A PREDICTION RULE TO IDENTIFY LOW-RISK PATIENTS WITH COMMUNITY-ACQUIRED PNEUMONIA

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ABSTRACT

Background There is considerable variability in rates of hospitalization of patients with community-acquired pneumonia, in part because of physicians' uncertainty in assessing the severity of illness at presentation.

Methods From our analysis of data on 14,199 adult inpatients with community-acquired pneumonia, we derived a prediction rule that stratifies patients into five classes with respect to the risk of death within 30 days. The rule was validated with 1991 data on 38,039 inpatients and with data on 2287 inpatients and outpatients in the Pneumonia Patient Outcomes Research Team (PORT) cohort study. The prediction rule assigns points based on age and the presence of coexisting disease, abnormal physical findings (such as a respiratory rate of $\geq$30 per minute or a temperature of $\geq$40°C), and abnormal laboratory findings (such as a pH $<$7.35, a blood urea nitrogen concentration $\geq$30 mg per deciliter [11 mmol per liter] or a sodium concentration $<$130 mmol per liter) at presentation.

Results There were no significant differences in mortality in each of the five risk classes among the three cohorts. Mortality ranged from 0.1 to 0.4 percent for class I patients ($P=0.22$), from 0.6 to 0.7 percent for class II ($P=0.67$), and from 0.9 to 2.8 percent for class III ($P=0.12$). Among the 1575 patients in the three lowest risk classes in the Pneumonia PORT cohort, there were only seven deaths, of which only four were pneumonia-related. The risk class was significantly associated with the risk of subsequent hospitalization among those treated as outpatients and with the use of intensive care and the number of days in the hospital among inpatients.

Conclusions The prediction rule we describe accurately identifies the patients with community-acquired pneumonia who are at low risk for death and other adverse outcomes. This prediction rule may help physicians make more rational decisions about hospitalization for patients with pneumonia. (N Engl J Med 1997;336:243-50.)

COMMUNITY-ACQUIRED pneumonia is diagnosed in approximately 4 million adults each year in the United States, and more than 600,000 of these are hospitalized.[1,2] The site of care — home or hospital — often determines the extensiveness of the diagnostic evaluation, the route of antimicrobial therapy, and the intensity of clinical observation. The aggregate cost of hospitalization for the disease approaches $4 billion per year.[2-4]

Hospital admission rates for pneumonia vary markedly from one geographic region to the next,[5-7] suggesting that the criteria used for hospitalization are inconsistent. Physicians often rely on their subjective impressions of a patient's clinical appearance in making the initial decision about the site of care.[8] Physicians tend to overestimate the risk of death in patients with pneumonia, and these overestimates are associated with the decision to hospitalize patients at low risk.[8]

Accurate, objective models of prognosis for community-acquired pneumonia could help physicians assess patients' risks and improve the decisions about hospitalization.[9-19] Previous models have been limited by retrospective design,[11,14,15,19] the use of predictor variables about which information is not readily available to physicians when patients present,[9,11,13,15,17-19] and dependence on complex calculations that are difficult to apply in the clinical setting.[19] The general applicability of these studies has been limited by the evaluations of performance at single study sites,[13,15,16] failure to validate findings in independent patient populations,[13,15,19] and a nearly exclusive focus on hospitalized patients.[10,11,13-15,19] Finally, clinical relevance has been compromised by a reliance on mortality as the sole measure of patient outcomes.[10-19]

The purposes of this study were to develop a prediction rule for prognosis that would accurately identify patients with community-acquired pneumonia who are at low risk of dying within 30 days of presentation and to assess the predictive accuracy of this rule for clinically relevant major outcomes.

METHODS

Deriving the Prediction Rule

We derived a prediction rule for prognosis by analyzing data on 14,199 adult inpatients with community-acquired pneumonia in the 1989 MedisGroups Comparative Hospital Database, which contains information on patients discharged from 78 hospitals in

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23 states. In the MedisGroups system, patients' charts are abstracted to collect data on more than 250 key clinical findings relating to demographics, history, physical examination, coexisting illnesses, laboratory results, and radiographic findings.[20-22] The MedisGroups admission review is based on the most-abnormal key clinical findings on hospital day 1 or 2.

