Usefulness of a predictive model to hospitalize patients with low-risk community-acquired pneumonia

Adriana Lama[1] · Francisco Gude[2] · María Elena Toubes[1] · Ana Casal[1] · Jorge Ricoy[1] · Carlos Rábade[1] · Nuria Rodríguez-Núñez[1] · Ana Cao-Ríos[2] · Uxío Calvo[1] · Luis Valdés[1,3,4]

Abstract

Introduction A high proportion of patients with low-risk community-acquired pneumonia (CAP) (classes I-III of the Pneumonia Severity Index) are hospitalized. The purpose of this study was to determine whether validated severity scales are used in clinical practice to make admission decisions, identify the variables that influence this decision, and evaluate the potential predictive value of these variables.

Materials and methods A prospective, observational study of patients ≥ 18 years of age with a diagnosis of low-risk CAP hospitalized or referred from the Emergency Department to outpatient consultations. A multivariate logistic regression predictive model was built to predict the decision to hospitalize a patient.

Results The study population was composed of 1,208 patients (806 inpatients and 402 outpatients). The severity of CAP was estimated in 250 patients (20.7%). The factors that determined hospitalization were "abnormal findings in complementary studies" (643/806: 79.8%; due to respiratory failure in 443 patients) and "signs of clinical deterioration" [64/806 (7.9%): hypotension (16/64, 25%); hemoptoic expectoration (12/64, 18.8%); tachypnea (10/64, 15.6%)]. In total, ambulatory management was not contraindicated in 24.7% of hospitalized patients (199). The predictive model built to decide about hospitalization had a good power of discrimination (AUC 0.876; 95%CI: 0.855–0.897).

Conclusions Scales are rarely used to estimate the severity of CAP at the emergency department. The decision to hospitalize or not a patient largely depends on the clinical experience of the physician. Our predictive model showed a good power to discriminate the patients who required hospitalization. Further studies are warranted to validate these results.

Keywords Community-acquired pneumonia · Low-risk · Hospitalization · Predictive model

✉ Ana Casal
ana.casal.mourino@sergas.es

Adriana Lama
adriana.lama.lopez@sergas.es

Francisco Gude
francisco.gude.sampedro@sergas.es

María Elena Toubes
maria.elena.toubes.navarro@sergas.es

Jorge Ricoy
jorge.ricoy.gabaldon@sergas.es

Carlos Rábade
crabcas@gmail.com

Nuria Rodríguez-Núñez
nuria.rodriguez.nunez@sergas.es

Ana Cao-Ríos
ana.cao.rios@rai.usc.es

Uxío Calvo
uxio.calvo.alvarez@sergas.es

Luis Valdés
luis.valdes.cuadrado@sergas.es

1   Servicio de Neumología, Complejo Hospitalario Universitario de Santiago, Travesía da Choupana S/N, 15706 Santiago de Compostela, Spain

2   Concepción Arenal Primary Care Centre Grupo de Métodos de Investigación, Instituto de Investigaciones Sanitarias de Santiago (IDIS), Unidad de Epidemiología Clínica Complejo Hospitalario Clínico-Universitario de Santiago, Santiago de Compostela, Spain

3   Grupo Interdisciplinar de Investigación en Neumología, Instituto de Investigaciones Sanitarias de Santiago (IDIS), Santiago de Compostela, Spain

4   Departamento de Medicina, Facultad de Medicina, Universidad de Santiago de Compostela, Santiago de Compostela, Spain

Introduction

Community-acquired pneumonia (CAP) is considered a public health problem owing to its high incidence and morbimortality, and the economic burden it represents for public health systems [1–4]. Determining whether a patient needs or not hospital care is one of the most complex and relevant decisions in clinical practice. The evidence available suggests that clinicians often overestimate patient risk, thereby resulting in many patients being unnecessarily hospitalized. This practice increases health spending. A range of prognostic scales have been developed for estimating CAP severity. These scales help clinicians estimate the severity of CAP objectively, thereby facilitating decision making [5, 6]. Based on these scales, clinical practice guidelines (CPG) recommend that low-risk patients are managed in ambulatory care and only the patients with a higher risk of mortality are hospitalized [7, 8]. However, the evidence available shows that patients with a low risk of mortality are frequently hospitalized [9, 10]. Some authors suggest that hospitalization decisions should also be based on clinician's experience [11–13], on the basis of a set of criteria that has not been clearly established. As a result, the decision is made on a case-by-case basis after the clinician has estimated the severity of CAP.

We posited that some factors are not considered or are underestimated in prognostic scales, which influences the decision to admit patients with low-risk CAP [*Pneumonia Severity Index* (PSI), classes I-III][5]. The objectives of this study was: (i) to determine whether validated severity assessment scales are used in decision-making concerning the hospitalization of patients with CAP; (ii) to determine whether the decision to hospitalize a patient with low-risk CAP is influenced by any variables, regardless of them being considered or not in prognostic scales; and (iii) determine the value of some factors to predict hospitalization.

