MAJOR ARTICLE

Causes and Risk Factors for Rehospitalization of Patients Hospitalized with Community-Acquired Pneumonia

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Background. Rehospitalization after inpatient treatment of community-acquired pneumonia occurs in one-tenth of all hospitalizations, but the clinical circumstances surrounding readmission to the hospital have not been well studied. The objective of this study was to identify the causes and risk factors for rehospitalization of inpatients with community-acquired pneumonia.

Methods. This project was performed as part of a randomized, multicenter, controlled trial of the implementation of practice guidelines to reduce the duration of intravenous antibiotic therapy and duration of hospitalization for patients who have received a clinical and radiographic diagnosis of pneumonia. The trial was conducted at 7 hospitals in Pittsburgh, Pennsylvania, from February 1998 through March 1999. The primary outcome for these analyses was rehospitalization within 30 days after the index hospitalization. Two physicians independently assigned the cause of rehospitalization as pneumonia related, comorbidity related, or both; consensus was reached for all assignments. Patient demographic characteristics and clinical factors independently associated with rehospitalization were identified using multiple logistic regression analysis.

Results. Of the 577 patients discharged after hospitalization for community-acquired pneumonia, 70 (12%) were rehospitalized within 30 days. The median time to rehospitalization was 8 days (interquartile range, 4–13 days). Overall, 52 rehospitalizations (74%) were comorbidity related, and 14 (20%) were pneumonia related. The most frequent comorbid conditions responsible for rehospitalization were cardiovascular ($n = 19$), pulmonary ($n = 6$), and neurological ($n = 6$) in origin. Less than a high school education (odds ratio, 2.0; 95% confidence interval, 1.1–3.4), unemployment (odds ratio, 3.7; 95% confidence interval, 1.1–12.3), coronary artery disease (odds ratio, 2.7; 95% confidence interval, 1.5–4.7), and chronic obstructive pulmonary disease (odds ratio, 2.3; 95% confidence interval, 1.3–4.1) were independently associated with rehospitalization.

Conclusions. The majority of rehospitalizations following pneumonia are comorbidity related and are the result of underlying cardiopulmonary and/or neurologic diseases. Careful attention to the clinical stability of patients with these coexisting conditions at and following hospital discharge may decrease the frequency of rehospitalization of patients with community-acquired pneumonia.

Community-acquired pneumonia (CAP) accounts for >1 million hospitalizations annually at a cost exceeding $9.7 billion [1]. Rehospitalization because of failed treatment or a new or worsening comorbid illness can further contribute to medical resource use and could lead to iatrogenic complications that are more likely to occur in the inpatient setting [2]. Hospital readmissions for conditions such as congestive heart failure, diabetes, and obstructive lung disease have also been used as indirect markers for reduced quality of care or premature hospital discharge [3–7].

Interventions to decrease rehospitalization rates require an understanding of the causes of and risk factors for hospital readmission. Previous studies of predictors of rehospitalization have focused on medical condi-

Received 12 June 2007; accepted 9 October 2007; electronically published 14 January 2008.

The view expressed in this article are those of the authors and do not necessarily represent the view of the Department of Veteran Affairs or Department of Health and Human Services.

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Clinical Infectious Diseases 2008; 46:550–6

1058-4838/2008/4604-0011
DOI: 10.1086/526526

tions, such as coronary heart disease, cancer, and pneumonia, in patients infected with HIV [8–15]. Although one prior study assessed the causes of and risk factors for subsequent hospitalization of patients with pneumonia initially treated as outpatients [16], to our knowledge, no studies have assessed the clinical circumstances surrounding the rehospitalization of patients initially hospitalized with CAP. The specific aims of this study were to (1) determine the incidence and timing of rehospitalization, (2) identify the reasons for rehospitalization, and (3) assess risk factors for rehospitalization in a cohort of patients hospitalized for pneumonia.

METHODS

This project was performed as part of a multicenter, randomized, controlled trial conducted at 7 teaching and community hospitals in Pittsburgh, Pennsylvania, from February 1998 through March 1999. This trial assessed the effectiveness and safety of a guideline implementation strategy in reducing the duration of intravenous antibiotic therapy and duration of hospitalization for patients with pneumonia. The methods and primary results of this trial were reported in detail elsewhere [17].