To be included in the derivation cohort, patients had to be at least 18 years of age and have a principal diagnosis of pneumonia according to the *International Classification of Diseases, 9th Revision, Clinical Modification* (ICD-9-CM).[18] We excluded patients with a history of the acquired immunodeficiency syndrome or a positive titer of antibodies to the human immunodeficiency virus (HIV), as well as patients who had been hospitalized previously within seven days before the current admission or transferred from another acute care hospital.[9,17-19]

We developed the prediction rule with 30-day hospital mortality as the outcome. Patients in the derivation cohort who were discharged or transferred from the hospital in less than 30 days or who remained in the hospital for more than 30 days were considered alive for this analysis.

Development of the prediction rule was based on a previously validated index that predicted 60-day mortality among patients with community-acquired pneumonia.[19] The following modifications were made in the original index to improve ease of use and clinical relevance[23-25]: the follow-up interval was reduced from 60 to 30 days to increase the proportion of deaths attributable to pneumonia,[11,26,27] uncommonly ordered base-line laboratory tests were eliminated as predictor variables, residence in a nursing home and the presence of renal and liver disease were considered as potential predictor variables, predictor variables with continuous and ordinal scales were converted into dichotomous variables, and all interaction terms in the model were eliminated.

Finally, the prediction rule was developed in two steps to parallel more closely physicians' decision-making processes. Step 1 was designed to identify a subgroup of patients at low risk of death solely on the basis of their history and physical-examination findings. In step 2, the risk of death was quantified in the remaining patients with the same findings used in step 1 plus selected laboratory and radiographic data.

Candidate predictor variables analyzed in step 1 consisted of three demographic variables (age, sex, and nursing home residence), six coexisting illnesses (neoplastic disease, congestive heart failure, cerebrovascular disease, coronary artery disease, renal disease, and liver disease), and five physical-examination findings (pulse rate, respiratory rate, systolic blood pressure, temperature, and mental status). Significant predictors of mortality ($P<0.05$) were identified through logistic-regression analyses. The logistic model was used to rank patients according to their predicted probability of death. On the basis of this ranking, patients with the lowest risk of death were assigned to class I. These patients had an observed cumulative mortality of less than 0.5 percent and none of the independent predictors of mortality identified in step 1.

Candidate predictor variables analyzed in step 2 consisted of the 14 predictor variables considered in step 1 plus 7 laboratory measurements and radiographic findings (blood urea nitrogen, glucose, hematocrit, sodium, partial pressure of arterial oxygen, arterial pH, and pleural effusion). To generate a simple-integer point score, the logistic-regression–model coefficients for all statistically significant ($P<0.05$) predictors of mortality in step 2 were divided by the coefficient for age and rounded to the nearest multiple of 10, with one exception: abnormal temperature was assigned 15 points because temperatures of less than 35.0°C and 40.0°C or higher had estimates of 15 and 14 points, respectively. A total point score for each patient, reflecting the probability of death, was computed by adding the age in years (age minus 10 for women) and all additional points for the documented predictor variables. After the total point scores were calculated, patients were assigned to risk class II, III, IV, or V. The cutoff for risk class II was the highest total point score in which the observed cumulative mortality was less than 1.0 percent. Patients in risk class III had a predicted probability of death of less than 0.04, and patients in risk classes IV and V had predicted probabilities of death of 0.04 to 0.10 and greater than 0.10, respectively.

Validation of the Prediction Rule

The prediction rule was validated with data from a 1991 Pennsylvania MedisGroups statewide data base on 38,039 adult patients hospitalized with community-acquired pneumonia. The data base contains information about patients discharged from 193 general medical and surgical hospitals in Pennsylvania. The methods used to collect information on key clinical findings and identify patients with pneumonia in this data base corresponded directly to the methods used in the 1989 MedisGroups cohort.[28]

The prediction rule was also validated with data on patients enrolled in the Pneumonia PORT prospective cohort study. This observational study of outpatients and inpatients with community-acquired pneumonia was conducted at five medical institutions: the University of Pittsburgh Medical Center and St. Francis Medical Center, in Pittsburgh; Massachusetts General Hospital and Harvard Community Health Plan–Kenmore Center, in Boston; and Victoria General Hospital, in Halifax, Nova Scotia, Canada.

