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Improving the 2007 IDSA/ATS severe Community-Acquired Pneumonia criteria to predict ICU admission

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Abstract

Purpose—To improve 2007 IDSA/ATS severity criteria to predict ICU admission in patients hospitalized with pneumonia.

Methods—A composite score that included the 2007 IDSA/ATS criteria for severe pneumonia and additional significant variables identified by recent publications was tested in patients hospitalized with CAP.

Results—Among 787 patients hospitalized with CAP, 156 (19.8%) required admission to the ICU. We identified one major criterion (arterial pH <7.30), and four minor criteria (tachycardia >125 bpm, arterial pH 7.30–7.34, sodium <130 mEq/L and glucose >250 mg/dl) to be associated with ICU admission. Adding arterial pH <7.30 to the two 2007 IDSA/ATS major criteria increased sensitivity from 61.5% to 71.8% and AUC from 0.80 to 0.86. Adding in sequence the four minor criteria to the 2007 IDSA/ATS minor criteria, increased sensitivity from 41.7% to 53.8%, and AUC from 0.65 to 0.69. In the new composite score, combining 1 of 3 major criteria with 3 of 12 minor criteria showed a sensitivity of 92.9% and an AUC of 0.88.

Conclusion—The addition of arterial pH <7.30 to the 2007 IDSA/ATS major criteria improves sensitivity and AUC to identify patients who will require ICU care.

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Keywords

Community-acquired pneumonia; ICU admission; arterial acidosis; severity scores

INTRODUCTION

Community-acquired pneumonia (CAP) is the leading infectious cause of death in the United States [1]. It affects 5–6 million people each year, and leads to 1 million hospital admissions [2–3]. Among patients hospitalized with CAP, approximately 10–20% will require admission to the intensive care unit (ICU) with hospital mortality as high as 50% [4–5]. The decision of where to treat a patient with CAP is crucial impacting treatment alternatives, outcomes, and costs [6–8].

In hospitalized CAP patients, demographic characteristics, comorbid conditions, physiological variables, laboratory values and radiological findings have been associated with higher mortality and the need for higher level of care. For several decades, a number of predictor tools including CURB65 [9], Pneumonia Severity Index (PSI) [10] and Infectious Disease Society of America (IDSA)/American Thoracic Society (ATS) criteria [11] were developed to predict 30-day mortality. These tools are also used to identify patients with higher severity of illness and guide decisions regarding ICU admission. The limitations of these tools were highlighted in a recent meta-analysis by Chalmers and colleagues [12] showing that scoring systems designed to predict 30-day mortality are insensitive in predicting ICU admission. Among these scores, the 2007 IDSA/ATS severe CAP criteria [11] was identified as the best predictor of ICU admission with a sensitivity of only 65% [12].

Improving the predictive value of severe CAP scores is important for early intervention and to strengthen enrollment of eligible patients in randomized control trials. For this reason, we tested how the additional of predicting variables to the 2007 IDSA/ATS severe CAP criteria can enhance the ability to predict need for ICU admission in patients hospitalized with CAP.

METHODS

This is a retrospective cohort study of hospitalized patients with pneumonia admitted over a four year period (January 1, 1999 to December 1, 2002) at two academic teaching tertiary care hospitals in San Antonio, Texas. The Institutional Review Board of the University of Texas Health Science Center at San Antonio approved the research protocol with exempt status.

Inclusion and Exclusion Criteria

Patients were identified using the primary discharge diagnosis of pneumonia (ICD-9 codes 480.0–483.99 or 485–487.0) or secondary discharge diagnosis of pneumonia with a primary diagnosis of respiratory failure (518.81) or sepsis (038.xx). Subjects were included if they were 1) greater than 18 years of age, 2) had an admission diagnosis of pneumonia, and 3) had a radiographically confirmed infiltrate on chest x-ray or computed tomography scan obtained within 24 hours of admission.

Exclusion criteria included 1) discharged from an acute care facility within 14 days of admission, 2) transferred to the ICU after 48 hours of admission and 3) comfort measures only on this admission. If a subject was admitted more than once during the study period, only the first hospitalization was abstracted.