Study population. Patient inclusion criteria included a clinical diagnosis of and documented treatment plan for pneumonia and the presence of an acute pulmonary infiltrate on a chest radiograph at presentation for the index hospitalization. Exclusion criteria included (1) age, <18 years; (2) discharge from an acute-care hospital within 10 days prior to presentation; (3) cystic fibrosis; (4) active pulmonary tuberculosis; (5) immunosuppression; (6) positive antibody titer for HIV or history of AIDS; (7) current illicit drug use; (8) alcohol abuse with organ damage; (9) hospitalization for palliative care only; (10) homelessness; (11) prior enrollment in the study; (12) duration of hospitalization $\leq$1 day; (13) culture of a blood specimen, urine specimen, sputum specimen, or specimen from another source that was positive for methicillin-resistant *Staphylococcus aureus* within 24 h of presentation or current treatment for methicillin-resistant *S. aureus* infection; (14) unresolved or incompletely treated pneumonia or empyema diagnosed within the 30 days prior to presentation; or (15) enrollment in another pneumonia research protocol that conflicted with the proposed study.

Baseline and follow-up data collection. Baseline patient sociodemographic characteristics and clinical data were collected from patient interviews, medical records, and interviews of patients' families or caregivers. Clinical data at presentation included vital signs and mental status, comorbid conditions, antibiotics used within 7 days before presentation, physical examination findings, pertinent laboratory test results, and chest radiograph findings. Severity of illness at presentation was quantified in terms of 5 risk classes using the Pneumonia Severity Index [18]. For the current study, the primary study outcome was rehospitalization within 30 days after the initial hospitalization. This outcome, which was a secondary outcome in the original trial, was assessed during the follow-up interviews and the medical record review.

We defined instability at hospital discharge using a modified version of established criteria documented in the medical record within 24 h before hospital discharge [19]. A patient was considered to be unstable if any of the following criteria were fulfilled: (1) temperature, >37.8°C; (2) heart rate, >100 beats per min; (3) systolic blood pressure, <90 mm Hg; (4) respiratory rate, >24 breaths per min; and (5) oxygen saturation, <90%. Two additional criteria previously used to define instability at hospital discharge, abnormal mental status and inability to eat, were not available for chart review.

Assignment of reasons for rehospitalization. For the assignment of reasons for rehospitalization, the hospital admission and discharge records of patients who were rehospitalized within 30 days after the index hospitalization were reviewed by 2 physicians (H.J. and E.M.M.). On the basis of demographic, clinical, laboratory, and radiological data, each physician used a set of predefined criteria to independently assign the reason(s) for rehospitalization. For all cases in which there was disagreement between reviewers with regard to the reasons for rehospitalization ($n = 6$), consensus was reached by review of all clinical data and discussion of each case. The reasons for rehospitalization were categorized as (1) pneumonia-related worsening of signs or symptoms, (2) new or worsening comorbid condition(s) independent of pneumonia, or (3) any combination of pneumonia-related and comorbidity-related reasons.

A patient was defined as having a pneumonia-related rehospitalization using a modification of published criteria to assign reasons for subsequent hospitalization of outpatients with pneumonia [16]. A pneumonia-related rehospitalization was defined by the presence of (1) a radiographic infiltrate and (2) acute onset of symptoms suggestive of pneumonia at the time of hospital readmission. Pneumonia symptoms were classified into typical (i.e., fever, pleuritic chest pain, shortness of breath, and sputum production) and atypical (i.e., abdominal pain, anorexia, chills, confusion, diarrhea, fatigue, headache, hemoptysis, myalgia, nausea, sore throat, sweats, and vomiting) categories.

Patients were defined as having a pneumonia-related rehospitalization if a chest radiograph showed an infiltrate and if $\geq$3 typical or atypical symptoms of pneumonia were present. If there was insufficient documentation to establish the presence of a radiographic infiltrate at the time of hospital readmission, an oxygen saturation of <92% or an increased WBC count and the presence of $\geq$3 symptoms was used to define a pneumonia-related rehospitalization. If oxygen saturation or WBC count

Table 1. Comparison of baseline characteristics from the index hospitalization for rehospitalized and nonrehospitalized patients with pneumonia.