To be included in the Pneumonia PORT cohort study, patients had to be at least 18 years of age, have one or more symptoms suggestive of pneumonia, have radiographic evidence of pneumonia within 24 hours of presentation, and provide informed consent for base-line and follow-up interviews. Patients were ineligible for the study if they had been discharged from an acute care hospital within 10 days before presentation for pneumonia or were known to be HIV-positive.

During the study enrollment period (October 1991 to March 1994), 4002 persons who satisfied all the criteria for study eligibility were identified, of whom 2287 (57.1 percent) were enrolled. The leading reason for the nonenrollment of eligible patients was patients' or physicians' refusal to participate (43.3 percent of those not enrolled). Enrolled patients were younger than eligible nonenrolled patients (mean age, 56 years vs. 61 years) and were more often classified as being at low risk for mortality in the short term (68.9 percent vs. 57.8 percent).

Data on the 21 predictor variables considered in the derivation of the prediction rule were collected through chart review and patient interviews. In contrast to the data from the MedisGroups data bases, the information on vital signs and laboratory values represented the first values available to physicians after patient presentation, rather than the most-abnormal results obtained within the first 48 hours after presentation, and coexisting illnesses were defined according to predetermined clinical definitions rather than ICD-9-CM diagnosis codes.

Patients in the Pneumonia PORT cohort study were followed prospectively to assess their vital status and a variety of outcomes 30 days after the radiographic diagnosis of pneumonia. For all the patients who died, underlying and immediate causes of death were assigned independently by two investigators[29]; disagreements were resolved by the consensus of a panel of five investigators using a standard protocol.[26] Deaths were defined as pneumonia-related if pneumonia was designated as the underlying or immediate cause of death or was determined to have had a major contributing role in the cause of death.[26,29] For outpatients, all subsequent hospitalizations were recorded. For all inpatients and outpatients who were subsequently hospitalized, admission to an intensive care unit for hemodynamic instability, respiratory failure, or mechanical ventilation during the index hospitalization was recorded. For all inpatients discharged alive, the length of their hospital stay was measured.

Statistical Analysis

Three methods were used to validate the prediction rule. Mortality rates in each of the five risk classes were compared in the derivation and validation cohorts with the use of chi-square statistics. The areas beneath the receiver-operating-characteristic curves for predicting mortality in each of the five risk classes were compared in the derivation and validation cohorts.[30,31] The asso-

ciations between risk class and other medical outcomes were assessed with the use of the Cochran–Armitage test for trend[32] for subsequent hospitalization and admission to an intensive care unit and with a test for trend in survival curves for length of stay.[33] For all analyses, a two-tailed P value of less than 0.05 was considered to indicate statistical significance.

RESULTS

Patients' Characteristics

Patients in the Pneumonia PORT cohort were younger and had a lower prevalence of coexisting illnesses and fewer abnormal findings on physical examination and laboratory tests than patients in the two MedisGroups cohorts, reflecting the younger age and lower prevalence of coexisting illnesses among the outpatients in the Pneumonia PORT cohort (Table 1). Mortality in the MedisGroups derivation and validation cohorts was 10.2 and 10.6 percent, respectively (P = 0.24). Overall mortality was lower in the Pneumonia PORT cohort than in both MedisGroups cohorts (P<0.001 for both comparisons), primarily because of the 0.6 percent mortality among outpatients.

Derivation of the Prediction Rule

In step 1 of the prediction rule, the following were independently associated with mortality: an age of more than 50 years, each of five coexisting illnesses (neoplastic disease, congestive heart failure, cerebrovascular disease, renal disease, and liver disease), and each of five physical examination findings (altered mental status; pulse, ≥125 per minute; respiratory rate, ≥30 per minute; systolic blood pressure, <90 mm Hg; and temperature, <35°C or ≥40°C). Of the 14,199 patients in the derivation cohort, 9.7

