Original Research Article

Comprehensive analysis of prognostic factors in hospitalized patients with pneumonia occurring outside hospital: Serum albumin is not less important than pneumonia severity assessment scale

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Abstract

Purpose: This study aimed to elucidate factors related to 30-day mortality of pneumonia occurring outside hospital by comprehensively analyzing data considered relevant to prognosis.

Methods: Data considered relevant to prognosis were retrospectively examined from clinical charts and chest X-ray images of all patients with pneumonia occurring outside hospital admitted to our hospital from 2010 to 2016. The primary outcome was 30-day mortality.

Results: Data were collected from 534 patients (317 community-acquired pneumonia and 217 nursing- and healthcare associated pneumonia patients; 338 men (63.3%); mean age, 76.2 years-old). Eighty-three patients (9.9%) died from pneumonia within 30 days from the date of admission. The numbers of patients with pneumonia severity index (PSI) classes of I/II/III/IV/V and age, dehydration, respiratory failure, orientation disturbance, pressure (A-DROP) scores of 0/1/2/3/4/5 were 29/66/127/229/83, and 71/107/187/132/30/7, respectively. Mean (standard deviation) body mass index (BMI), serum albumin, blood procalcitonin, white blood cell and C-reactive protein were 20.00 (4.12) kg/m^2, 3.16 (0.60) g/dL, 3.69 (13.15) ng/mL, 11559.4 (5656.9)/mm^3, and 10.92 (8.75) mg/dL, respectively. Chest X-ray images from 152 patients exhibited a

pneumonia shadow over a quarter of total lung field. Logistic regression analysis revealed that PSI class or A-DROP score, BMI, serum albumin, and extent of pneumonia shadow were related to 30-day mortality. Receiver operating characteristics curve analysis revealed that serum albumin was superior to PSI class or A-DROP score for predicting 30-day mortality.

Conclusion: Serum albumin is not less important than PSI class or A-DROP score for predicting 30-day mortality in hospitalized patients with pneumonia occurring outside hospital.

Key Words

Pneumonia, Prognosis, Albumin, Procalcitonin, Pneumonia severity index, A-DROP

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Introduction

Community-acquired pneumonia (CAP) is a prominent cause of morbidity and mortality throughout the world [1]. Until now, many investigators have reported various prognostic factors of pneumonia occurring outside hospital, such as pneumonia severity index (PSI) [2-6], age, dehydration, respiratory failure, orientation disturbance, pressure (A-DROP) scoring system [7, 8], procalcitonin (PCT) [9-12], albumin [13-16], body mass index (BMI) [13, 17], healthcare-associated pneumonia (HCAP) [18, 19] or nursing- and healthcare-associated pneumonia (NHCAP) [20, 21], aspiration [22], or extent of pneumonia shadow [15]. Of these, recent studies of prognostic factors seem to focus their attention on the severity assessment scale such as PSI or A-DROP, or biomarker such as PCT. However, some investigators have still emphasized the prognostic importance of albumin, though they did not directly compare the prognostic significance of albumin with that of PSI or PCT [14–16]. Few studies have comprehensively examined the prognostic importance of these parameters in patients with pneumonia occurring outside hospital. Therefore, it is our question which parameter best predicts the prognosis of pneumonia occurring outside hospital among those previously reported to influence the prognosis of pneumonia, especially albumin, PSI or A-DROP, PCT, NHCAP, or extent of pneumonia shadow.

The present study was undertaken to elucidate prognostic factors of pneumonia occurring outside hospital by comprehensively analyzing factors previously reported to influence the prognosis of pneumonia.

Patients and methods

Clinical charts and chest X-ray images of all consecutive patients admitted to our hospital from October 2010 to September 2016 with primary diagnoses of CAP and NHCAP were retrospectively reviewed. Cases that fulfilled the following criteria of pneumonia were enrolled in the study: (1) onset of illness occurring outside the hospital, (2) an acute illness and symptoms including new cough with or without sputum, fever or chills, pleuritic chest pain, or dyspnea, and (3) a chest X-ray showing an opacity compatible with the presence of acute pneumonia. Validity of the pneumonia diagnosis was confirmed by two respiratory physicians. NHCAP included any patients who (1) were hospitalized in an acute care hospital for two or more days within the past 90 days, (2) resided in a nursing home or long-term care facility, (3) were elderly or handicapped persons who needed daily healthcare, or (4) continuously visited a hospital or hemodialysis clinic for intravenous antibiotic therapy, chemotherapy, or hemodialysis [20]. Exclusion criteria were the presence of pulmonary edema, massive pleural fluid,

or other non-pneumonia conditions that would interfere with the assessment of the extent of pneumonia. Data on admission considered related to prognosis were examined, including age, sex, category of pneumonia occurring outside the hospital (CAP or NHCAP), aspiration pneumonia or the lack thereof, PSI class, A-DROP score, comorbidities, body mass index (BMI), serum albumin levels, white blood cell (WBC) count, C-reactive protein (CRP) and PCT levels, and chest X-ray extent of pneumonia shadow. We also examined the serial data of serum albumin and blood PCT levels, and obtained the lowest albumin and highest PCT levels within a first week after admission in available cases. The microbiologic examinations included sputum samples for Gram stain and culture, two blood samples for culture, urine samples for detection of *Streptococcus pneumoniae* and *Legionella pneumophila* antigens, and serum samples for serologic testing against IgM antibodies for *Mycoplasma pneumoniae* and *Chlamydophila pneumoniae*. As for sputum examination, predominantly grown bacteria detected in the qualified sputum were considered to be causative pathogens.

