

BEYOND CONVENTIONAL MARKERS: EXPLORING THE BLOOD UREA NITROGEN TO SERUM ALBUMIN RATIO AS A POTENTIAL PREDICTOR IN COMMUNITY-ACQUIRED PNEUMONIA PROGNOSIS

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ABSTRACT

Objectives To evaluate the diagnostic accuracy of BUN/albumin, in predicting the severity of CAP, keeping actual severity (ICU admission and mortality within 30 days) as gold standard and to compare the diagnostic accuracy of the BUN/albumin with CURB-65 keeping actual severity (ICU admission and mortality within 30 days) as gold standard.

Study Design: Cross-sectional study.

Study Setting and Duration: Conducted at a tertiary care hospital from May-Aug 2025. **Methods:** A total of 236 patients aged 18–65 years diagnosed with CAP were included. Serum BUN and albumin levels were measured at admission, and the BUN/albumin ratio was calculated. CURB-65 scores were determined for all patients. Both the predictors were evaluated/compared for their diagnostic accuracy by applying ROC curve analysis and 2x2 table keeping the gold standard of 30-day mortality and ICU admission.

Results: The BUN/albumin ratio demonstrated excellent diagnostic accuracy in predicting ICU admission, with high sensitivity and specificity. It also showed good performance in predicting 30-day mortality. CURB-65 exhibited higher sensitivity for mortality prediction but lower specificity compared to the BUN/albumin ratio. Overall, the BUN/albumin ratio showed a more balanced diagnostic profile.

Conclusion: The BUN/albumin ratio is a simple, cost-effective, and reliable biomarker for predicting severity and outcomes in CAP. When used alongside CURB-65, it may enhance early risk stratification and support clinical decision-making.

INTRODUCTION

Worldwide, community-acquired pneumonia (CAP) is a major cause of hospitalization and mortality.^{1,2} It may present as mild illness and treated as out-patient or as severe leading to inpatient admission, Intensive care unit (ICU) admission. For favourable outcome, it needs early diagnosis.³ The major known causes of CAP include viruses, bacteria, and fungi.⁴ Typical bacterial agents may include: Streptococcus pneumoniae, Staphylococcus aureus, group A streptococci, Haemophilus influenzae, Moraxella catarrhalis and Enterobacteri.^{5,6} The global CAP rates range at 1.5 to 14 cases per 1000 person-years.⁷ In Asia-Pacific region, prevalence of lifetime pneumonia stood at 10%. An examination of the National Health Survey of Pakistan data, 1990-94 shows that the incidence of CAP in adulthood was 1,690 per 100,00.^{8,9}

The CURB-65 and the Pneumonia Severity Index (PSI) are traditional severity assessment scores and frequently used in routine practice, however, they have some limitations including inter-observer variability and complexities particularly in resource dependent settings. Consequently, there is an increasing concern in identifying of simple and easy to assess biomarkers that are able to forecast the severity of CAP with high accuracy. One such measure is the blood urea nitrogen (BUN) to serum albumin ratio. A previous study shows a cut off value of B/A ratio of 10.2 mg/g to predict mortality with a sensitivity of 70% and specificity of 92%. The optimal B/A cut off point of admission to ICU was 9.84mg/g with sensitivity of 68% and specificity of 88%.¹⁰ A 30 day mortality after CAP was 19.6% and ICU admission was 35.7%.¹⁰ According to another study by Jin Hwa Lee et al, mortality due to severe CAP has reached 50% in some series.¹¹ BUN may increase with dehydration or dysfunction in the kidney commonly observed with severe CAP, whereas serum albumin levels fall in relation to inflammation or malnutrition, also common with severe infections. Therefore, the BUN/albumin ratio can be used as a helpful indicator

of the severity of CAP, which is easy to obtain and economical to use by clinicians, especially in low-resource centers such as Pakistan.

Literature deficit emphasizes the use of BUN/Albumin ratio to predict severity of CAP still exists. Also, it is the first of its kind of study to be conducted in one institute in Pakistan. Thus, the purpose of the present study is to evaluate the BUN/Albumin level as a sole risk factor to predict the severity of CAP and to estimate whether it could be used in clinical practice as an early predictor of patients with a high risk of severe outcomes, including ICU admission and 30-day mortality.

METHODOLOGY:

This was a cross-sectional validation study carried out in the Departments of Pulmonology, Internal Medicine and Critical Care of Shifa International Hospital, Islamabad, Pakistan. The research was conducted in a three months timeframe following the consent of the synopsis by the College of Physicians and Surgeons Pakistan (CPSP) and the Institutional Review Board (IRB) of the hospital.

