcomes of patients hospitalized for pneumonia have changed little over the last 7 years, it is possible that trends in the use of hospital services have gradually led to increased severity of illness among those patients who do undergo hospitalization that might not be reflected in administrative claims data. In a related way, some of the reduction in the hospitalization rate for patients with the principal diagnosis of pneumonia may be explained by growth in outpatient management or more widespread use of pneumococcal vaccination.[33] Third, the NIS does not provide information about survival beyond the inpatient period. Changes in inpatient outcomes may not correlate with changes in 30-day outcomes, and our observations should be confirmed in other data sets.[34,35] Nevertheless, there were not major changes in the proportion of patients being discharged to non–acute care facilities or to hospice during the study period.

In conclusion, changing patterns in diagnostic coding provide reason to doubt that improvements in the mortality of patients with a principal diagnosis of pneumonia accurately reflect trends in pneumonia outcomes. Without taking into account the broader range of principal and secondary diagnosis combinations that can be used to assign codes to a patient with pneumonia, efforts to examine trends in outcomes or to compare hospital performance may produce biased results.

Author Contributions: Dr Lindenauer 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.
Study concept and design: Lindenauer, Lagu, Rothberg.
Acquisition of data: Lindenauer, Shieh.
Analysis and interpretation of data: Lindenauer, Lagu, Shieh, Pekow, Rothberg.
Drafting of the manuscript: Lindenauer, Lagu.
Critical revision of the manuscript for important intellectual content: Lindenauer, Lagu, Shieh, Pekow, Rothberg.
Statistical analysis: Lindenauer, Lagu, Shieh, Pekow.
Administrative, technical, or material support: Shieh.
Study supervision: Lindenauer, Pekow, Rothberg.
Conflict of Interest Disclosures: All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest and none were reported.
Online-Only Material: The eTable is available at http://www.jama.com.

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