Materials and methods

A prospective, observational study was conducted involving patients older than 18 years who received a diagnosis of CAP between October 1st, 2016 and December 31st, 2021. The sample was composed of consecutive patients admitted to the Unit of Pulmonology for CAP, along with outpatients referred from the emergency department (ED) to the CAP Unit for follow-up. Informed consent was obtained.

Patients were included if they were ≥ 18 years; immunocompetent; diagnosed with CAP (based on consistent symptoms and the presence of a de novo pulmonary infiltrate on chest X-ray) [14] classified as PSI class I-III[5] (low severity) that was not expected to require hospitalization [7, 8]. Pneumonias in institutionalized patients were also included, since the latest CPG consider them community-acquired pneumonias [8].

Patients were categorized into two groups: inpatients (defined as cases) and outpatients (defined as controls). Hospital-acquired pneumonias, tuberculosis, or CAPs in immunocompromised patients were excluded.

The reasons why ED clinicians and specialists on-call made the decision to hospitalize a patient were grouped into six categories, following the classification of previous studies [10]: [i) psychosocial factors; ii) comorbid conditions; iii) signs of clinical deterioration; iv) abnormal findings in clinical studies; v) readmissions to the ED in the last two weeks; and vi) other causes not included in other categories], each being divided into different subcategories. The physicians responsible for each patient during hospitalization reviewed admission criteria and divided patients into three groups based on the appropriateness of their admission, namely: Group 1, patients in whom outpatient care was contraindicated, independently of the severity of their CAP. Group 2, patients with identifiable risk factors that were not absolute indications for hospitalization nor were associated with a higher risk of mortality. Group 3, patients in whom outpatient care was not contraindicated and without any identifiable risk factor that warranted hospitalization.

The variables selected to assess the appropriateness of hospitalization are detailed in the Supplementary Material. The socio-familial situation of the patient was defined as good if a relative agreed to take care for the patient after discharge, regardless of them being cohabitants or not.

This study was approved by the Ethics Committee of Santiago-Lugo (code 2016/388).

Statistical analysis

Continuous variables were expressed as medians (25-75th percentiles), since most did not follow normal distribution. Qualitative variables were described as absolute frequencies and percentages. Chi-squared (qualitative variables), Cochran-Mantel–Haenszel Wilcoxon (ordinal) and Wilcoxon (continuous) test were used to assess the association between patient characteristics and decision about hospitalization or pneumonia severity.

A multivariate logistic regression model was built. The decision about hospitalization (yes/no) was the dependent variable for the patient. Independent variables included sex; age; medical history; previous vaccination (flu/pneumococcus); comorbilities; cardiovascular risk factors; Charlson index; radiological abnormalities and a range of laboratory variables. Variables with less than five patients were excluded.

The Akaike information criterion (AIC) was used to select the variables to be included in the model [15]. Based on the independent variables previously described, stepwise regression was used to sequentially identify and exclude the variables without any predictive value. Potential non-linear effects were examined using generalized additive models and spline models [16]. Results are expressed as Odds Ratio (OR) with their 95% confidence intervals (CI). Then, aspects related to performance were assessed, including calibration and discrimination. Discrimination was verified by the use of ROC curves and area under the curve. Calibration was performed using calibration plots and Brier score [17]. Data analysis was performed using *R* software, available at http://cran.r-project.org, with the *mgcv, rms*, *vcdExtra* y *pROC* packages. All analyses were carried out in accordance with TRIPOD standards [18].

Results

During the study period, a total of 1,208 patients with CAP PSI class I-III were included. Of them, 806 were admitted to the Unit of Pulmonology, whereas 402 were referred for outpatient follow-up. Figure 1 displays patient flow chart.

At the ED, CAP severity was only assessed (PSI class assessment) in 20.7% of patients [250/1208; inpatients, 181/806 (22.5%); outpatients, 69/402 (17.2%)]. In relation to hospitalized patients, if severity had not been assessed at the ED, assessment was performed within 24 h from admission. In outpatients, the risk of mortality was estimated in the first follow-up visit.

Hospitalized patients were significantly older ($p < 0.001$); reported a heavier alcohol use ($p = 0.004$); and had a higher number of chronic lung diseases ($p < 0.001$) and a higher Charlson index ($p < 0.001$), as compared to outpatients. The former also had a higher number of oxygen therapy ($p = 0.007$), CPAP ($p = 0.011$), and non-invasive mechanical ventilation ($p = 0.020$) machines at home. Moreover, a higher percentage of inpatients had a respiratory rate > 30 bpm and a heart rate > 120 bpm, as compared to outpatients ($p < 0.001$ and $p = 0.008$, respectively). Respiratory failure ($PaO_2 < 60$ mmHg) was also more frequent among hospitalized patients [58% of inpatients (460/793) vs. 3.6% of outpatients (11/304)] ($p < 0.001$). Hospitalized patients more frequently had a BUN > 30 mg/dL ($p = 0,002$); lymphopenia (< 700 cell/mm^3) ($p < 0.001$); multilobular/bilateral pulmonary infiltrates ($p < 0.001$ each); pulmonary cavitation ($p = 0.019$) and pleural effusion ($p = 0.002$). Factors influencing hospitalization included age; alcoholism; drug abuse; diagnosis of chronic lung disease; presence of comorbidities; home CPAP usage; respiratory rate > 30 BPM; or HR > 120 BPM; acute respiratory failure; and a variety of specific analytical [BUN > 30 mg/dL, sodium < 130 mE/L, lymphopenia (< 700 cells/mm^3)] or radiological (multilobar/bilateral infiltrates, pulmonary cavitation or pleural effusion) abnormalities (see Table 1).