TABLE 1. DEMOGRAPHIC AND CLINICAL CHARACTERISTICS OF THE PATIENTS IN THE DERIVATION AND VALIDATION COHORTS.*

CHARACTERISTIC	MEDISGROUPS DERIVATION COHORT (N = 14,199)	MEDISGROUPS VALIDATION COHORT (N = 38,039)	PNEUMONIA PORT VALIDATION COHORT		
			INPATIENTS (N = 1343)	OUTPATIENTS (N = 944)	TOTAL (N = 2287)
			percent		
Demographic factor					
Age <50 yr	16.7	15.5	25.4	67.4	42.7
Female sex	50.8	52.3	47.7	53.3	50.0
Nursing home resident	9.9	10.8	13.8	1.0	8.5
Coexisting conditions					
Congestive heart failure	28.0	28.1	16.8	3.0	11.1
Cerebrovascular disease	12.5	15.8	14.2	2.0	9.2
Neoplastic disease	10.1	15.3	8.7	1.7	5.8
Renal disease	3.4	5.9	10.3	1.5	6.7
Liver disease	1.1	1.6	2.2	0.3	1.4
Active use of injection drugs†	—	—	1.8	1.0	1.4
Alcohol abuse†	—	—	12.0	2.0	7.9
Physical-examination findings					
Altered mental status	16.3	10.3	17.3	0.6	10.4
Pulse ≥125/min	9.3	12.5	13.0	2.8	8.7
Respiratory rate ≥30/min	29.9	37.4	21.9	1.2	13.3
Systolic blood pressure <90 mm Hg	9.3	11.5	3.4	0.4	2.1
Temperature <35°C or ≥40°C	3.7	4.0	2.3	0.5	1.6
Laboratory and radiologic findings					
Blood urea nitrogen ≥30 mg/dl (11 mmol/liter)	22.3	22.3	23.5	1.1	14.3
Glucose ≥250 mg/dl (14 mmol/liter)	9.6	11.2	6.6	0.7	4.2
Hematocrit <30%	10.8	11.9	10.0	1.2	6.3
Sodium <130 mmol/liter	7.7	6.5	6.1	0.7	3.9
Partial pressure of arterial oxygen <60 mm Hg‡	28.1	26.2	34.5	0.7	20.6
Arterial pH <7.35	7.9	8.3	6.2	0.1	3.7
Pleural effusion	11.6	7.9	12.5	3.8	8.9

*Since it was not possible to distinguish missing and normal data in the MedisGroups derivation and validation cohorts, the proportions in this table reflect the number of patients with each finding divided by the total number of patients in each cohort.

†Data on the prevalence of these conditions were not available in the two MedisGroups cohorts.

‡In the Pneumonia PORT cohort study, an oxygen saturation of less than 90 percent on pulse oximetry or intubation before admission was also considered abnormal.