A calculator based on sensitivity and specificity was used to estimate the sample size. The sensitivity of the BUN/Albumin ratio to predicting ICU admission was considered to be 68, specificity 88, prevalence 35.77% and confidence level 95. On these parameters a total sample of 236 patients was obtained. The sampling method used was consecutive non-probability and all patients who met the eligibility criteria (presented with community-acquired pneumonia (CAP)) in the course of the study were sampled. The study population comprised adult patients aged between 18-65 years who had acquired pneumonia in the community on a clinical and/or radiological basis with informed consent. Hospital-acquired pneumonia cases, ventilator-associated pneumonia cases, and the patients who had been hospitalized in the last three months were excluded from the study. All those cases suffering with Chronic Liver Disease, chronic kidney disease (serum

creatinine ≥ 1.5 mg/dL), on immunosuppressive treatment including long-term steroids or immune modulators, already taken antibiotics within 14 days before admission, incomplete medical records and/or those who had been lost to follow-up were also excluded.

We followed the ethical principles in addition to taking an informed consent from the patients. The confidentiality of the data was assured by keeping their record in safe place under lock and key. While for the evaluation of CAP, a comprehensive assessment proforma was used. Necessary demographic details including their gender/age and comorbidities: interstitial lung disease (ILD), chronic obstructive pulmonary disease (COPD), hypertension (HTN), diabetes mellitus (DM) and cardiovascular disease (CVD). At the time of presentation of the patients, vitals were documented in addition to lab investigations for arterial blood gases, blood urea nitrogen (BUN) and serum albumin levels, within 24 hours. The BUN/Albumin ratio was calculated for each patient by dividing serum BUN by serum albumin levels. The patients categorization was done with pre-defined cut-off values i.e. ≥ 9.84 mg/g indicating increased risk for ICU admission and ≥ 10.2 mg/g indicating increased risk for 30-day mortality. We followed American Thoracic Society guidelines for evaluation of sputum sample for antibiotic therapy and sputum culture. The severity of the disease was determined by the CURB-65 scoring

system. The CURB-65 score was determined by giving one point in each case of confusion, serum urea >7 mmol/L, respiratory rate ≥ 30 /min, low blood pressure (SBP less than 90 mmHg or DBP less than 60 mmHg) and age 65 and above. The age component did not add considerable value to the total CURB-65 score due to the upper age limit of 65 years of the study population. A CURB-65 score of 3 or above was deemed to be a sign of severe pneumonia. Each patient was followed up with clinical outcomes, such as ICU admission and 30-day mortality. The analysis and input of the data were processed with the help of SPSS version 26.0. The presentation of categorical variables was made in terms of the frequencies and percentages, whereas the continuous variables (age, GCS score, CURB-65 score, BUN, serum albumin, and other laboratory variables) were presented as mean plus standard deviation. p-value below 0.05 was taken to be statistically significant. BUN/Albumin ratio and CURB-65 score were developed as two-by-two contingency tables against the actual severity, which was the ICU admission and 30-day mortality, which are the gold standards. Independent determination of the sensitivity, specificity, positive predictive value and negative predictive value were determined in terms of admission to ICU and mortality. To compare the predictive ability of the two markers and to determine the optimum cut-off values, the analysis of Receiver Operating Characteristic (ROC) curves was performed. Likelihood ratios (LR+ and LR-) were as well computed.

Table 1: Baseline Characteristics of Study Population (n = 236)

Variable	Category	n (%)
Age Group (years)	18-50	162 (68.6)
	51-65	74 (31.4)
Gender	Male	106 (44.9)
	Female	130 (55.1)
Diabetes Mellitus	Yes	89 (37.7)
	No	147 (62.3)
Hypertension	Yes	109 (46.2)

	No	127 (53.8)
COPD	Yes	57 (24.2)
	No	179 (75.8)
CVD	Yes	79 (33.5)
	No	157 (66.5)
Neoplastic Disease	Yes	29 (12.3)
	No	207 (87.7)
ICU Admission	Yes	97 (41.1)
	No	139 (58.9)
30-day Mortality	Yes	38 (16.1)
	No	198 (83.9)

RESULTS:

Baseline Characteristics of Study Population

In Table 1, most of the participants (68.6 %) were aged between 18 and 50 years, with 31.4% of that of 51-65 years. The proportion of females in the study population (55.1%) was a little higher than that of males (44.9%). With comorbid conditions, 37.7% of the patients had diabetes mellitus and 46.2% had hypertension. Thirty five percent of the cases had CVD while 24.2% had COPD. A decreased percentage of patients (12.3%) had underlying neoplastic disease. Clinically, 41.1% of patients had to be admitted to ICU and 16.1% died in 30-days of the study period. Table 3 shows that the BUN/Albumin ratio is a diagnostic predictor of ICU admission. Eighty-nine patients who were correctly identified as true positives and 3 patients were missed (false negatives) among patients who needed to be admitted to the ICU. Out of the patients that did not need admission to the ICU, 139 were correctly

identified as true negatives, and 5 were wrongly identified as false positives. This result suggests that the BUN/Albumin ratio is very sensitive and specific in predicting the ICU admission, and there is little misclassification.