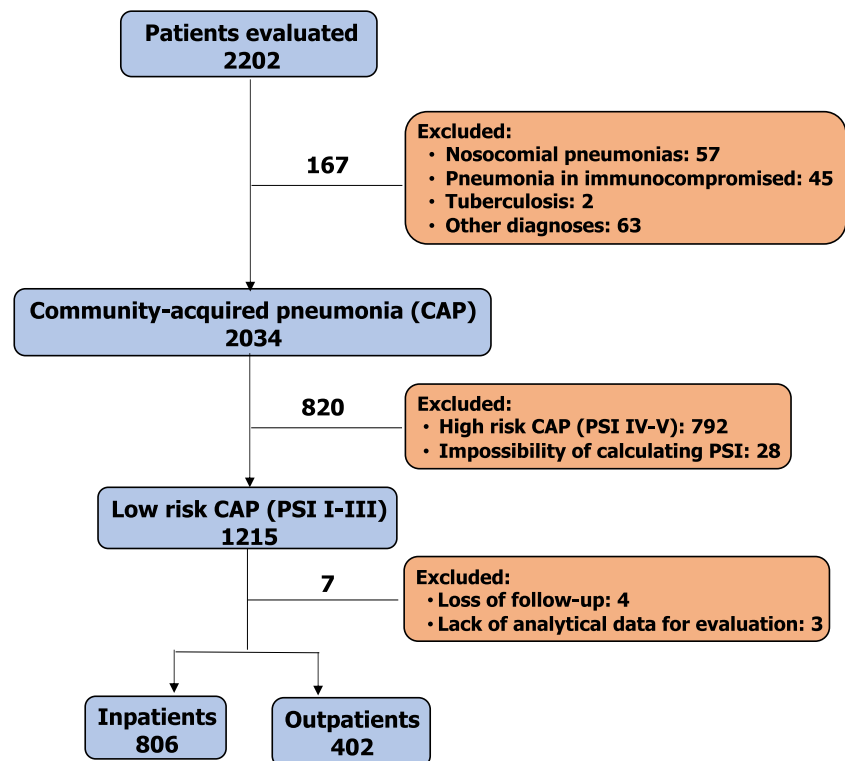**Fig. 1** Flow chart of patients with community-acquired pneumonia

Table 1 Baseline characteristics of patients with low-risk pneumonia based on the site of care (hospital/home) and association with the hospitalization decision