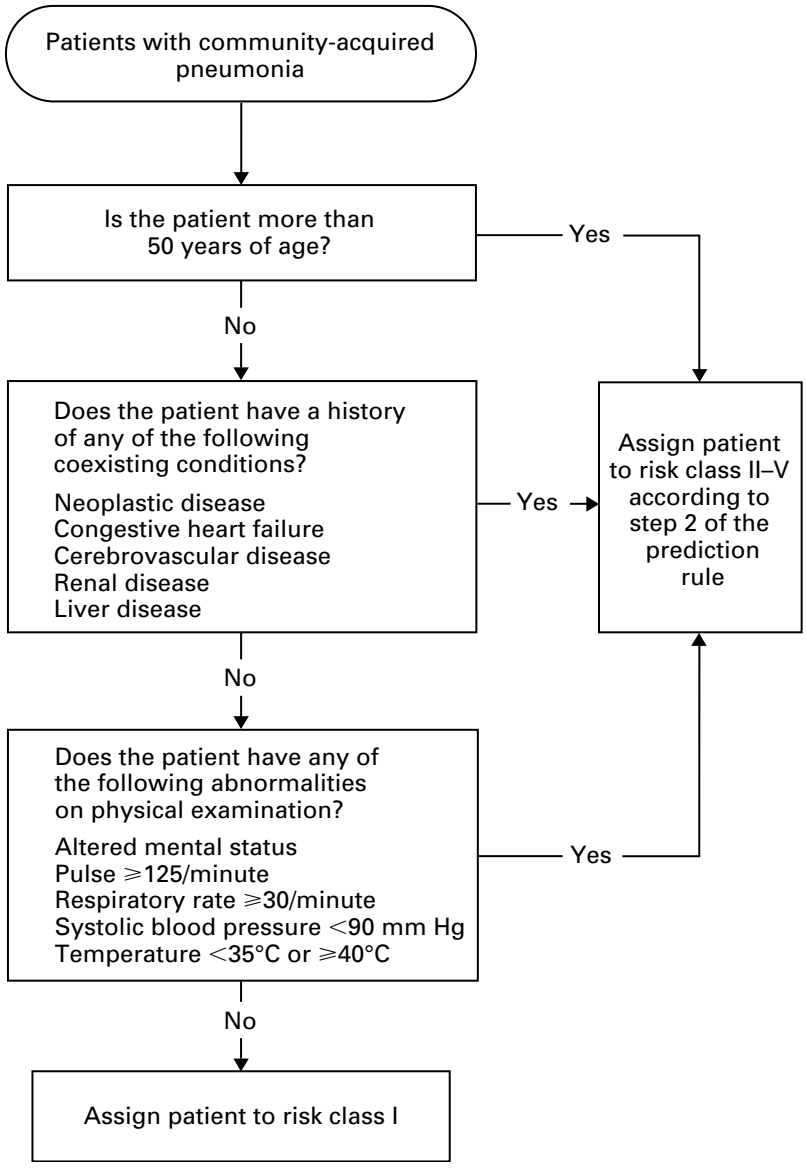

Figure 1. Identifying Patients in Risk Class I in the Derivation of the Prediction Rule.

In step 1 of the prediction rule, the following were independently associated with mortality: an age of more than 50 years, five coexisting illnesses (neoplastic disease, congestive heart failure, cerebrovascular disease, renal disease, and liver disease), and five physical-examination findings (altered mental status; pulse, ⩾125 per minute; respiratory rate, ⩾30 per minute; systolic blood pressure, <90 mm Hg; and temperature, <35°C or ⩾40°C). In the derivation cohort, 1372 patients (9.7 percent) with none of these 11 risk factors were assigned to risk class I. All 12,827 remaining patients were assigned to risk class II, III, IV, or V according to the sum of the points assigned in step 2 of the prediction rule (see Tables 2 and 3).

percent with none of these 11 risk factors were assigned to risk class I (Fig. 1).

In step 2, in addition to the 11 factors identified in step 1, 2 demographic factors (male sex and nursing home residence) and 7 laboratory or radiographic findings (blood urea nitrogen concentration, ⩾30 mg per deciliter [11 mmol per liter]; glucose concentration, ⩾250 mg per deciliter [14 mmol per liter]; hematocrit, <30 percent; sodium concentration, <130 mmol per liter; partial pressure of oxygen, <60 mm Hg; arterial pH, <7.35; and pleural effusion) were each independently associated with mortality in the remaining 12,827 patients. The point scoring system shown in Table 2 was used to meas-

ure the magnitude of the association of each of these 20 factors with mortality.

Validation of the Prediction Rule

No significant differences in mortality in each of the five risk classes were found among the three study cohorts (Table 3). Mortality was low for risk classes I, II, and III, ranging from 0.1 to 0.4 percent for class I, from 0.6 to 0.7 percent for class II, and from 0.9 to 2.8 percent for class III. There was no significant difference ($P = 0.15$) in the area under the receiver-operating-characteristic curves between the MedisGroups derivation cohort (0.84) and the MedisGroups validation cohort (0.83). Although the area under the curve was significantly greater in the Pneumonia PORT cohort (0.89) than in either of the MedisGroups cohorts ($P<0.001$), the absolute differences in area were minimal.

Of the 1575 Pneumonia PORT patients in the three lowest risk classes, only 7 died (1 in class I, 3 in class II, and 3 in class III). Only 4 of these deaths were pneumonia-related: 3 in patients with terminal cancer and 1 in a patient with obstructive pulmonary disease, alcoholism, and malnutrition. None of these deaths were judged to have been preventable.

There was a significant relation between risk class and each of the other medical outcomes evaluated in the Pneumonia PORT cohort (Table 4). Among outpatients, the rate of subsequent hospitalization within 30 days ranged from 5.1 percent for class I patients to 20.0 percent for class IV ($P<0.001$). None of the 62 class I, II, or III outpatients who were subsequently hospitalized died, and only 1 was admitted to an intensive care unit. Of the eight outpatients in classes IV or V who were subsequently hospitalized, three died and one was admitted to an intensive care unit.

Among inpatients, admissions to intensive care units ranged from 4.3 percent for class I to 17.3 percent for class V ($P<0.001$). For all 1236 inpatients who were discharged alive, the proportion who stayed in the hospital three days or fewer was 26.1 percent for class I and 3.7 percent for class V ($P<0.001$).