Characteristic	Patients		
	Rehospitalized[a] (n = 70)	Nonrehospitalized[a] (n = 507)	All (n = 577)
Demographic factor			
Age, median years (IQR)[b]	76 (66–82)	70 (56–80)	71 (58–80)
Male sex	47.1	45.4	45.6
White race	82.4	81.9	82.0
Employed[b,c]	4.3	24.1	21.7
Married	45.7	56.1	54.8
Nursing home resident	11.4	9.5	9.7
Private residence	80.0	81.3	81.1
Uninsured or Medicaid recipient	10.0	16.0	15.3
High school graduate	55.4	75.4	72.9
Comorbid condition			
Chronic obstructive pulmonary disease[b]	61.4	37.3	40.2
Asthma	21.4	13.8	14.7
Chronic oxygen use[b]	15.7	4.9	6.2
Interstitial lung disease	5.3	3.7	4.0
Malignancy[d]	18.6	12.8	13.5
Coronary artery disease[b]	64.3	33.5	37.3
Liver disease	0.0	0.8	0.7
Congestive heart failure[b]	41.4	19.5	22.2
Cerebral vascular accident	20.0	15.4	15.9
Renal disease	10.0	6.9	7.3
Atrial dysrhythmia[b]	27.1	16.2	17.5
Ventricular dysrhythmia[b]	5.7	1.6	2.1
Blood disorder[e]	21.4	17.6	18.0
Diabetes[b]	32.9	21.5	22.9
Seizure disorder	1.4	7.1	6.4
Neuromuscular disorder	15.7	9.5	10.2
Medical history			
History of alcohol abuse	4.3	3.7	3.8
History of smoking	61.4	55.2	56.0
Current smoker	14.9	21.6	20.8
History of aspiration event	14.3	8.5	9.2
History of illicit drug use	0.0	1.8	1.6
Hospitalization within previous 30 days	10.0	5.1	5.7
History of antibiotic use within previous 7 days	22.9	25.3	25.0
Duration of first hospitalization, median days (IQR)[b]	6 (4–9)	5 (3–7)	5 (3–8)
Pneumonia Severity Index			
Risk class I	4.3	11.6	10.7
Risk class II	12.9	23.3	22.0
Risk class III	21.4	20.7	20.8
Risk class IV	40.0	32.2	33.1
Risk class V	21.4	12.2	13.3
Physical examination findings			
Respiratory rate, ≥30 per min	25.7	17.6	18.6
Pulse, ≥125 beats per min	15.7	11.6	12.1
Systolic blood pressure, <90 mm Hg	2.9	3.2	3.1
Temperature, <35°C	0.0	0.6	0.5
Temperature, ≥40°C	0.0	3.6	3.1
Altered mental status	15.7	15.4	15.4

(continued)

Table 1. ***(Continued.)***

Characteristic	Patients		
	Rehospitalized[a] (n = 70)	Nonrehospitalized[a] (n = 507)	All (n = 577)
Radiographic finding			
Pleural effusion	18.6	16.6	16.8
Bilateral infiltrate	22.9	18.3	18.9
Multilobar infiltrate	27.1	25.6	25.8
Physical examination finding indicating instability at hospital discharge[f]			
Respiratory rate, >24 breaths per min	2.9	2.4	2.4
Pulse >100, beats per min	2.9	2.2	2.3
Systolic blood pressure, <90 mm Hg	0.0	1.2	1.0
Temperature, >37.8°C	1.4	0.6	0.7
Oxygen saturation, <90%	2.9	4.5	4.3
⩾1 Abnormality at hospital discharge	10.0	10.3	10.2

NOTE. Data are percentage of patients, unless otherwise indicated. IQR, interquartile range.

[a] Proportions were calculated after subtracting missing observations from the denominator. For rehospitalized patients, ⩽4% had missing data for 4 variables (ethnicity, employment, insurance, and smoking). For nonrehospitalized patients, ⩽4% had missing data for 5 variables (ethnicity, employment, insurance, smoking, and respiratory rate).

[b] $P < .05$.

[c] Employed was defined as working either full- or part-time outside the home; homemakers, retirees, and persons without jobs were defined as unemployed.

[d] Malignancy was defined as a history of cancer or active cancer.

[e] Blood disorder was defined as anemia, leukopenia, or thrombocytopenia.

[f] A patient was considered to be unstable at the time of hospital discharge if any of the criteria were fulfilled. We also quantified the number of instabilities present during the 24 h prior to hospital discharge.

was not available, then at least 2 typical and 2 atypical symptoms were required to establish a pneumonia-related cause of rehospitalization.