Data Abstraction

Chart review data included baseline demographics characteristics, comorbid conditions, physical examination findings, laboratory and microbiology data, and chest radiograph reports. We assessed these measures either at the time of presentation to the emergency department, or for those who were admitted directly from clinic, at time of hospital admission.

Severe CAP variables

Table 1 shows the 2 major and 9 minor 2007 IDSA/ATS criteria, and the additional major and minor prediction variables reported in other scores [13–15] or recent publications [16, 17]. Among major criteria, hypotension (systolic blood pressure < 90 mmHg) [13] overlapped with the 2007 IDSA/ATS [11] minor criteria hypotension requiring fluid resuscitation and was not considered. In Table 2 we describe the combination of major and minor criteria used in this study. The minor criteria selection was dependent on the strength of the association with ICU admission and variable occurrence frequency. We used a modified minor criteria set forth by the IDSA/ATS guidelines [11], due to the lack of our ability to assess thrombocytopenia (platelet count <100,000 cells/mm³).

Outcomes

Our primary outcome was ICU admission. The decision for admission to an ICU vs. the medicine ward was made by the treating physicians.

Statistical Analyses

Categorical variables were analyzed using the Chi-square test. We performed a logistic regression model with ICU admission as the dependent variables and individual severity criteria as independent variables. To assess whether adding additional variables (major or minor criteria) was associated with improved prediction for ICU admission, we calculated the corresponding sensitivity and the discriminatory power using the receiver operating characteristic (ROC) and area under the curve (AUC). All analyses were performed using SPSS version 18.0 for Windows (SPSS, Chicago, IL, USA).

RESULTS

Severity criteria and ICU admission

We identified 787 episodes of CAP among hospitalized patients during the study period, 156 (19.8%) were admitted to the ICU. Patient characteristics are shown in table 3.

Major criteria—All patients with at least one of the two 2007 IDSA/ATS major criteria were admitted to the ICU; 77/77 (100%) with invasive mechanical ventilation and 34/34 (100%) with vasopressor support. All but one patient with an arterial pH <7.30 was admitted to the ICU (25/26 [96.1%]).

Minor criteria—Among the nine 2007 IDSA/ATS minor criteria, the most common were hypoxemia (64%) and multilobar infiltrates (57%). In univariate analysis (Table 4), all minor 2007 IDSA/ATS criteria were associated with ICU admission, with exception of hypothermia. The three strongest predictors for ICU admission were hypoxemia, confusion and leucopenia in the univariate analyses.

Among non-2007 IDSA/ATS minor criteria, the most common were: age greater than 65 years (44%), tachycardia >125 (25%), and hyponatremia (21%). In univariate analysis (Table 4), the variables associated with ICU admission were: arterial pH 7.30–7.34 (OR

2.86, 95% CI 1.41–5.77, $p=0.001$), tachycardia >125 (OR 2.85, 95% CI 1.83–4.44, $p<0.001$), sodium <130 (OR 1.77, 95% CI 1.13–2.77, $p=0.01$) and glucose >250 (OR 1.75, 95% CI 1.03–2.77, $p=0.03$). In contrast, hematocrit $<30\%$ and age at presentation above 65 or 80 years were not associated with ICU admission and were not included in the combination analysis.

Combination of different severity criteria

Strengthening the 2007 IDSA/ATS major criteria—When arterial pH <7.30 was added to the 2007 IDSA /ATS major criteria the sensitivity to identify ICU care improved from 61.5% to 71.8% with an AUC that increased from 0.80 to 0.86 (Table 5).

Strengthening the 2007 IDSA/ATS minor criteria—When other minor non-IDSA/ATS criteria significantly associated with ICU admission were added sequentially to the 2007 ATS/IDSA minor criteria the sensitivity increased from 41.7% to 53.8% when adding four variables (tachycardia >125 , pH 7.30–7.34, sodium <130 and glucose >250). The AUC increased from 0.65 to 0.69 (Table 5).

Combining major and minor criteria for severe CAP—Using the 2007 IDSA/ATS severity criteria, the combination of 1 of 2 major criteria and /or 3 minor had a sensitivity of 84.6% and an AUC of 0.87 to predict ICU admission. The sequential addition of other non-2007 IDSA/ATS severity minor criteria improved marginally the sensitivity to 89.1% with an AUC of 0.88 (Table 5).