The clinical profiles of patients within risk classes were nearly identical in the three study cohorts.* Class I patients were all young (median age, 35 to 37 years) and had none of the pertinent coexisting illnesses or abnormalities on physical examination. Class II patients were typically middle-aged (median age, 58 to 59 years), and most were assigned to this class by virtue of their age alone. Class III patients were typically older (median age, 72), and most had at least one pertinent coexisting illness, one physical-examination abnormality, or one laboratory or radiographic abnormality. Class IV and V patients were somewhat older (median age, ≥75) and were virtually never assigned to these classes by virtue of their age alone; the majority had abnormalities in two (class IV) or all three (class V) of the pertinent risk factor categories.

TABLE 2. POINT SCORING SYSTEM FOR STEP 2 OF THE PREDICTION RULE FOR ASSIGNMENT TO RISK CLASSES II, III, IV, AND V.

CHARACTERISTIC	POINTS ASSIGNED*
Demographic factor	
Age	
Men	Age (yr)
Women	Age (yr) − 10
Nursing home resident	+10
Coexisting illnesses†	
Neoplastic disease	+30
Liver disease	+20
Congestive heart failure	+10
Cerebrovascular disease	+10
Renal disease	+10
Physical-examination findings	
Altered mental status‡	+20
Respiratory rate ≥30/min	+20
Systolic blood pressure <90 mm Hg	+20
Temperature <35°C or ≥40°C	+15
Pulse ≥125/min	+10
Laboratory and radiographic findings	
Arterial pH <7.35	+30
Blood urea nitrogen ≥30 mg/dl (11 mmol/liter)	+20
Sodium <130 mmol/liter	+20
Glucose ≥250 mg/dl (14 mmol/liter)	+10
Hematocrit <30%	+10
Partial pressure of arterial oxygen <60 mm Hg§	+10
Pleural effusion	+10

*A total point score for a given patient is obtained by summing the patient's age in years (age minus 10 for women) and the points for each applicable characteristic. The points assigned to each predictor variable were based on coefficients obtained from the logistic-regression model used in step 2 of the prediction rule (see the Methods section).

†Neoplastic disease is defined as any cancer except basal- or squamous-cell cancer of the skin that was active at the time of presentation or diagnosed within one year of presentation. Liver disease is defined as a clinical or histologic diagnosis of cirrhosis or another form of chronic liver disease, such as chronic active hepatitis. Congestive heart failure is defined as systolic or diastolic ventricular dysfunction documented by history, physical examination, and chest radiograph, echocardiogram, multiple gated acquisition scan, or left ventriculogram. Cerebrovascular disease is defined as a clinical diagnosis of stroke or transient ischemic attack or stroke documented by magnetic resonance imaging or computed tomography. Renal disease is defined as a history of chronic renal disease or abnormal blood urea nitrogen and creatinine concentrations documented in the medical record.

‡Altered mental status is defined as disorientation with respect to person, place, or time that is not known to be chronic, stupor, or coma.

§In the Pneumonia PORT cohort study, an oxygen saturation of less than 90 percent on pulse oximetry or intubation before admission was also considered abnormal.

*See NAPS document no. 05359 for 1 page of supplementary material. Order from NAPS, c/o Microfiche Publications, P.O. Box 3513, Grand Central Station, New York, NY 10163-3513. Remit in advance (in U.S. funds only) $7.75 for photocopies or $5 for microfiche. Outside the U.S. and Canada, add postage of $4.50 for the first 20 pages and $1.00 for each 10 pages of material thereafter or $1.75 for the first microfiche and $0.50 for each microfiche thereafter. There is a $15 invoicing charge on all orders filled before payment.