The chest X-ray extent of the pneumonia shadow was examined by dividing each lung field on plain chest X-ray into upper and lower zones. Each zone encompassed half of the craniocaudal distance of the lung on frontal radiographs, and the number of zones with the lesions was counted [23].

The initial antibiotic treatment was chosen based on guidelines set forth by the Japan Respiratory Society. The primary outcome was death within 30 days from the date of admission. We analyzed factors related to 30-day mortality using logistic regression and receiver operating characteristic (ROC) curve analyses. The difference in mortality between two groups was analyzed with the Mann-Whitney U test (Excel Tokei 2015, Social Survey Research Information, Co., Ltd., Tokyo, Japan). $P < 0.05$ was considered statistically significant. This study was performed in accordance with the Declaration of Helsinki. This human study was approved by Fukuoka University-Medical Ethics Review Board - approval: R16-059. The review board exempted the acquisition of informed consent from patients included in the study.

Results

Study population

We identified 566 patients with a primary diagnosis of pneumonia during the study period. Of these, 12 patients with hospital-acquired pneumonia were excluded. We also excluded 20 patients with pulmonary edema, massive pleural fluid, or other non-pneumonia conditions that would interfere with the assessment of the extent of pneumonia. The final study population comprised 534 patients. Serial data of serum

albumin and blood PCT levels were available in 492 and 329 patients, respectively. Clinical features of these patients are summarized in Table 1. The study population consisted of 534 patients (317 CAP and 217 NHCAP patients; 338 men (63.3%); mean age, 76.2 years-old). Eighty-four patients (15.7%) were considered to have aspiration pneumonia; 134 patients (25.1%) were administered antibiotics before admission; and 53 patients (9.9%) died from pneumonia within 30 days from the date of admission. Numbers (percentage) of patients with PSI classes of I/II/III/IV/V and A-DROP scores of 0/1/2/3/4/5 were 29 (5.4%) / 66 (12.4%) / 127 (23.8%) / 229 (42.9%) / 83 (15.5%), and 71 (13.3%) / 107 (20.1%) / 187 (35.0%) / 132 (24.7%) / 30 (5.6%) / 7 (1.3%), respectively. Mean (standard deviation) BMI, albumin, lowest albumin levels within a first week after admission, blood PCT, highest PCT levels within a first week after admission, WBC, and CRP were 20.00 (4.12) kg/m^2, 3.16 (0.60) g/dL, 2.58 (0.53) g/dL, 3.69 (13.15) ng/mL, 5.17 (15.12) ng/mL, 11559.4 (5656.9)/mm^3, and 10.92 (8.75) mg/dL, respectively. Numbers (percentage) of patients with an extent of pneumonia shadow of 1, 2, 3, and 4 were 382 (71.5%), 120 (22.5%), 28 (5.3%), and 4 (0.7%), respectively. With regard to comorbidities, 140 patients presented with chronic lung disease, 103 with diabetes mellitus, 98 with dementia, 54 with cerebrovascular disease, 49 with chronic heart failure, 24 with kidney disease, 20 with malignancy, and 12 with liver disease. We

identified 296 causative pathogens, as follows: *Streptococcus pneumoniae* was the leading pathogen (n=101), followed by *Haemophilus influenzae* (n=31), *Mycoplasma pneumoniae* (n=27), *Chlamydophila pneumonia*e (n=24), *Klebsiella pneumoniae* (n=20), *Escherichia coli* (n=19), *Pseudomonas aeruginosa* (n=18), *Moraxella catarrhalis* (n=14), and *Methicillin-resistant Staphylococcus aureus* (n=11).

Factors related to 30-day mortality

Univariate analysis revealed the following variables to be significantly associated with 30-day mortality: age (odds ratio (OR): 1.0454, 95% confidence interval (CI): 1.0167 - 1.0749, p=0.0018), PSI class (OR: 3.1187, 95%CI: 2.0724 – 4.6933, p<0.001), A-DROP score (OR: 2.4518, 95%CI: 1.8256 – 3.2927), category of pneumonia (OR: 2.2348, 95%CI: 1.2558 – 3.9771, p=0.0062), BMI (OR: 0.7696, 95%CI: 0.6953 – 0.8518, p<0.001), albumin (OR: 0.1370, 95%CI: 0.0769 – 0.2442, p<0.001), lowest albumin levels within a first week after admission (OR: 0.0641, 95%CI: 0.0295 – 0.1396, p<0.001), PCT (OR: 1.0275, 95%CI: 1.0112 – 1.0440, p<0.001), highest PCT levels within a first week after admission (OR: 1.0212, 95%CI: 1.0049 – 1.0378, p=0.0108), CRP (OR: 1.0386, 95%CI: 1.0087 – 1.0694; p=0.0111), extent of pneumonia shadow (OR: 4.8238, 95%CI: 3.2060 – 7.2580, p<0.001), malignant disease (OR: 4.2584, 95%CI: 1.5630 – 11.6020, p=0.0046),