A new major criteria method which includes the original 2007 IDSA/ATS with an arterial pH <7.30 as a third major criteria, had a sensitivity to 88.5% with an AUC of 0.89. In addition, if at least one of three major criteria added sequentially to at least 3 minor criteria including non-2007 IDSA/ATS criteria, showed a sensitivity as high as 92.9% with an AUC of 0.88 (Table 5).

DISCUSSION

The main finding of our study is that arterial pH <7.30 is a major criteria that should be considered as a predictor for ICU admission in patients with severe CAP in addition to other 2007 IDSA/ATS recommended criteria. Moreover, there are variations in the strength of association between individual minor criteria and other selected variables identifying the need of ICU admission. The 2007 IDSA/ATS CAP Guidelines major criteria including the pH <7.30 and at least 3 of the 8 minor criteria were predicted the need for ICU care with a sensitivity of 88.5% and an AUC of 89%. The addition of other non-2007 IDSA/ATS minor criteria did not add much to the prediction rule of identifying need for ICU admission in hospitalized CAP patients.

The need to identify prediction rules that determine when a patient with severe CAP requires ICU care are limited because they were designed to predict 30-day mortality and therefore, it has been used as marker for the need of a higher level of care. The best score identified in a recent meta-analysis by Chalmers et al to predict the need for ICU admission was the 2007 IDSA/ATS severe CAP score [12]. However, this score had a low sensitivity (65%) identifying patients who require ICU admission so still requires further refinement in order to accurately determine hospitalized CAP patients that require ICU care. They found that the 2007 IDSA/ATS score was better when compared to other severity scores such as CURB65 (9), PSI (10) and 2001 ATS criteria [18] to predict ICU admission. Comparison against other available severe CAP scores such as the SCAP score [13], REA-ICU [14], SMART-COP [15] and CORB [19] were not done in this meta-analysis due to insufficient data.

The 2007 IDSA/ATS CAP guidelines major criteria included the need of mechanical ventilation or vasopressor support, which are universally accepted indicators of ICU care, but are limited by their low frequency and high specificity. Liapikou et al. reported a low sensitivity using only mechanical ventilation (37%) or septic shock (32%) as major predictors for ICU admission [20]. Our results suggest that the addition of arterial pH <7.30 to the 2007 IDSA/ATS major criteria may improve sensitivity to 72%, when at least one of the 3 major criteria was documented at presentation.

The 2007 IDSA/ATS CAP guidelines minor criteria consist of nine physiological variables (Table 1) known to be associated with 30-day mortality and were used to define severe CAP and need for ICU care. The value of these criteria has not been firmly established in order to predict ICU care. Phua et al [21] showed a sensitivity of 58% and an AUC of 0.85, while Chalmers et al [22] showed a sensitivity of 75% and an AUC of 0.85. In our study, the use of at least 3 of 8 minor 2007 IDSA/ATS criteria variables showed a sensitivity of 42% to predict ICU care. The addition of other non-2007 IDSA/ATS selected minor criteria improved slightly the sensitivity to 54%. Therefore, the isolated use of the major or the minor 2007 IDSA/ATS criteria would lack enough sensitivity to determine the need for ICU care in hospitalized CAP patients. However, the combination of the major (at least one major of 3, including low pH) and minor (at least 3 minor) criteria improves the sensitivity up to 88 % and an AUC of 0.89. Incremental sensitivity and AUC was marginally observed with the sequential addition of the other non-2007 IDSA/ATS minor criteria variables. We suggest that adding more minor criteria variables does not have the same value as adding a low arterial pH to the prediction score.

An objective scoring system that could accurately identify hospitalized CAP patients requiring ICU admission could have important clinical applications. First, the appropriate location admission of patients optimizes the use of limited ICU resources. Second, an accurate prediction model will minimize delayed ICU admission, which is associated with increased mortality [6, 23]. Third, correct site-of-care can optimize initial antibiotic treatment, because the microbiological aetiologies of severe CAP differ from those associated with other hospitalized CAP patients [24–25]. Avoidance of initial inappropriate antibiotic treatment has been associated with lower hospitalized CAP mortality [26–27]. Finally, a higher sensitivity to predict ICU admission would facilitate the inclusion of patients in future prospective randomized and controlled trials.