Patients were defined as having a comorbidity-related rehospitalization if clinical data suggested an alternative reason for readmission. Examples of these diagnoses included congestive heart failure, gastrointestinal bleeding, and renal failure. Patients were assigned to the third category (combination of pneumonia- and comorbidity-related causes) if the primary reason for readmission could not be accurately determined (e.g., exacerbation of chronic lung disease in a patient with pneumonia).

Methods of analysis. We compared the baseline demographic characteristics, medical history, comorbid conditions, Pneumonia Severity Index risk class, duration of the index hospitalization, and assigned intervention arm in the original trial for patients who were rehospitalized with those for the patients who were not rehospitalized. We also compared all of these factors from the index hospitalization for the subset of patients who were readmitted ⩽1 week after the initial hospital discharge with such factors for the subset who were readmitted to the hospital >1 week after the initial hospital discharge. We assessed the 30-day mortality among patients who were and were not rehospitalized; among the subset of rehospitalized patients, we assessed the 30-day mortality among those who were rehospitalized ⩽1 week after the initial hospital discharge, compared with those who were rehospitalized >1 week after the initial hospital discharge. For these analyses, we used the χ^2 test for categorical variables and Student's t test for continuous variables; a 2-tailed P value of <.05 defined statistical significance. Interrater reliability for assignment of the reasons for rehospitalization was assessed using the κ statistic.

We used multiple logistic regression analyses to identify baseline patient characteristics (i.e., demographic and clinical factors) and measures of instability at discharge from the index hospitalization that were independently associated with rehospitalization. All predictors that were statistically significant at $P < .10$ in univariate analyses were entered sequentially into a forward stepwise logistic regression model using an entry criterion of $P < .05$. We assessed all 2-way interactions between the final predictor variables and examined goodness-of-fit using the Hosmer and Lemeshow test [20].

RESULTS

Overall, 608 inpatients met all study eligibility criteria for pneumonia, 27 of whom died during the initial hospitalization and 4 of whom had a duration of hospitalization that exceeded 30 days. Of the 577 patients who were discharged from the hospital within 30 days, 70 (12%) were rehospitalized within 30 days after initial presentation. Among those 70 patients, 30 (42.9%) were readmitted to the hospital ⩽1 week after the initial hospital discharge.

Overall, the median age of the patients was 71 years, 263

Table 2. Reasons for rehospitalization.

Reason	No. (%) of patients
Comorbidity related[a]	52 (74.2)
Cardiovascular	19 (27.1)
Neurologic	6 (8.6)
Pulmonary (unrelated to pneumonia)	6 (8.6)
Gastrointestinal	5 (7.1)
Genitourinary	5 (7.1)
Orthopedic	4 (5.7)
Neoplastic	3 (4.3)
Other	4 (5.7)
Pneumonia related	14 (20.0)
Pneumonia and comorbidity related[b]	3 (4.3)

NOTE. Reasons for rehospitalization were assessed for 69 of the 70 patients who were rehospitalized. A chart was not available for review for 1 patient.

[a] For patients who were rehospitalized for comorbidity-related reasons alone, the comorbid conditions were as follows: cardiovascular causes were coronary artery disease (angina, myocardial infarction, and/or coronary artery bypass graft [$n = 7$]), congestive heart failure and/or cardiomyopathy ($n = 6$), supraventricular tachycardia and/or atrial fibrillation ($n = 5$), and ruptured abdominal aortic aneurysm ($n = 1$); neurologic causes were cerebral vascular accident ($n = 5$) and dementia ($n = 1$); pulmonary causes were exacerbations of chronic obstructive pulmonary disease ($n = 4$) and asthma ($n = 2$); gastrointestinal causes were ileus and/or small bowel obstruction ($n = 2$), percutaneous endoscopic gastrostomy tube placement ($n = 1$), gastrointestinal bleeding ($n = 1$), and *Clostridium difficile* colitis ($n = 1$); genitourinary causes were urinary tract obstruction ($n = 1$), urinary tract infection and/or urosepsis ($n = 3$), and prostatitis ($n = 1$); orthopedic causes were tendonitis ($n = 1$), cervical spine decompression ($n = 1$), hip fracture ($n = 1$), and sciatica ($n = 1$); neoplastic causes were prostate cancer ($n = 1$), carcinomatous meningitis ($n = 1$), and non–small cell cancer ($n = 1$); and other causes were renal failure ($n = 1$), hyponatremia ($n = 1$), hyperglycemia ($n = 1$), and anemia ($n = 1$).