dementia (OR: 2.3320, OR: 1.2491 – 4.3535, p=0.0079), and liver disease (OR: 4.8265, 95%CI: 1.4027 – 16.6078, p=0.0125) (Table 2). Age and/or malignant and liver diseases were excluded from the multivariate analysis, because these factors are included in PSI or A-DROP as clinical parameters. Multivariate analysis revealed that PSI class (OR: 1.7574, 95%CI: 1.0806 – 2.8581, p=0.0231), BMI (OR: 0.8147, 95%CI: 0.7178 – 0.9246, p=0.0015), albumin (OR: 0.3545, 95%CI: 0.1544 – 0.8138, p=0.0145), and extent of pneumonia shadow (OR: 3.3921, 95%CI: 2.0292 – 5.6703, p<0.001) remained significant as factors related to 30-day mortality (Table 3). Analysis using lowest albumin levels within a first week after admission instead of albumin showed similar results, that is, BMI (OR: 0.8431, 95%CI: 0.7400 – 0.9606, p=0.0103), lowest albumin levels within a first week after admission (OR: 0.1134, 95%CI: 0.0379 – 0.3397, p<0.001), and extent of pneumonia shadow (OR: 3.4524, 95%CI: 2.0276 – 5.8785, p<0.001) were significantly related to 30-day mortality. PSI class tended to be related to 30-day mortality (OR: 1.6572, 95%CI: 0.9941 – 2.7625, p=0.0527) (Table 3). Multivariate analysis showed that highest PCT levels within a first week after admission did not remain significant as factors related to 30-day mortality. Next, we performed multivariate analysis using A-DROP score instead of PSI class as a variable of pneumonia severity assessment scale. A-DROP score (OR: 1.8347, 95%CI: 1.1979 – 2.8101, p=.0053), BMI (OR: 0.7989, 95%CI:

0.7008 – 0.9108, p<0.001), albumin (OR: 0.3775, 95%CI: 0.1609 – 0.8860, p=0.0252), extent of pneumonia shadow (OR: 3.6552, 95%CI: 2.1441 – 6.2311, p<0.001), and malignant disease (OR: 6.4780, 95%CI: 1.6637 – 25.2230, p=0.0071) remained significant as factors related to 30-day mortality (Table 4). Analysis using lowest albumin levels within a first week after admission instead of albumin showed similar results, that is, A-DROP score (OR: 1.7386, 95%CI: 1.1025 – 2.7417, p=.00173), BMI (OR: 0.8248, 95%CI: 0.7205 – 0.9442, p=0.0052), lowest albumin levels within a first week after admission (OR: 0.1379, 95%CI: 0.0449– 0.4237, p<0.001), extent of pneumonia shadow (OR: 3.8028, 95%CI: 2.1953 – 6.5873, p<0.001), and malignant disease (OR: 6.0602, 95%CI: 1.5302 – 24.0004, p=0.0103) were significantly related to 30-day mortality (Table 4). Multivariate analysis showed that highest PCT levels within a first week after admission did not remain significant as factors related to 30-day mortality.

ROC curve analysis revealed that area under the curve (AUC) values for PSI class, BMI, A-DROP score, extent of pneumonia shadow, albumin, and lowest albumin levels within a first week after admission for predicting 30-day mortality were 0.7273 (95%CI: 0.6585 – 0.7961, p=0.0274 vs albumin), 0.7439 (95%CI: 0.6564 – 0.8314, p=0.7764 vs PSI class; p=0.1696 vs albumin), 0.7527 (95%CI: 0.6833 – 0.8220, p=0.4369

vs PSI class; p=0.1583 vs albumin), 0.7691 (95%CI: 0.6906 – 0.8477, p=0.4041 vs PSI class; p=0.3957 vs albumin), 0.8127 (95%CI: 0.7504 – 0.8749, p=0.0274 vs PSI class), and 0.8566 (95%CI: 0.8071 – 0.9061, p<0.001 vs PSI class; p=0.0600 vs albumin), respectively (Figure 1, Table 5). It also revealed that best discriminal cut-off value, specificity, sensitivity, and odds ratio were 4, 45.0%, 84.1%, 4.3191 for PSI class, 3, 71.7%, 65.9%, 4.9066 for A-DROP score, 17.7 kg/m^2, 72.8%, 70.5%, 6.3840 for BMI, 3 g/dL, 63.4%, 84.1%, 9.1495 for serum albumin, 2.2 g/dL, 79.1%, 76.2%, 12.1169 for lowest albumin levels within a first week after admission, and 2, 76.0%, 72.7%, 8.4524 for extent of pneumonia shadow, respectively.