TABLE 3. COMPARISON OF RISK-CLASS–SPECIFIC MORTALITY RATES IN THE DERIVATION AND VALIDATION COHORTS.*

RISK CLASS (NO. OF POINTS)†	MEDISGROUPS DERIVATION COHORT		MEDISGROUPS VALIDATION COHORT		PNEUMONIA PORT VALIDATION COHORT					
					INPATIENTS		OUTPATIENTS		ALL PATIENTS	
	no. of patients	% who died	no. of patients	% who died	no. of patients	% who died	no. of patients	% who died	no. of patients	% who died
I	1,372	0.4	3,034	0.1	185	0.5	587	0.0	772	0.1
II (≤70)	2,412	0.7	5,778	0.6	233	0.9	244	0.4	477	0.6
III (71–90)	2,632	2.8	6,790	2.8	254	1.2	72	0.0	326	0.9
IV (91–130)	4,697	8.5	13,104	8.2	446	9.0	40	12.5	486	9.3
V (>130)	3,086	31.1	9,333	29.2	225	27.1	1	0.0	226	27.0
Total	14,199	10.2	38,039	10.6	1343	8.0	944	0.6	2287	5.2

*There were no statistically significant differences in overall mortality or mortality within risk class among patients in the MedisGroups derivation, MedisGroups validation, or overall Pneumonia PORT validation cohort. The P values for the comparisons of mortality across risk classes are as follows: class I, P = 0.22; class II, P = 0.67; class III, P = 0.12; class IV, P = 0.69; and class V, P = 0.09.

†Inclusion in risk class I was determined by the absence of all predictors identified in step 1 of the prediction rule. Inclusion in risk classes II, III, IV, and V was determined by a patient's total risk score, which was computed according to the scoring system shown in Table 2.

TABLE 4. MEDICAL OUTCOMES IN THE PNEUMONIA PORT COHORT ACCORDING TO RISK CLASS.

MEDICAL OUTCOME	CLASS I	CLASS II	CLASS III	CLASS IV	CLASS V	TOTAL	P VALUE
Outpatient							
No. of patients	587	244	72	40	1	944	
Subsequent hospitalization (% of patients)	5.1	8.2	16.7	20.0	0	7.4	<0.001
Inpatient							
No. of patients	185	233	254	446	225	1343	
Admission to intensive care unit (% of patients)*	4.3	4.3	5.9	11.4	17.3	9.2	<0.001
Length of hospital stay†							
Median no. of days	5.0	6.0	7.0	9.0	11.0	7.0	<0.001
≤3 days (% of patients)	26.1	22.1	13.1	5.9	3.7	13.1	<0.001
4–7 days (% of patients)	48.9	44.2	41.0	31.3	23.8	37.3	
>7 days (% of patients)	25.0	33.8	45.8	62.8	72.6	49.6	

*This category includes all patients admitted to an intensive care unit for hemodynamic instability, respiratory failure, or mechanical ventilation during their index hospitalization.

†The assessment of the length of hospital stay was restricted to 1236 inpatients who were discharged after the index hospitalization.

DISCUSSION

In comparison with previous prognostic models for community-acquired pneumonia,[9-19] our prediction rule has distinctive strengths.[23-25,34] First, the predictor variables are all explicitly defined and can be readily assessed at the time of patient presentation. Second, patients can be assigned to the lowest risk class (class I) on the basis of information from the initial history and physical examination alone, which permits physicians to avoid ordering laboratory tests that are costly and often difficult to perform in an outpatient setting. Third, the accuracy and generalizability of the rule are supported by its derivation and validation in over 50,000 inpatients from 275 hospitals across the United States and Canada. Finally, validation in the Pneumonia PORT cohort allowed assessment of the rule in outpatients, follow-up for mortality after hospitalization for those treated as inpatients, and examination of additional medical outcomes that are critical to fully evaluating the prognosis for patients with pneumonia.

The prognosis for patients with community-acquired pneumonia ranges from rapid recovery to death.[35] The great variability seen in rates of hospital admission and lengths of stay for pneumonia in part reflects uncertainty among physicians in assessing

the severity of this illness and the perceived benefits of hospital care.[5-7,36] Our prediction rule was designed to reduce such uncertainty and to foster more appropriate use of hospitals in the management of this illness.

The prediction rule identifies three distinct risk classes (I, II, and III) of patients who are at sufficiently low risk for death and other adverse medical outcomes that physicians can consider outpatient treatment or an abbreviated course of inpatient care for them. All patients 50 years of age or less who have none of the coexisting illnesses or physical-examination abnormalities identified in step 1 of the rule (class I) should be candidates for outpatient treatment. Many patients in risk classes II and III are also potential candidates for outpatient treatment. This strategy should apply to the majority of patients assigned to these two risk classes by virtue of age alone or the presence of a single pertinent coexisting illness or abnormal finding on physical examination or laboratory testing. For the remaining patients in classes II and III for whom treatment at home with oral antimicrobial therapy is judged to be unsuitable, there are alternatives to traditional inpatient care. These include parenteral antimicrobial therapy at home or a short stay (<24 hours) in a hospital observation unit. Previous studies have suggested that one fifth of all patients hospitalized with pneumonia remain in the hospital after becoming medically stable.[37] The risk stratification provided by our rule could also help target low-risk patients at the time of admission for whom rapid conversion from intravenous to oral antimicrobial therapy[38-42] and early discharge[43] might be appropriate.