Characteristics	Hospitalized patients (n=806)	Outpatients (n=402)	p	Odds ratio (95% confidence interval)
Age, median (IQR)	62 [49,72]	57 [41,68]	<0.001	1.02 (1.01, 1.03)
Men, n (%)	441 (54.7%)	220 (54.7%)	1.000	Ref 1.00 (0.79, 1.27)
Place of residence				
Home	798 (99.0%)	400 (99.5%)	0.511	Ref
Nursing home	8 (1.0%)	2 (0.5%)		2.01 (0.50, 13.32)
Habits				
Smokers	224 (27.8%)	94 (23.4%)	0.111	1.26 (0.96, 1.67)
Alcoholism	70 (8.7%)	17 (4.2%)	0.004	2.15 (1.28, 3.83)
Abuse drugs	15 (1.9%)	2 (0.5%)	0.070	3.79 (1.06, 24.14)
Comorbidities				
Cardiac insufficiency	39 (4.8%)	11 (2.7%)	0.093	1.81 (0.95, 3.74)
Stroke	20 (2.5%)	6 (1.5%)	0.300	1.68 (0.71, 4.62)
Active neoplasm	10 (1.2%)	6 (1.5%)	0.791	0.83 (0.31, 2.45)
Kidney failure	6 (0.7%)	4 (1.0%)	0.739	0.75 (0.21, 2.93)
Chronic liver disease	24 (3.0%)	6 (1.5%)	0.168	2.03 (0.88, 5.50)
Chronic respiratory disease	283/803 (35.2%)	82/400 (20.5%)	<0.001	2.11 (1.60, 2.81)
Charlson index, median (IQR)	1 [0,1]	0 [0,1]	<0.001	
0				Ref
1				1.72 (1.31, 2.27)
2				2.30 (1.51, 3.61)
≥3				4.25 (1.78, 12.56)
Home therapies				
Oxygen therapy	13 (1.6%)	0 (0.0%)	0.007	13.70 (0.81, 230.97)
CPAP	31 (3.8%)	5 (1.2%)	0.011	3.18 (1.34, 9.36)
Non-invasive ventilation	11 (1.4%)	0 (0.0%)	0.020	11.64 (0.68, 197.98)
Physical examination				
Confusion	5 (0.6%)	0 (0.0%)	0.176	
Oral tolerance	4 (0.5%)	0 (0.0%)	0.308	
Respiratory rate > 30 BPM	54/803 (6.7%)	3 (0.7%)	<0.001	9.59 (3.51, 39.53)
BP < 90 mm Hg	22 (2.7%)	5 (1.2%)	0.103	2.33 (0.95, 6.99)
Heart rate > 120 bpm	56 (6.9%)	13 (3.2%)	0.008	2.23 (1.25, 4.31)
Temperature < 35ºC or > 40ºC	7 (0.9%)	3 (0.7%)	1.000	1.17 (0.32, 5.43)
Blood gas test				
$PaO_2 < 60$ mm Hg or $SaO_2 < 90\%$	460/793 (58.0%)	11/304 (3.6%)	<0.001	36.79 (20.80, 72.47)
pH < 7.35	5/797 (0.6%)	1/311 (0.3%)	1.000	1.96 (0.31, 37.58)
Analytical				
BUN > 30 mg/dL or 11 mmol/L	41/805 (5.1%)	6/396 (1.5%)	0.002	3.49 (1.58, 9.22)
Sodium < 130 mEq/L	12/805 (1.5%)	1 (0.2%)	0.072	6.07 (1.19, 110.75)
Glucose > 250 mg/dL	22/805 (2.7%)	6 (1.5%)	0.225	1.85 (0.79, 5.07)
Leukocytes < 4,000 cel/mm^3	28 (3.5%)	7 (1.7%)	0.103	2.03 (0.93, 5.09)
Lymphopenia < 700 cel/ mm^3	219/804 (27.2%)	48 (11.9%)	<0.001	2.76 (1.98, 3.91)
Radiology				
Multilobar infiltrates	228 (28.3%)	42 (10.4%)	<0.001	3.38 (2.40, 4.88)
Bilateral infiltrates	155 (19.2%)	23 (5.7%)	<0.001	3.92 (2.54, 6.34)
Cavitation	23 (2.9%)	3 (0.7%)	0.019	3.91 (1.35, 16.54)
Pleural effusion	79 (9.8%)	19 (4.7%)	0.002	2.19 (1.34, 3.77)
Severity				
PSI I, n (%)	107 (13.3%)	171 (42.5%)	<0.001	
PSI II, n (%)	273 (33.9%)	149 (37.1%)	0.277	

Table 1 (continued)

Characteristics	Hospitalized patients (n=806)	Outpatients (n=402)	p	Odds ratio (95% confidence interval)
PSI III, n (%)	426 (52.9%)	82 (20.4%)	<0.001	
PSI score, median (IQR)	71 [57,82]	53.5 [38,68]	<0.001	
CURB65 0–1, n (%)	536 (66.5%)	330 (82.1%)	<0.001	
Distance to the hospital (kilometres), median (IQR)	26 [11, 40]	26 [8, 38]	0.120	

CPAP continuous positive airway pressure, *CURB65* confusion, urea, respiratory rate, blood pressure, ≥ 65 years, *PSI pneumonia severity index*; *BP* systolic blood pressure, *IQR* interquartile range, *BUN* blood urea nitrogen

Ref control group

Table 2 Reasons of admission reported by the ED physician/specalist on-call, according to the severity of pneumonia

Admission Reason Groups	Total (806)	PSI I (107)	PSI II (273)	PSI III (426)	p
Pscyhosocial factors	**6 (0.7%)**	2 (1.9%)	1 (0.4%)	3 (0.7%)	0.306
• Absence of family support	5	2	0	3	
• Alcoholism	1	0	1	0	
Comobid conditions	**39 (4.8%)**	8 (7.5%)	12 (4.4%)	19 (4.5%)	0.394
• Stable chronic disease	8	0	2	6	
• Decompensation of baseline disease	16	6	3	7	
• Incidental findings requiring additional treatment	14	2	7	5	
• Use of home NIMV	1	0	0	1	
Signs of clinical deterioration	**64 (7.9%)**	14 (13.1%)	25 (9.2%)	25 (5.9%)	0.031
• Persistent fever	12	8	3	1	
• Chest pain	2	0	1	0	
• Hypotension	16	1	8	8	
• Tachypnea	10	0	5	5	
• Poor general condition	4	0	1	3	
• Hemoptoic expectoration/hemoptysis	12	2	6	4	
• Bronchospasm	8	3	1	4	
Abnormal results of complementary studies	**643 (79.8%)**	64 (59.8%)	211 (77.3%)	368 (86.4%)	<0.001
• Respiratory failure	443	26	139	278	
• Hypoxemia	64	9	28	27	
• Multilobar infiltrates	19	5	6	7	
• Bilateral infiltrates	30	12	11	7	
• Atelectasis	1	0	1	0	
• Cavitation	12	3	3	6	
• Pleural effusion	29	2	12	15	
• Kidney failure	21	1	5	15	
• Hyponatremia	4	0	0	4	
• Leukocytosis, leukopenia	18	5	5	8	
• Cholestasis pattern	1	1	0	0	
• Oral anticoagulation overdosing	1	0	1	0	
Poor response to ambulatory care	**23 (2.9%)**	4 (3.7%)	11 (4.0%)	8 (1.9%)	0.210
Other reasons not included in previous groups	**31 (3.8%)**	15 (14.0%)	13 (4.8%)	3 (0.7%)	<0.001
• Suspicion of viral pneumonia	17	6	10	1	
• Suspicion of tuberculosis	3	3	0	0	
• Varicella pneumonia	2	2	0	0	
• Bacteremia	3	1	1	1	
• Foreign body aspiration	1	0	0	1	
• Post-surgical fever	1	0	1	0	
• Oral intolerance	2	2	0	0	
• Suspicion of pulmonary mass	1	1	0	0	
Mean stay (days)	**6.1**	5.0	6.0	6.4	0.001