Mortality of patients with mild (PSI class = I - III), moderate (PSI class = IV), and severe (PSI class = V) pneumonia were 3.2%, 10%, and 22.7%, respectively. When considering serum albumin in addition to PSI class, mortality rates of mild, moderate and severe pneumonia patients with serum albumin <3.0 g/dL and ≥3.0 g/dL were 9.8% and 1.7% (p=0.0148), 15.6% and 5.9% (p=0.0150), and 35.8% and 13.3% (p=0.0176), respectively (Table 6). Combination of PSI and other independent prognostic variables (lowest albumin levels within a first week after admission, BMI, or extent of pneumonia shadow) resulted similar mortality rates as the combination of PSI and albumin (Table 6). When using A-DROP score instead of PSI class as a pneumonia severity scale,

mortality of patients with mild (A-DROP score = 0), moderate (A-DROP score = 1 – 2), severe (A-DROP score = 3), and very severe (A-DROP score = 4 -5) pneumonia were 0%, 6.5%, 15.9%, and 35.1%, respectively. Mortality rates of moderate, severe and very severe pneumonia patients with serum albumin <3.0 g/dL and ≥3.0 g/dL were 10.9% and 4.5% (p=0.0039), 25% and 7.0% (p=0.0083), and 46.2% and 9.1% (p=0.0383), respectively (Table 7). Combination of A-DROP and other prognostic variables (lowest albumin levels within a first week after admission, BMI, or extent of pneumonia shadow) resulted similar mortality rates as the combination of A-DROP and albumin (Table 7).

Discussion

Serum albumin or BMI influences the clinical course of several respiratory disorders, including chronic obstructive pulmonary disease [24, 25], pulmonary tuberculosis [23, 26-28], non-tuberculous mycobacterial infection [29, 30], idiopathic interstitial pneumonia [31, 32], and CAP [13-16]. We also reported the clinical significance of serum albumin levels or BMI in patients with pulmonary tuberculosis [27, 28] and non-tuberculous mycobacterial infections [30]. As for pneumonia occurring outside hospital, various parameters other than serum albumin or BMI have been

reported to impact the prognosis [2-12, 18-24]. Recent studies on pneumonia occurring outside hospital have focused their attention on the severity assessment scales such as PSI or A-DROP, or biomarkers such as PCT, and do not seem to focus on the prognostic importance of serum albumin or BMI in these patients. In fact, neither serum albumin nor BMI are included in the assessments of PSI or A-DROP. Few studies on pneumonia occurring outside hospital have comprehensively examined the prognostic significance of factors reported so far to impact the prognosis, especially albumin, PSI or A-DROP, PCT, HCAP or NHCAP, and extent of pneumonia shadow. To our knowledge, the present study firstly elucidated that serum albumin is still significant prognostic factor, even if PSI class or A-DROP score, PCT, NHCAP and extent of pneumonia shadow in addition to serum albumin were comprehensively analyzed, and that serum albumin is not less important than PSI class or A-DROP score for predicting 30-day mortality in hospitalized patients with pneumonia occurring outside hospital.

We found that PSI class or A-DROP score, BMI, albumin levels on admission or lowest albumin levels within a first week after admission, and extent of pneumonia shadow were independently related to 30-day mortality (Table 3, 4). Among these parameters, ROC curve analysis revealed that predictive capacity of albumin (AUC = 0.8063) was significantly superior to that of PSI class (AUC = 0.7208) for 30-day

mortality. Albumin also tended to be superior to A-DROP score (AUC = 0.7490) for predicting of 30-day mortality (Table 5). Furthermore, lowest albumin levels within a first week after admission might be superior to albumin levels on admission for predicting 30-day mortality. Prospective study for investigating the prognostic significance of lowest albumin levels within a first week after admission is necessary. While serum albumin and PSI class showed same sensitivity (84.1%) for predicting 30-day mortality, serum albumin revealed superior specificity (63.4%) to that of PSI class (45.0%). Given that PSI class or A-DROP score is widely used to assess pneumonia severity, it would be practical to add serum albumin to assessments in order to allow for a more accurate evaluation of pneumonia severity. Mortality was significantly different between each severity patients with low (<3.0 mg/dL) and preserved (≥3.0 mg/dL) serum albumin levels. In addition, mortality of severe and very severe pneumonia patients with preserved serum albumin levels was comparable to that of moderate pneumonia patients. Mortality of very severe pneumonia patients with low serum albumin levels was extremely high. Recent report of Lee et al. [14] showed that serum albumin level was an independent predictor with the same sensitivity and specificity in the 30-days mortality in patients with CAP. In addition, Viasus et al. [15] also reported the usefulness of the combination of serum albumin level

and PSI/CURB-65 in predicting the 30-day mortality compared with the single use of PSI/CURB-65. The present study revealed that the combinations of PSI / A-DROP and lowest albumin levels within a first week after admission / BMI / extent of pneumonia shadow were also superior to PSI or A-DROP alone for more precise prediction of 30-day mortality. Moreover, the combination is considered to be applicable to prediction of 30-day mortality of pneumonia patients including not only CAP, but also NHCAP.