Our study has several limitations. First, this is a retrospective study involving only two centers and it was relatively small sample, so the results should be viewed with caution. Second, platelet count was not examined in our study, and it is possible that thrombocytopenia or thrombocytosis may further improve the performance of the proposed score [28]. Third, specific interventions more easily performed in the ICU (e.g. urgent bronchoscopy, arrhythmia management, electrolyte correction) have not been included, but should be considered in future studies. Finally, we used the decision of ICU admission as the gold standard, because this reflected the actual clinical practice. However, the variability of clinician's judgment and frequent constraints on the availability of ICU beds may have influenced the site-of-care decisions.

In conclusion, adding new major criteria (arterial pH <7.30) to the 2007 IDSA/ATS CAP guidelines criteria improves the sensitivity and AUC to identify patients who will require need for ICU care. The combination of at least 1 of 3 major criteria (including low pH) and at least 3 minor of the current 2007 IDSA/ATS criteria performed best to determine the need for ICU admission. Further studies are needed to determine how to improve current methods that may be translated to earlier care and improve CAP patient outcomes.

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Table 1

Major and minor criteria recognized by different severity scores

Severity score	Major criteria	Minor criteria
2007 IDSA/ATS (11)	<ul style="list-style-type: none"> • Invasive mechanical ventilation • Septic shock requiring vasopressors 	<ul style="list-style-type: none"> • Confusion/disorientation • Uremia (BUN level 20 mg/dL) • Respiratory Rate >30 breaths/min • Hypotension requiring fluid resuscitation • PaO₂/FiO₂ <250 • Multilobar infiltrates • Leucopenia (<4000 cells/mm³) • Thrombocytopenia (<100,000 cells/mm³) • Hypothermia (<36C)
Other scores (13–17)	<ul style="list-style-type: none"> • Arterial pH <7.30 (13) • Systolic Blood Pressure < 90mmHg (13) 	<ul style="list-style-type: none"> • Tachycardia >125 beats/min (14) • Arterial pH 7.30–7.34 (14,15) • Sodium <130 mEq/L (14) • Hematocrit <30% (16) • Glucose >250 mg/dl (17) • Age 65 (9) • Age 80 (13)

Table 2

Major and minor criteria stratification method

Description	
Major Criteria	
Major 1/2	Invasive mechanical ventilation + septic shock requiring vasopressors
Major 1/3	2 Major criteria (above) + arterial pH <7.30.
Minor Criteria	
Minor 3/8	1. Confusion; 2. Uremia (BUN ≥20 mg/dL); 3. RR ≥30 bpm; 4. BP ≤90/60 mmHg; 5. PF ≥250; 6. Multilobar infiltrates; 7. Leucopenia (WBC <4000cell/mm ³); 8. Hypothermia (temperature ≤36°C)
Minor 3/9	8 Minor criteria (above) + Variable 9 (Tachycardia >125 bpm)
Minor 3/10	9 Minor criteria (above) + Variable 10 (pH 7.30–7.34)
Minor 3/11	10 Minor criteria (above) + Variable 11 (Sodium <130 mEq/L)
Minor 3/12	11 Minor criteria (above) + Variable 12 (Glucose >250 mg/dL)

BUN, blood urea nitrogen; RR, Respiratory Rate; bpm, beats per minute; BP, blood pressure; WBC, white blood cells

Table 3

Patient demographic and clinical characteristics among all hospitalized CAP patients (n=787)

Age, yr	60.4 (SD, 16.4)
Men	621 (78.9%)
Preexisting comorbid conditions	
• CHF	123 (15.6%)
• COPD	218 (27.7%)
• Diabetes Mellitus	230 (29.2%)
• Chronic Liver Disease	94 (11.9%)
• History of malignancy	78 (9.9%)
• Renal insufficiency	87 (11.1%)
• History of stroke	105 (13.3%)
Clinical outcomes	
• Length of stay	7.6 (SD 15.2)
• ICU admission	156 (19.8%)
• 30-d mortality	72 (9.1%)