Descriptive Statistics of Continuous Variables

In table 2, the descriptive statistics of important continuous variables. The mean age of the patients was 40.92 ± 14.07 years, ranging from 18 to 65 years. The average blood urea nitrogen (BUN) was 23.25 ± 8.81 mg/dl and the average serum albumin was 3.30 ± 0.61 g/dl. The mean BUN/Albumin ratio calculated was 7.76 ± 4.25 with a range of 2.86 to 16.52. The mean CURB-65 score was 1.82, SD was 1.52 (maximum of 4 and minimum of 0) which shows that the distribution of the severity of the disease was wide among the study population.

Table 2: Descriptive Statistics of Continuous Variables

Variable	Mean $\pm$ SD	Min	Max
Age (years)	40.92 ± 14.07	18	65
BUN (mg/dL)	23.25 ± 8.81	12	39
Albumin (g/dL)	3.30 ± 0.61	2.3	4.2
BUN/Albumin Ratio	7.76 ± 4.25	2.86	16.52

CURB-65 Score	1.82 ± 1.52	0	4
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Table 3: ICU Admission – BUN/Albumin Ratio

	ICU(Yes)	ICU(No)	Total
Positive	89 (TP)	5 (FP)	94
Negative	3 (FN)	139 (TN)	142
Total	92	144	236

Table 4: ICU Admission – CURB-65

	ICU(Yes)	ICU(No)	Total
Positive	90 (TP)	7 (FP)	97
Negative	1 (FN)	138 (TN)	139
Total	91	145	236

ICU Admission – CURB-65

The CURB-65 score predicts ICU admission as shown in Table 4. There were 90 correctly identified patients who needed ICU admission (true positives) and 1 false negative. In the group of patients who did not need ICU treatment, 138 patients were correctly identified as true negatives, and 7 patients were wrongly identified as patients who needed to be admitted to the ICU. These findings indicate that CURB-65 is a little more sensitized as compared to

BUN/Albumin ratio in predicting ICU but with relatively higher false positives. 30-Day Mortality – BUN/Albumin Ratio

Table 5 assessed the diagnostic value of BUN/Albumin ratio in the prediction of 30-day mortality. Out of the patients who succumbed to death, 73 individuals were correctly identified as true positives whilst 24 were missed (false negatives). On the side of survivors, 124 were rightly classified as true negatives and 15 were false positives. These results show that the BUN/Albumin ratio has good specificity in predicting mortality, but a relatively low sensitivity, which leads to some false negative cases of

mortality. Table 6 shows the predictive ability of the CURB-65 on 30-day mortality. The correct identifications of 38 mortality cases were all true positives, and no false-negative cases were found. But there were 59 false positives and 139 true negatives among the survivors. This implies that CURB-65 is very sensitive (100%) to predict mortality, but with low specificity because it shows more false positives.

Table 7 is a holistic comparison between the predictive power of the two predictors. To be admitted to the ICU, both BUN/Albumin ratio and CURB-65 had very high sensitivity and specificity (96.6% accuracy in diagnosis). The area under the curve (AUC) was almost ideal with both the predictors (1.000 with BAR and 0.995 with CURB-65), implying excellent discriminatory power. In the case of 30-day mortality, CURB-65 had the highest sensitivity (100), thus being a good screening tool, but the BUN/Albumin ratio had a higher specificity (89.2) and, generally, a higher accuracy (83.5), thus, a better confirmatory value. The ROC analysis revealed a marginally better AUC of CURB-65 (0.850) over BUN/Albumin ratio (0.819) indicating excellent overall discriminatory ability to predict mortality.