PSI pneumonia severity index, *VMNI* ventilación mecánica no invasiva

Table 3 Appropriateness of hospitalization based on the discretion of the physicians responsible for the inpatient

Group	Reason	n	%
1	Pscyhosocial reasons	6	61.5%
	Decompensation of comorbid condition (unstable comorbid conditions)	17	
	Acute concomitant severe diseases	11	
	Severe acute kidney failure (baseline creatinine > 2 mg/dL)	4	
	Oral intolerance	2	
	Respiratory failure	443	
	Moderate/large or complicated pleural effusion	13	
	Total	496	
2	Poor response to antibiotic therapy	23	13.8%
	Multilobar/bilateral condensation, cavitation, atelectasis, small pleural effusion	78	
	Comorbidities	9	
	Total	110	
3	Hypoxemia	64	24.7%
	Hyponatremia (Na 130–135 mEq/L)	4	
	Oral anticoagulation overdosage	1	
	Cholestasis	1	
	Leukocytosis	18	
	Bacteremia	3	
	Hemoptoic expectoration	12	
	Suspicion of viral pneumonia	17	
	New onset atrial fibrillation	2	
	Suspicion of post-surgery fever	1	
	Suspicion of pulmonary mass	1	
	Suspicion of tuberculosis	3	
	Varicella pneumonia	2	
	Persistent fever	12	
	Chest pain	2	
	Hypotension (albeit systolic arterial pressure > 90 mm Hg)	16	
	Tachypnea (albit < 30 breaths/minute)	10	
	Poor general condition	4	
	Brochospasm	8	
	- Chronic kidney failure (creatinine < 2 mg/dL)	17	
	Pregnancy	1	
	Total	199	

In relation to inpatients, the median age and percentage of males increased significantly as PSI severity increased, whereas the percentage of smokers and abuse drug users decreased. A higher PSI class was associated with a higher frequency of the following variables: multiple comorbidities; Charlson index; need for home oxygen therapy; respiratory rate > 30/minute; acute respiratory failure; BUN > 30 mg/dL; and a longer mean length of hospital stay. On another note, the percentage of patients with pulmonary infiltrates and pulmonary cavitation decreased significantly as CAP severity increased. In outpatients, the severity of pneumonia increased significantly with age, percentage of males, presence of some comorbidities, Charlson index, and percentage of patients with acute respiratory failure, glucose > 250 mg/dL and lymphopenia (lymphocytes < 700 cell/mm³). In contrast, the higher the severity of pneumonia, the lower the number of smokers (see Table 1S and Table 2S in supplementary material).

The group in which the most income was included was "abnormal findings in complementary studies" (79.8%), followed by "signs of clinical deterioration" (7.9%). In the first group, the most frequent reason was respiratory failure (443 patients). The higher the severity of pneumonia was, the higher the percentage of patients who were admitted specifically for respiratory failure, and more generally for abnormal findings in complementary studies. Similarly, the more severe pneumonia was, the longer the mean length of hospital stay ($p < 0.001$) (see Table 2).

In total, 61.5% (496/806) of hospitalized patients were classified as group 1 (outpatient care was contraindicated); 13.8% (110 patients) as group 2 (presence of risk factors for admission but without absolute indication for admission); and 24.7% (199 patients) as group 3 (no contraindication for outpatient care and absence of any identifiable risk factor for admission) (Table 3).