Although several studies have found that PCT is a significant prognostic factor of HCAP [12] as well as CAP [9-11], PCT did not remain as an independent prognostic factor in the present study. PCT is considered to be one of inflammation markers such as CRP or WBC, though more specific to bacterial infections compared to the latter. In the present study, none of inflammation markers remained as significant prognostic factors. Inflammation markers might not be independent prognostic markers when parameters reported to influence the prognosis, especially including albumin, were comprehensively analyzed in patients with pneumonia occurring outside hospital. In fact, investigators who reported the prognostic significance of PCT did not include albumin as a prognostic factor in their studies [9-12]. PCT is not reported to increase in sera of elderly patients [33]. Compared to the previous studies which investigated the clinical significance of PCT in patients with CAP, the present study included more

elderly patients. This finding may be another explanation as to why PCT was not associated with 30-day mortality. Moreover, PCT levels in *Streptococcus pneumoniae* pneumonia is reported to be significantly higher than those caused by other bacteria [34], though prognosis of the former is not necessarily poor compared to that of the latter.

The prognosis of NHCAP is poor compared to that of CAP. In the present study, univariate analysis showed significantly higher 30-day mortality of NHCAP than that of CAP. However, NHCAP did not remain as significant prognostic factor in multivariate analysis. Poor nutritional status, higher pneumonia severity, and widespread pneumonia shadows are considered essentially related to poor prognosis of patients with NHCAP. Nutritional status, PSI class or A-DROP score, and extent of pneumonia shadow rather than category of pneumonia, i.e. CAP vs NHCAP, might be important when evaluating the prognosis of pneumonia occurring outside hospital.

In the present study, we included all consecutive pneumonia patients admitted during 6 years, except for those with hospital-acquired pneumonia, and those who accompanied with conditions that would interfere with the assessment of the extent of pneumonia. The primary outcome was 30-day mortality, which was an objective endpoint. Though the study was retrospective in nature, we believe the results

obtained have some clinical impacts on the clinical practice of pneumonia occurring outside hospital.

There are several limitations to this study worth noting. First, the study was retrospectively conducted in a single hospital, and data were missing for a few patients. A prospective cohort study conducted in plural hospitals is needed to confirm our results. Second, we did not investigate how antibiotics were used. Because antibiotics are chosen based on guidelines set forth by the Japan Respiratory Society, it is likely that antibiotics were properly used in most patients.

Conclusion

Serum albumin is still significant prognostic factor, even if PSI class or A-DROP score, PCT, NHCAP and extent of pneumonia shadow in addition to serum albumin were comprehensively analyzed. Serum albumin is not less important than PSI class or A-DROP score for predicting 30-day mortality in hospitalized patients with pneumonia occurring outside hospital.

Conflict of interest

The authors declare that they have no conflicts of interest.

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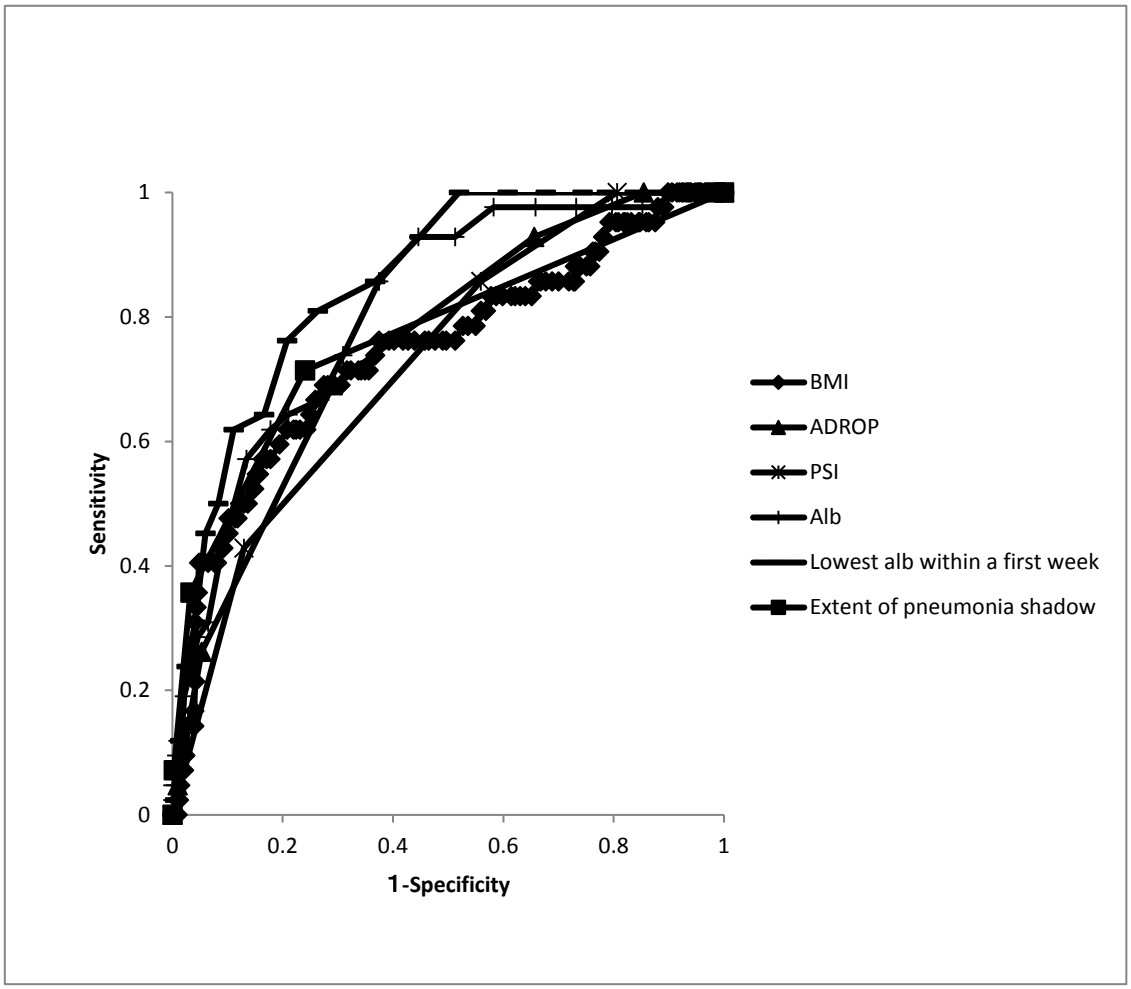
Legend for figure