The potential impact of this prediction rule can be estimated by using projections from the Pneumonia PORT cohort. A strategy of outpatient care for all class I and II patients, brief inpatient observation for patients in class III, and traditional inpatient care for all patients in classes IV and V would have reduced the proportion of patients receiving traditional inpatient care by 31 percent and meant a brief observational hospital stay for an additional 19 percent of those who were treated as inpatients. Of the Pneumonia PORT inpatients who would have been recommended for outpatient care if this strategy had been used, fewer than 1 percent died (3 patients) and 4.3 percent (18 patients) were admitted to an intensive care unit.

An additional margin of safety could be provided by amending this strategy to include traditional inpatient care for all patients in classes I, II, and III who have hypoxemia at presentation (i.e., who have an oxygen saturation of less than 90 percent or a partial pressure of oxygen of less than 60 mm Hg while breathing room air). Special attention to oxygenation status is consistent with published criteria for hospitalization and with actual clinical practice[8,44]; in the Pneumonia PORT cohort study, 99 percent of the patients known to have hypoxemia at presentation were hospitalized. Under this amended strategy, the proportion of patients who received traditional inpatient care would still have been reduced by 26 percent, and an additional 13 percent of inpatients would have been treated with a brief observational hospital stay. Of the inpatients for whom outpatient care would have been recommended according to this strategy, mortality was the same (three patients), and only 1.6 percent (four patients) were admitted to an intensive care unit. With both of the strategies we have described, inpatient care would have been recommended for five of the six patients treated in the outpatient setting who died (all in class IV). Given the prevalence of this illness, strategies that reduce the use of traditional hospital care could result in large aggregate cost savings. Furthermore, reducing the rate of hospitalization of low-risk patients with pneumonia is consistent with the clear preferences of patients for treatment at home rather than in the hospital.[45]

We must address the potential limitations of our prediction rule before recommending its use in clinical practice. First, patients designated as being at low risk may have important medical and psychosocial contraindications to outpatient care. For example, administering oral antibiotics in an outpatient setting to patients with intractable vomiting is not an option.[8] Likewise, patients who use intravenous drugs or who are alcoholic or unreliable or have severe psychiatric conditions may require hospitalization to ensure compliance with treatment. Finally, patients with severely impaired cognitive function who are unable to carry out activities of daily living independently and those with little social support may require traditional inpatient care regardless of the severity of their illness.

Second, some patients have rare conditions, such as severe neuromuscular disease or immunosuppression, that are not included as predictors in our model but that clearly increase the likelihood of a poor outcome. In such cases, our rule would not supersede a physician's judgment.

Third, the rule was constructed with dichotomous predictor variables (abnormal vs. normal) to facilitate its use in practice. As a result, it may oversimplify the way physicians interpret the predictor variables. For example, a clinician would be unlikely to discharge a previously healthy 25-year-old patient with severe hypotension and tachycardia and no additional pertinent prognostic factors, despite the patient's having a class II designation according to the rule.

In conclusion, we derived and validated a prediction rule that identifies patients with community-acquired pneumonia who are at low risk for death and other adverse outcomes. Our projections from the observational Pneumonia PORT cohort provide preliminary evidence that one or more strategies for applying this rule could safely reduce the need for hospitalization in the treatment of patients with pneu-

monia. However, it is important to note that the premise that a large proportion of low-risk inpatients could be treated safely in an outpatient setting or with very short hospital stays assumes that the processes of care in the hospital are not critical determinants of medical outcomes among low-risk patients. Although this study provides preliminary evidence that our prediction rule could help physicians determine when hospital care is appropriate for patients with community-acquired pneumonia, firm recommendations for its clinical use will depend on future prospective trials to confirm its effectiveness and safety.

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