[b] For patients who were rehospitalized for both pneumonia- and comorbidity-related reasons, the comorbid conditions were exacerbation of chronic obstructive pulmonary disease, emphysema, and aspiration.

(45.6%) were male, and 459 (82.0%) were white. Patients who were rehospitalized were older; were less likely to be employed; had a higher frequency of cardiovascular disease, pulmonary disease, and diabetes; and had a longer duration of hospitalization, compared with nonrehospitalized patients (table 1). No difference in rehospitalization rates was observed between patients in the intervention (14%) and control (11%) arms of the original trial ($P = .42$).

Time to rehospitalization. The median time to rehospitalization was 8 days (interquartile range [IQR], 4–13 days). The median time to rehospitalization was 7.5 days (IQR, 3–11 days) for the CAP-related subgroup, 7 days (IQR, 3–12 days) for the comorbidity-related subgroup, and 4 days (IQR, 1–20 days) for the combined subgroup ($P = .90$). There were also no significant differences in the proportion of each of these 3 subgroups that were rehospitalized within 1 week after hospital discharge (41.5% of patients in the CAP-related group, 42.9% in comorbidity-related group, and 66.7% in the combined group; $P = .73$)

Reasons for rehospitalization. As shown in table 2, the most common reasons for rehospitalization were comorbidity related ($n = 52$) and pneumonia related ($n = 14$). The most frequently identified comorbid conditions causing rehospitalization were cardiovascular ($n = 19$), pulmonary ($n = 6$), and neurological ($n = 6$) in origin. The κ statistic assessing interrater reliability for the reasons for rehospitalization was 0.78, indicating a high degree of interrater agreement.

Factors associated with rehospitalization. As shown in table 3, increasing age, education level, employment status, 9 comorbid illnesses, and Pneumonia Severity Index risk class had significant univariate associations with rehospitalization. In multivariate analyses, less than a high school education (OR, 2.0; 95% CI, 1.1–3.4), unemployment (OR, 3.7; 95% CI, 1.1–12.3), coronary artery disease (OR, 2.7; 95% CI, 1.5–4.7), and chronic obstructive pulmonary disease (OR, 2.3; 95% CI, 1.3–4.1) were independently associated with rehospitalization.

Outcomes associated with rehospitalization. There was no significant difference in the 30-day mortality ($P = .20$) between patients who were readmitted to the hospital (7.1%) and those who were not readmitted to the hospital (3.7%). There was also no significant difference ($P = .64$) in mortality between patients rehospitalized $\leq$1 week after hospital discharge (10.0%) and those rehospitalized >1 week after hospital discharge (5.0%). We found no significant difference in duration of hospitalization ($P = .62$) during the episode of rehospitalization between patients rehospitalized $\leq$1 week after hospital discharge and those rehospitalized >1 week after hospital discharge (median duration of hospitalization for both groups, 6 days).

DISCUSSION

Our study involving patients hospitalized with CAP demonstrated that 12% of patients are rehospitalized within 30 days after initial presentation and that one-half of these readmissions occur within 8 days after the initial hospital discharge. Rehospitalization is most often comorbidity related and a result of new or worsening cardiac, pulmonary, and neurological diseases. Patients with underlying chronic obstructive pulmonary disease and coronary artery disease had odds of rehospitalization those were 2 to 3 times higher than that for patients without these conditions. Only one-fifth of rehospitalizations were a result of treatment failure or worsening of symptoms of pneumonia.

One unexpected finding in our study was that employment status and educational level were independently associated with rehospitalization, even after controlling for other potentially confounding factors, including age and medical insurance status. Lack of employment and lower educational levels may be a reflection of low socioeconomic status that was not captured by the other sociodemographic variables assessed in this study. Previous research has shown that a low socioeconomic

Table 3. Factors associated with rehospitalization in univariate and multivariate analyses.