Values are given as No (%), unless otherwise indicated

CHF: Chronic Heart Failure, COPD: Chronic Pulmonary Disease

Table 4
Description of univariable analyses of specific minor severity variables according to Intensive Care Unit (ICU) Admission.

	n (%)	n (%)	Univariable		
Variable	No ICU	ICU	OR	95% CI	p
<u>2007 IDSA/ATS minor criteria:</u>					
RR 30	53 (8.5)	31 (20.5)	2.77	1.71–4.51	<0.001
PaO ₂ /FiO ₂ 250	84 (26.8)	78 (64.5)	4.94	3.15–7.74	<0.001
Multilobar infiltrates	184 (29.4)	88 (56.8)	3.14	2.19–4.51	<0.001
Confusion	44 (7)	41 (26.3)	4.75	2.97–7.61	<0.001
BUN 20	243 (38.8)	92 (59)	2.27	1.58–3.24	<0.001
Leucopenia	23 (3.6)	18 (11.5)	3.44	1.81–6.56	<0.001
Hypothermia	50 (7.9)	19 (12.2)	1.61	.920–2.82	0.09
Hypotension	156 (24.9)	54 (35.3)	1.64	1.12–2.39	0.01
<u>Other minor criteria:</u>					
Arterial pH 7.30–7.34	21 (3.3)	14 (9.0)	2.86	1.41–5.77	0.001
Tachycardia > 125 bpm	66 (10.5)	39 (25.0)	2.85	1.83–4.44	<0.001
Sodium <130	83 (13.2)	33 (21.2)	1.77	1.13–2.77	0.01
Glucose >250	54 (8.6)	22 (14.1)	1.75	1.03–2.98	0.03
Hematocrit <30%	52 (8.2)	20 (12.8)	1.63	0.94–2.83	0.07
Age 65 years old	258 (40.6)	69 (44.2)	1.15	0.81–1.65	0.41
Age 80 years old	90 (14.3)	16 (10.3)	0.68	0.39–1.20	0.18

BUN, blood urea nitrogen; CI, confidence interval; inf., infiltrates; OR, odds ratio.

Table 5

Combination of different Severity Criteria

Parameters	No ICU N=631 n (%)	ICU N=156 n (%)	P value	AUC
Major Criteria				
Major 1/2	0	96 (61.5)	<0.001	0.80
Major 1/3	1 (0.2)	112 (71.8)	<0.001	0.86
Minor Criteria				
Minor 3/8	63 (10.0)	65 (41.7)	<0.001	0.65
Minor 3/9	75 (11.9)	72 (46.2)	<0.001	0.67
Minor 3/10	79 (12.5)	74 (47.4)	<0.001	0.67
Minor 3/11	89 (14.1)	84 (53.8)	<0.001	0.70
Minor 3/12	99 (15.7)	84 (53.8)	<0.001	0.69
Combination Major and Minor criteria				
Combo – Major 1/2 or Minor 3/8	63 (10.0)	132 (84.6)	<0.001	0.87
Combo – Major 1/2 or Minor 3/9	75 (11.9)	136 (87.2)	<0.001	0.87
Combo – Major 1/2 or Minor 3/10	79 (12.5)	137 (87.8)	<0.001	0.88
Combo – Major 1/2 or Minor 3/11	89 (14.1)	139 (89.1)	<0.001	0.88
Combo – Major 1/2 or Minor 3/12	99 (15.7)	139 (89.1)	<0.001	0.86
Combo – Major >1/3 or Minor >3/8	64 (10.1)	138 (88.5)	<0.001	0.89
Combo – Major >1/3 or Minor >3/9	76 (12.0)	142 (91.0)	<0.001	0.89
Combo – Major >1/3 or Minor >3/10	80 (12.7)	143 (91.7)	<0.001	0.89
Combo – Major >1/3 or Minor >3/11	91 (14.4)	145 (92.9)	<0.001	0.89
Combo – Major >1/3 or Minor >3/12	101 (16.0)	145 (92.9)	<0.001	0.88

AUC, Area under the curve

The column results represents the sensitivity