Figure 1

Receiver operating characteristic curve of body mass index (BMI), pneumonia severity index (PSI) class, age, dehydration, respiratory failure, orientation disturbance, pressure (A-DROP) score, albumin (Alb), lowest albumin levels within a first week after admission (Lowest alb within a first week), and extent of pneumonia shadow for prediction of 30-day mortality.

Definition of extent of pneumonia shadow is described in the Patients and methods section of the main text.


1
0.8
0.6
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Sensitivity
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1
1-Specificity
BMI
ADROP
PSI
Alb
Lowest alb within a first week
Extent of pneumonia shadow

Table 1. Baseline characteristics

No. patients		534	Comorbidities	
died within 30 days		53 (9.9%)	Chronic lung disease	140
aspiration pneumonia		84 (15.7%)	Diabetes mellitus	103
antibiotics before admission		134 (25.1%)	Dementia	98
Male/female		338 (63.3%)/196 (36.7%)	Cerebrovascular disease	54
Age (years)		76.2 ± 16.6	Chronic heart failure	49
CAP/NHCAP		317 (59.4%)/217 (40.6%)	Kidney disease	24
PSI class	I	29 (5.4%)	Malignancy	20
	II	66 (12.4%)	Liver disease	12
	III	127 (23.8%)	Pathogens	
	IV	229 (42.9%)	Streptococcus pneumoniae	101
	V	83 (15.5%)	Streptococcus agalactiae	5
A-DROP score	0	71(13.3%)	MSSA	9
	1	107(20.1%)	MRSA	11
	2	187(35.0%)	Enterococcus faecalis	7
	3	132(24.7%)	Klebsiella pneumoniae	20
	4	30(5.6%)	Haemophilus influenzae	31
	5	7(1.3%)	Moraxella catarrhalis	14
BMI (kg/m^2)		20.00 ± 4.12	Escherichia coli	19
Albumin (g/dL)		3.16 ± 0.60	Serratia marcescens	5
PCT (ng/mL)		3.69 ± 13.15	Proteus mirabilis	5
WBC ($/mm^3$)		11559.4 ± 5656.9	Pseudomonas aeruginosa	18
CRP (mg/dL)		10.92 ± 8.75	Mycoplasma pneumoniae	27
Extent of pneumonia shadow	1	382 (71.5%)	Chlamydophila pneumoniae	24
	2	120 (22.5%)		
	3	28 (5.3%)		
	4	4 (0.7%)		

CAP: Community-acquired pneumonia, NHCAP: Nursing- and healthcare-associated pneumonia, PSI: Pneumonia severity index, A-DROP: Age, dehydration, respiratory failure, orientation disturbance, pressure, BMI: Body mass index, PCT: Procalcitonin WBC: White blood cell, CRP: C-reactive protein, MSSA: Methicillin-sensitive Staphylococcus aureus, MRSA: Methicillin-resistant Staphylococcus aureus

Definition of extent of pneumonia shadow is described in the Patients and methods section of the main text.

Data are presented as number (%) or mean ± standard deviation.

Table 2. Univariate analysis of factors related to 30-day mortality

	Univariate Logistic Regression		
Variable	OR	95%CI	P value
Age (years)	1.0454	1.0167-1.0749	0.0018*
Sex	1.3829	0.7478-2.5574	0.3014
PSI class	3.1187	2.0724-4.6933	<0.001*
A-DROP score	2.4518	1.8256-3.2927	<0.001*
Category of pneumonia	2.2348	1.2558-3.9771	0.0062*
BMI (kg/m^2)	0.7696	0.6953-0.8518	<0.001*
Albumin (g/dL)	0.1370	0.0769-0.2442	<0.001*
Lowest albumin levels within a first week after admission (g/dL)	0.0641	0.0295-0.1396	<0.001*
PCT (ng/mL)	1.0275	1.0112-1.0440	<0.001*
Highest PCT levels within a first week after admission (ng/mL)	1.0212	1.0049-1.0378	0.0108
WBC($/mm^3$)	1.0000	0.9999-1.0000	0.3508
CRP (mg/dL)	1.0386	1.0087-1.0694	0.0111*
Extent of pneumonia shadow	4.8238	3.2060-7.2580	<0.001*
Aspiration pneumonia	1.4638	0.7204-2.9745	0.2922
Malignancy	4.2584	1.5630-11.6020	0.0046*
Dementia	2.3320	1.2491-4.3535	0.0079*
Diabetes mellitus	0.8421	0.3971-1.7856	0.6541
Chronic heart failure	1.5906	0.6759-3.7433	0.2879
Chronic lung disease	1.6626	0.9143-3.0234	0.0957
Cerebrovascular disease	1.6773	0.7453-3.7746	0.2114
Liver disease	4.8265	1.4027-16.6078	0.0125*
Kidney disease	0.8182	0.1870-3.5804	0.7899
Antibiotics before admission	1.0342	0.5352-1.9984	0.9203