Variable	OR (95% CI)	
	Univariate analysis	Multivariate analysis
Age		
45–64 years	6.9 (0.9–54.6)	3.2 (0.4–26.7)
⩾65 years	11.5 (1.6–84.6)	2.7 (0.3–21.6)
Less than high school education	2.5 (1.4–4.2)	2.0 (1.1–3.4)[a]
Unemployed at baseline	7.0 (2.2–22.7)	3.7 (1.1–12.3)[a]
Congestive heart failure	2.9 (1.7–4.9)	1.6 (0.9–3.0)
Coronary artery disease	3.6 (2.1–6.0)	2.7 (1.5–4.7)[a]
Ventricular dysrhythmia	3.8 (1.1–12.9)	2.4 (0.6–8.9)
Atrial dysrhythmia	1.9 (1.1–3.4)	1.2 (0.6–2.3)
Chronic obstructive pulmonary disease	2.7 (1.6–4.5)	2.3 (1.3–4.1)[a]
Asthma	1.7 (0.9–3.2)	2.0 (1.0–4.1)
Long-term oxygen use	3.6 (1.7–7.7)	1.7 (0.7–4.0)
Interstitial lung disease	1.6 (0.5–4.7)	1.2 (0.4–4.1)
Diabetes	1.8 (1.0–3.1)	1.4 (0.7–2.5)
Pneumonia Severity Index		
Risk class 1	Reference	Reference
Risk class 2	1.5 (0.4–5.7)	0.7 (0.2–2.9)
Risk class 3	2.8 (0.8–10.1)	0.8 (0.2–3.1)
Risk class 4	3.4 (1.0–11.5)	0.8 (0.2–3.0)
Risk class 5	4.8 (1.3–17.3)	1.3 (0.3–5.3)

[a] $P < .05$.

status is associated with diminished access to health care services, quality of care, communication with providers, and ability to adhere to recommended medical therapy [21–25]. These potential associations could result in inadequate treatment, increased risk of complications, and higher rates of rehospitalization.

Compared with a previous study by Halm et al. [26], we observed no statistically significant association between rehospitalization and instability at the time of hospital discharge. In the study by Halm et al. [26], 130 patients (19%) with ⩾1 clinical criterion for instability were discharged from the hospital, whereas in our study, only 10% had ⩾1 criterion for instability at hospital discharge. Thus, the lower rate of instability at hospital discharge observed in our study could have decreased our power to detect a statistically significant association of this factor with rehospitalization.

Our findings have potential clinical implications. Careful attention to the treatment of common comorbid illnesses that are associated with an increased risk of rehospitalization, such as chronic obstructive pulmonary disease and coronary artery disease, may help reduce hospital readmission rates. Strategies to prevent such hospital readmissions at the time of initial hospital discharge include immunizations for influenza and pneumococcus when indicated, clear instructions for the correct use of medications, a review of signs or symptoms that may suggest a worsening of the underlying condition, and an emphasis on appropriate outpatient follow-up with a medical provider within 1 week after hospital discharge, when there is greatest risk for hospital readmission.

Our study has several limitations that should be acknowledged. First, the small number of hospital readmissions may reduce the power of the study to identify important risk factors for rehospitalization. Second, because of the limited clinical information available from the hospital admission history and physical examination and from the discharge summary from the hospital readmission, we could not clearly define CAP-related reasons for hospital readmission based on a new or worsening chest radiograph infiltrate. In addition, this limited clinical information did not allow us to determine whether a change in microbiological etiology or treatment failure was a cause for rehospitalization. Finally, despite the fact that physicians vary in their threshold for hospital admission, we did not assess the appropriateness of rehospitalization and, therefore, cannot comment on this aspect of our primary study outcome.

In conclusion, this study demonstrates that 12% of patients hospitalized for CAP are rehospitalized within 30 days after the initial presentation and that 75% of rehospitalizations occur because of comorbid conditions, such as coronary artery disease and chronic obstructive pulmonary disease. Careful attention

to clinical stability and preventative care before hospital discharge and close follow-up of patients with these coexisting conditions after hospital discharge may decrease the frequency of rehospitalization of patients with CAP.

Acknowledgments

Financial support. Agency for Healthcare Research and Quality and the National Institute of Allergy and Infectious Diseases (RO1 HS08282; as part of the Dissemination of Guidelines for Pneumonia Length of Stay Project), Robert Wood Johnson Foundation Generalist Physician Faculty Scholar and K24 Career Development Award (5K24 AI01769) from the National Institute of Allergy and Infectious Diseases (to M.J.F.), and National Research Service Award Grant (F32 HS00135) from the Agency for Healthcare Research and Quality (to E.M.M.).

Potential conflicts of interest. All authors: no conflicts.

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