The results of the multivariate analysis of baseline clinical and epidemiological characteristics that influenced hospitalization decision are shown in Table 4. Figure 2A displays the ROC curve of the predictive model of hospitalization
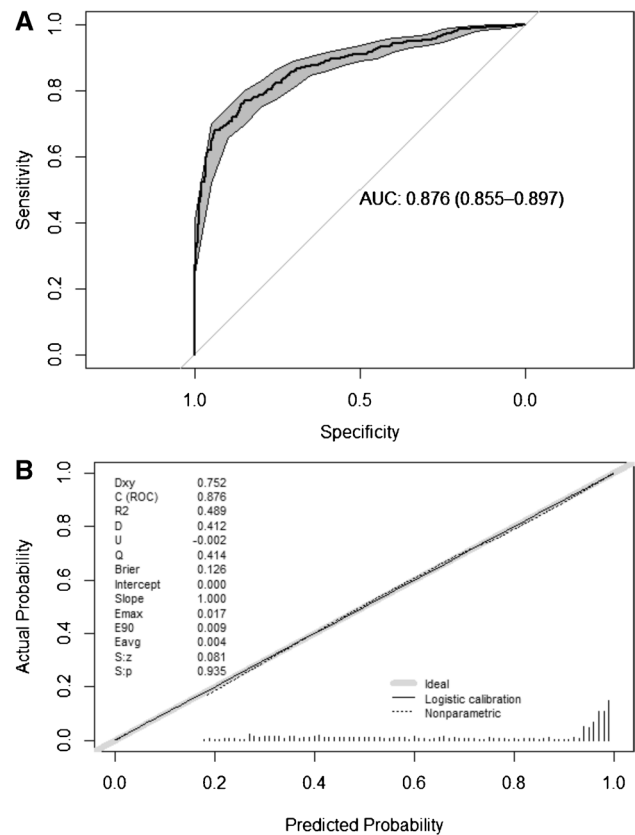
Table 4 Multivariate analysis of the baseline clinical-epidemiological characteristics of low-risk patients with community-acquired pneumonia influencing admission decision making

Characteristics	Odds ratio (95% confidence interval)	p
Age, years	1.01 (1.00, 1.02)	0.045
Habits		
• Smoker		
○ Never smoker	Ref	-
○ Smoker	1.99 (1.29, 3.06)	0.002
○ Former smoker	1.30 (0.86, 1.96)	0.221
Comorbidities		
• Chronic respiratory disease	1.66 (1.11, 2.46)	0.013
Physical examination		
• Respiratory rate > 30 BPM	7.19 (2.00, 25.83)	0.003
• BP < 90 mm Hg	4.17 (1.30, 13.41)	0.017
• Heart rate > 120 bpm	2.93 (1.35, 6.35)	0.007
Arterial gasommetry		
• $PaO_2 < 60$ mm Hg or $SO_2 < 90\%$	41.79 (22.17, 78.78)	< 0.001
Analytical		
• BUN > 30 mg/dL or 11 mmol/L	4.75 (1.85, 12.22)	0.001
• Lymphopenia < 700 cell/ mm^3	2.15 (1.38, 3.34)	0.001
Radiology		
• Multilobar infiltrates	3.24 (2.09, 5.04)	< 0.001
• Cavitation	12.42 (2.71, 56.92)	0.001
• Pleural effusion	3.00 (1.54, 5.85)	0.001

Ref, control group

Fig. 2 A ROC curve for the predictive model of admission decisions, **B** Prediction model of admission decisions

[AUC 0.876; 95%CI: 0.855–0.897]. Figure 2B describes the calibration of the prediction model.

To estimate the individual risk of being admitted for low-grade CAP, the total score of all the variables included in the model must be taken into accounnt. For example, a 70-year-old patient (21 points), smoker (18 points), with a chronic respiratory disease (14 points), respiratory rate 32 BPM (53 points), systolic blood pressure 110 mm Hg (0 points), heart rate 90 bpm (0 points), SaO_2 95% (0 points), BUN 40 mg/dL (42 points), lymphocytes 1,000 cells/mm^3 (0 points), without multilobar involvement (0 points), pulmonary cavitation (0 points) or pleural effusion (0 points), has a total score of 148 points, which is equivalent to a risk of admission greater than 98% (Table 5). The optimal cutpoint will depend on whether priority is given to the maximization of sensitivity; maximization of specificity with a minimum sensitivity value; equilibrium between sensitivity and specificity; maximization of sensitivity with a minimum specificity value; applying Youden index (a score higher than the sum of sensitivity plus specificity); or maximization of specificity (Table 5) [19]. To facilitate decision-making for clinicians, an Excel spreadsheet (HospitalizationClassificationRule) is attached in the Supplementary Material, which will allow

them to easily calculate the probability of admission for each patient.

Discussion

The two most relevant findings of this study are that clinicians make the decision to hospitalize patients with CAP based on their clinical experience, rather than on the severity of the disease, as assessed using mortality risk assessment scales. In addition, the predictive model accurately identified the patients who were hospitalized.