OR: Odds ratio, CI: Confidence interval, PSI: Pneumonia severity index, A-DROP: age, dehydration, respiratory failure, orientation disturbance, pressure , BMI: Body mass index, PCT: Procalcitonin, WBC: White blood cell, CRP: C-reactive protein

Definition of extent of pneumonia shadow is described in the Patients and methods sections of the main text.

* Statistically significant

Table 3. Multivariate analysis of factors related to 30-day mortality

The table at the bottom uses lowest albumin levels within a first week after admission as a variable instead of albumin in the upper table.

	Multivariate Logistic Regression		
Variable	OR	95%CI	P value
PSI class	1.7574	1.0806-2.8581	0.0231*
Category of pneumonia	0.8193	0.3339-2.0102	0.6634
BMI (kg/m^2)	0.8147	0.7178-0.9246	0.0015*
Albumin (g/dL)	0.3545	0.1544-0.8138	0.0145*
PCT (ng/mL)	1.0088	0.9915-1.0264	0.3200
CRP (mg/dL)	0.0019	0.9563-1.0497	0.9363
Extent of pneumonia shadow	3.3921	2.0292-5.6703	<0.001*
Dementia	0.8907	0.3688-2.1509	0.7969
PSI class	1.6572	0.9941-2.7625	0.0527
Category of pneumonia	0.7025	0.2767-1.7836	0.4577
BMI (kg/m^2)	0.8431	0.7400-0.9606	0.0103*
Lowest albumin levels within a first week after admission (g/dL)	0.1134	0.0379-0.3397	<0.001*
PCT (ng/mL)	1.0050	0.9873-1.0231	0.5810
CRP (mg/dL)	0.9783	0.9307-1.0285	0.3903
Extent of pneumonia shadow	3.4524	2.0276-5.8785	<0.001*
Dementia	0.8717	0.3420-2.2216	0.7736

OR: Odds ratio, CI: Confidence interval, PSI: Pneumonia severity index, BMI: Body mass index, PCT: Procalcitonin, CRP: C-reactive protein

Definition of extent of pneumonia shadow is described in the Patients and methods section of the main text.

* Statistically significant

Table 4. Multivariate analysis of factors related to 30-day mortality

The table at the bottom uses lowest albumin levels within a first week after admission as a variable instead of albumin in the upper table.

	Multivariate Logistic Regression		
Variable	OR	95%CI	P value
A-DROP score	1.8347	1.1979-2.8101	0.0053*
Category of pneumonia	0.7244	0.2915-1.8005	0.4877
BMI (kg/m^2)	0.7989	0.7008-0.9108	<0.001*
Albumin (g/dL)	0.3775	0.1609-0.8860	0.0252*
PCT (ng/mL)	1.0063	0.9890-1.0238	0.4770
CRP (mg/dL)	0.9996	0.9527-1.0489	0.9875
Extent of pneumonia shadow	3.6552	2.1441-6.2311	<0.001*
Dementia	0.9218	0.3689-2.3035	0.8617
Malignancy	6.4780	1.6637-25.2230	0.0071*
Liver disease	1.9723	0.3645-10.6728	0.4305
A-DROP score	1.7386	1.1025-2.7417	0.0173*
Category of pneumonia	0.6284	0.2459-1.6060	0.3319
BMI (kg/m^2)	0.8248	0.7205-0.9442	0.0052*
Lowest albumin levels within a first week after admission (g/dL)	0.1379	0.0449-0.4237	<0.001*
PCT (ng/mL)	1.0030	0.9852-1.0211	0.7468
CRP (mg/dL)	0.9780	0.9288-1.0297	0.3976
Extent of pneumonia shadow	3.8028	2.1953-6.5873	<0.001*
Dementia	0.9009	0.3421-2.3726	0.8327
Malignancy	6.0602	1.5302-24.0004	0.0103*
Liver disease	1.4590	0.2531-8.4109	0.6726

OR: Odds ratio, CI: Confidence interval, A-DROP: age, dehydration, respiratory failure, orientation disturbance, pressure, BMI: Body mass index, PCT: Procalcitonin, CRP: C-reactive protein

Definition of extent of pneumonia shadow is described in the Patients and methods section of the main text.