Following recommendations, patients with severe CAP (PSI class IV-V) are generally admitted. However, there is a tendency to admit patients with low-risk CAP (classes I-III) that could theoretically be treated in the ambulatory setting. The latter account for 30–65% of cases in each series [5, 9, 10, 20–45] (Table 6). Otherwise said, in clinical practice, a low risk of mortality does not mean that a patient can be treated safely in outpatient care [46]. It is at this point that physician's discretion emerges as a factor to be considered, as established in guidelines [7, 8, 11–13]. In our series, the most relevant factors considered by the physicians who made

Table 5 Model for predicting admission in low-risk patients with community-acquired pneumonia

Age	Pts	F	Pts	ERC	Pts	FR	Pts	TAs	Pts	FC	Pts	SO₂	Pts	BUN	Pts	LP	Pts	ML	Pts	CV	Pts	DP	Pts	PT	PB (%)
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	20
10	3	1	18	1	14	1	53	1	38	1	29	1	100	1	42	1	20	1	32	1	67	1	29	10	25
20	6	2	7																					17	30
30	9																							29	40
40	12																							40	50
50	15																							**50**	**60**
60	18																							70	75
70	21																							100	90
80	24																							125	95
90	27																							160	99

Total score	Likelihood (%)	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)	Criterion [19]
<1	19	100 (99–100)	0 (—)	0 (—)	100 (21–100)	MxSe
42	52	85 (83–88)	71 (66–76)	89 (86–91)	65 (60–70)	MinValueSe
51	61	79 (76–81)	79 (74–83)	91 (88–92)	59 (54–65)	SpEqualSe
57	66	76 (73–79)	85 (81–89)	93 (91–94)	57 (53–66)	MinValueSp
78	81	68 (64–71)	94 (91–96)	97 (95–98)	27 (23–31)	Youden
144	98	27 (24–30)	100 (99–100)	100 (98–100)	34 (31–37)	MxSp

BUN blood urea nitrogen (> 30 mg/dL), *CV* cavitation on chest X-ray, *PD* pleural effusion, *CKD* chronic respiratory disease, F, smoker (non-smoker, smoker, ex-smoker), *HR* heart rate (> 120/minute), *FR* respiratory rate (> 30/minute), *LP* lymphopenia (<700cell/mm³), *ML* multilobar condensation on chest radiograph, *PB* probability, *PT* total score, *pts* points, *SaO₂* oxygen saturation (< 90%), *BP* systolic blood pressure (<90 mm Hg)

MinValueSe "valor mínimo de la sensibilidad y maximizar la especificidad", *MinValueSp* "valor mínimo de la especificidad y maximizar la sensibilidad", *MxSe* "maximizar la sensibilidad", *MxSp* "maximizar la especificidad", *SpEqualSe* "igualar la sensibilidad a la especificidad", Youden "criterio de Youden"

Table 6 Classification of patients admitted for CAP according to their PSI risk score

Author	Year	Hospitalized patients	PSI Class I	PSI Class II	PSI Class III	PSI Class IV	PSI Class V
Fine et al. [5]	1997	1.343	185 (13,8%)	233 (17,3%)	254 (18,9%)	446 (33,2%)	225 (16,8%)
Halm et al. [24]	2000	163	71 (43,6%)			—	—
Marrie et al. [20]	2000	1.743	1032 (59,2%)			—	—
Rosón et al. [25]	2001	533	51 (9,6%)	62 (11,6%)	117 (22%)	198 (37,1%)	105 (19,7%)
España et al. [26]	2003	395	34 (8,6%)	38 (9,6%)	106 (26,8%)	140 (35,4%)	77 (19,5%)
Goss et al. [27]	2003	425	76 (18,9%)	89 (20,9%)	88 (20,7)	95 (22,3%)	77 (18,1%)
Arnold et al. [28]	2003	328	42 (12%)	44 (13%)	87 (27%)	110 (34%)	45 (14%)
Marrie et al. [29]	2004	1.577	28 (1,8%)	288 (18,3%)	292 (18,5%)	969 (61,4%)	
Calbo et al. [30]	2004	362	13 (3,6%)	47 (13%)	63(17,4%)	147 (40,6%)	92 (25,4%)
Marrie et al. [31]	2005	586	586 (100%)		--	--	--
Carratalà et al. [21]	2005	114	—	63 (55,3%)	51 (47.7%)	--	--
Labarere et al [22]	2006	845	120 (14,2%)	337 (39,9%)	388 (40,2%)	—	--
Buising et al. [32]	2006	392	47 (11,9%)	57 (14,5%)	68 (17,3%)	131 (33,4%)	89 (22,7%)
Johnstone et al. [33]	2008	3.284	617 (19%)		613(19%)	1306 (40%)	748 (23%)
Singanayagam et al. [34]	2009	1.050	579 (55,1%)			471 (44,9%)	
Aujesky et al. [23]	2009	855	258 (30,2%)			597 (69,8%)	
Chang et al. [35]	2013	454	69 (15,6%)	65 (14,6%)	90 (19%)	153 (32,3%)	77 (16,2%)
Viasus et al. [36]	2013	3.463	1461 (42,2%)			2002 (7,8%)	
Li et al. [37]	2015	202	3 (1,5%)	8 (4%)	45 (27,3%)	89 (44%)	57 (28,2%)
Jain et al. [9]	2015	2.320	1.510 (65%)			606 (26%)	204 (9%)
Marcos et al. [10]	2017	155	155 (100%)		—————		
Violi et al. [38]	2017	1.182	0 (0%)	154 (13%)	201 (17%)	508 (43%)	319 (27%)
Ramirez et al. [39]	2017	7.449	2947 (39,6%)			4502 (60,4%)	
Bramley et al. [40]	2017	2.291	1489 (65%)			596 (26%)	206(9%)
Çilli et al. [41]	2018	621	65 (10,5%)	90 (14,5%)	139 (22,4%)	246 (39,6%)	57 (9,2%)
Samaniego et al. [42]	2019	207	47 (23%)	33 (16%)	——-	———	———
Peyrani et al. [43]	2020	7.449	2933 (39,4%)			4516 (60,6%)	
Alonso et al. [44]	2021	340	36 (10,6%)	39 (11,5%)	55 (16,2%)	133 (39,1%)	77 (22,6%)
Dwyer et al. [45]	2021	826	88 (16,6%)	126 (15,2%)	192 (23,2%)	270 (32,6%)	150 (18,1%)

the admission decision included respiratory failure and, to a lesser extent, presence of clinical signs of deterioration, i.e. heart rate > 120 bpm and respiratory rate > 30 BPM. The fact that heart and respiratory rate are considered less frequently may be due to their low incidence in low-risk CAP. Although all these factors are considered in the PSI scale, physicians assess them separately in clinical practice. However, these medical criteria are not defined nor are there any recommendations in this regard. As a result, assessment of CAP severity is not free of subjectivity. In addition, the reported reason for admission does not necessarily mean that admission is warranted. This situation results in hardly acceptable variability across clinicians and institutions.

Some authors classify reasons for the hospitalization of patients with low-risk CAP into three large groups [22]. The first group includes patients in whom ambulatory care is contraindicated for medical or psychosocial reasons. This includes socio-economic reasons [25, 27, 28, 47], severe dementia or mental illness, inability to take oral antibiotics, severe neuromuscular diseases or acute comorbid conditions [25, 28]. Thus, authors agree that some patients with a low risk of mortality may require hospitalization [21]. The second group is composed of patients with identifiable risk factors that are not absolute indications of hospitalization, nor are they associated with a higher risk of mortality. These include patients with an advanced age [24], stable comorbidities [24, 28, 47] (especially when the comorbidity is COPD [48]), previous treatment with corticosteroids [47], and radiological abnormalities [24], to name a few. In these cases, the site of care is unclear. Finally, group 3, which includes 20% of patients with low-risk CAP. This group is composed of patients in whom ambulatory care is not contraindicated. These patients may not have any identifiable risk factors for hospitalization or a low risk for adverse events, therefore, ambulatory management is indicated. In this group, reasons for hospitalization include "pressure" exerted by the

patient or their family, or reluctance of physicians to send home patients who could later develop complications. In our series, 199 patients were included in group 3, which is consistent with the percentage reported in previous studies (24.7%)[22].

Validated scales should be routinely used at Emergency departments to estimate CAP severity and identify low-risk patients. Additionally, presuming that the use of this tool alone may be inappropriate, the clinical judgment of the physician should also be considered. This way, the number of patients that can be treated safely in the ambulatory setting would increase, since the number of patients in the third group would be minimized.

Our prognostic model for predicting the patients with CAP who will be hospitalized is based on the baseline characteristics of patients (Table 4) and includes variables that provide a good power of discrimination (AUC 0.876; 95%CI: 0.855–0.897). This model is useful, as it can be used in most clinical settings, since the variables assessed are routinely recorded in clinical practice. The risk score obtained would enable physicians to estimate the probability of admission and facilitate admission decision making.

This study has some limitations. It is a single-center study, which limits the external validity of the results to other populations, geographical regions or health systems. The results were not reproduced in a validation series. In most cases, the decision about admission was made without using any severity assessment scale, and an objective severity score was not available. It is possible that, if a severity score had been calculated, some patients would not have been admitted. However, this does not reflect the reality of clinical practice. Finally, although a strict definition of pneumonia was used, its clinical and radiological characteristics may mimic those of other diseases (congestive heart failure, cryptogenic pneumonitis obliterans, etc.), which may lead to misdiagnosis. However, this situation in the diagnosis and management of a case of pneumonia may occur in real clinical practice.

To conclude, the results of this study demonstrate that CAP severity is rarely assessed at the ED using validated scales. Thus, the decision about site of care largely relies on the clinical experience of the physician. This subjectivity results in large variability in decision making. Severity assessment scales should be routinely applied to all patients with CAP. However, admission decisions should not only be based on scales, but also on the clinical judgment of the physician, determined through the use of a predictive model with a good power of discrimination. These results require confirmation. Clinical practice in EDs should be standardized to improve the quality of care provided to CAP patients. Further studies are needed to validate these results.

Declarations

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