* Statistically significant

Table 5. Area under the curve (AUC) of pneumonia severity index (PSI) class, age, dehydration, respiratory failure, orientation disturbance, pressure (A-DROP) score, body mass index (BMI), extent of pneumonia shadow, albumin, and lowest albumin levels within a first week after admission of receiver operating characteristic curve to predict 30-day mortality

	AUC	95% CI	P value	
PSI class	0.7273	0.6585 – 0.7961	Reference	0.0274
BMI (kg/m^2)	0.7439	0.6564 – 0.8314	0.7764	0.1696
ADROP score	0.7527	0.6833 – 0.8220	0.4369	0.1583
Extent of pneumonia shadow	0.7691	0.6906 – 0.8477	0.4041	0.3957
Albumin (g/dL)	0.8127	0.7504 – 0.8749	0.0274	Reference
Lowest albumin levels within a first week after admission (g/dL)	0.8566	0.8071 – 0.9061	<0.001	0.0600

CI: Confidence interval

Definition of extent of pneumonia shadow is described in the Patients and methods section of the main text.

Table 6 Prognostic influence of serum albumin (Alb), lowest albumin levels within a first week after admission (Lowest alb), body mass index (BMI), and extent of pneumonia shadow on the severity determined by pneumonia severity index (PSI) class

Pneumonia severity	n	No. of death	Mortality (%)	Combined variable	Cut-off	n	No. of death	Mortality (%)	P value
Mild	222	7	3.2	Alb(g/dL)	<3.0	41	4	9.8	0.0148
					≥3.0	180	3	1.7	
				Lowest alb(g/dL)	<2.2	16	3	18.8	<0.001
					≥2.2	185	3	1.6	
				BMI(kg/m^2)	<17.7	49	6	12.2	<0.001
					≥17.7	169	1	0.6	
				Extent of pneumonia shadow	2,3,4	35	4	11.4	0.0023
					1	187	3	1.6	
Moderate	229	23	10	Alb(g/dL)	<3.0	90	14	15.6	0.0150
					≥3.0	137	8	5.9	
				Lowest alb(g/dL)	<2.2	48	11	22.9	<0.001
					≥2.2	166	10	6.0	
				BMI(kg/m^2)	<17.7	68	12	17.6	0.0034
					≥17.7	151	8	5.3	
				Extent of pneumonia shadow	2,3,4	74	17	23.0	<0.001
					1	155	6	3.9	
Severe	83	23	22.7	Alb(g/dL)	<3.0	53	19	35.8	0.0176
					≥3.0	30	4	13.3	
				Lowest alb(g/dL)	<2.2	38	15	39.5	0.0081
					≥2.2	39	5	12.8	
				BMI(kg/m^2)	<17.7	33	12	36.4	0.0205
					≥17.7	44	6	13.6	
				Extent of pneumonia shadow	2,3,4	43	17	39.5	0.0131
					1	40	6	15	

Mild: PSI class = I–III, Moderate: PSI class = IV, Severe: PSI class = V

Definition of extent of pneumonia shadow is described in the Patients and methods section of the main text.

Table 7 Prognostic influence of serum albumin (Alb), lowest albumin levels within a first week after admission (Lowest alb), body mass index extent of pneumonia shadow on the severity determined by age, dehydration, respiratory failure, orientation disturbance, pressure (A-DROP)

Pneumonia severity	n	No. of death	Mortality (%)	Combined variable	Cut-off	n	No. of death	Mortality (%)	P value
Mild	71	0	0	Alb (g/dL)	<3.0	6	0	0	
					≥3.0	65	0	0	
				Lowest alb (g/dL)	<2.2	0	0	0	
					≥2.2	65	0	0	
				BMI (kg/m^2)	<17.7	8	0	0	
					≥17.7	61	0	0	
				Extent of pneumonia shadow	2,3,4	3	0	0	
					1	68	0	0	
Moderate	294	19	6.5	Alb (g/dL)	<3.0	92	10	10.9	0.0039
					≥3.0	200	9	4.5	
				Lowest alb (g/dL)	<2.2	41	8	19.5	<0.001
					≥2.2	227	9	4.0	
				BMI (kg/m^2)	<17.7	83	10	12.0	0.0011
					≥17.7	200	5	2.5	
				Extent of pneumonia shadow	2,3,4	79	15	19.0	<0.001
					1	215	4	1.9	
Severe	132	21	15.9	Alb (g/dL)	<3.0	60	15	25	0.0083
					≥3.0	71	5	7	
				Lowest alb (g/dL)	<2.2	41	11	26.8	0.0117
					≥2.2	84	8	9.5	
				BMI (kg/m^2)	<17.7	40	10	25.0	0.0322
					≥17.7	87	9	10.3	
				Extent of pneumonia shadow	2,3,4	50	13	26.0	0.0137
					1	82	8	9.8	
Very severe	37	13	35.1	Alb (g/dL)	<3.0	26	12	46.2	0.0383
					≥3.0	11	1	9.1	
				Lowest alb (g/dL)	<2.2	20	10	50	0.0096
					≥2.2	14	1	7.1	
				BMI (kg/m^2)	<17.7	19	10	52.6	0.0037
					≥17.7	16	1	6.3	
				Extent of pneumonia shadow	2,3,4	20	10	50	0.0427
					1	17	3	17.6	

Mild: A-DROP score = 0, Moderate: A-DROP score = 1-2, Severe: A-DROP score = 3, Very severe: A-DROP score = 4-5

Definition of extent of pneumonia shadow is described in the Patients and methods section of the main text.