Table 5: (30-Day Mortality – BUN/Albumin Ratio)

	Mortality (Yes)	Mortality (No)	Total
Positive	73 (TP)	15 (FP)	88
Negative	24 (FN)	124 (TN)	148
Total	97	139	236

Table 6: Table (30-Day Mortality – CURB-65)

	Mortality (Yes)	Mortality (No)	Total
Positive	38 (TP)	59 (FP)	97
Negative	0 (FN)	139 (TN)	139
Total	38	198	236

Table 7: Diagnostic Performance and ROC Comparison

Parameter	BAR (ICU)	CURB (ICU)	BAR (Mortality)	CURB (Mortality)
Sensitivity (%)	96.7	98.9	75.3	100
Specificity (%)	96.5	95.2	89.2	70.2
PPV (%)	94.7	92.8	83.0	39.2
NPV (%)	97.9	99.3	83.8	100
Accuracy (%)	96.6	96.6	83.5	75.0
LR+	27.6	20.6	6.97	3.36
LR–	0.034	0.011	0.28	0.00
AUC	1.000	0.995	0.819	0.850

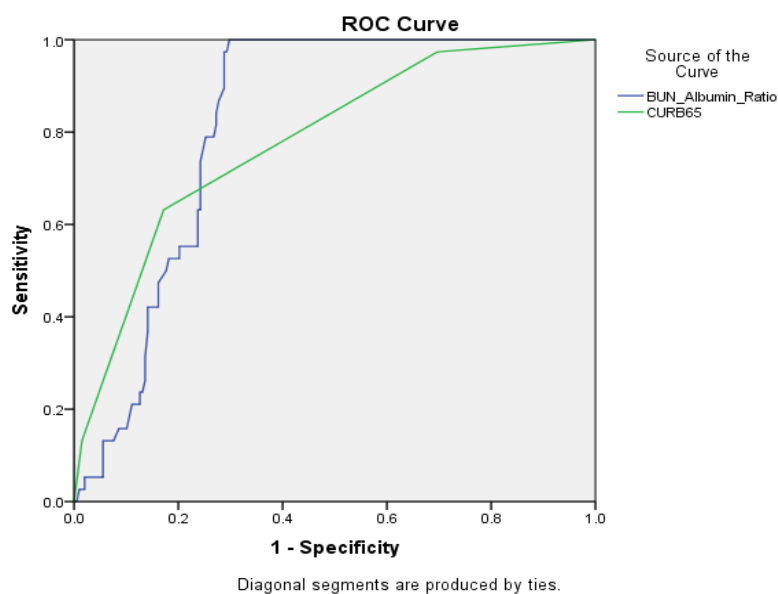


Fig. 1
Mortality of the patients

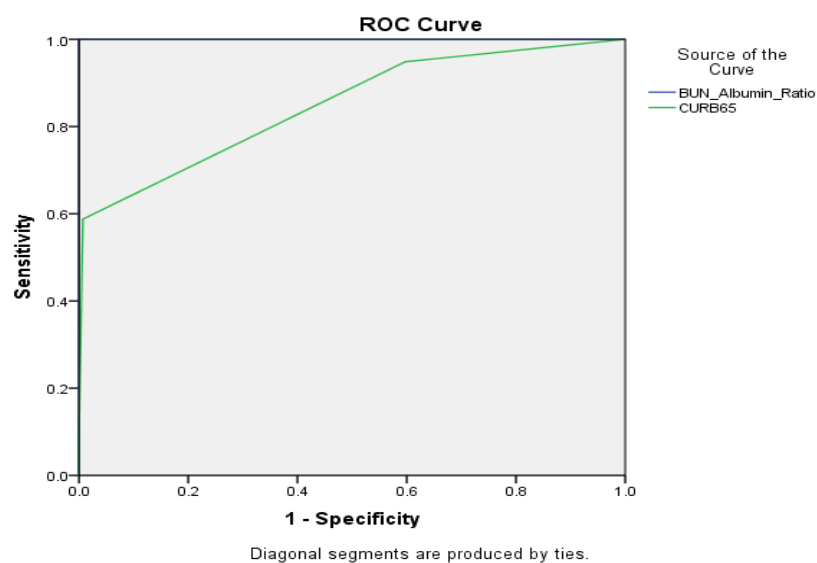


Fig. 2
ICU Admission



DISCUSSION

In this study, we evaluated the diagnostic accuracy of the BUN to albumin ratio for the determination of the severity of CAP and to its compare the results with CURB-65 scoring system and found both modalities as excellent to predict the outcome. It is important to note that BUN/albumin ratio exhibited a balanced diagnostic accuracy with high sensitivity and specificity of ICU admission, whereas CURB-65 had a high sensitivity with a lower specificity. The results of the current research closely correspond to the results obtained by Agarwal et al.,¹⁰ who provided a prospective observational study of 112 CAP patients. They showed that BUN/albumin ratio was a predictive independent variable of ICU admission and mortality in addition to other known clinical variables like age, CURB-65 score and procalcitonin. The astonishing odds ratios of mortality (67.8) and ICU admission (11.2) indicate the close relationship between high BUN/albumin ratio and negative results. Moreover, the analysis in the form of Cox regression proved that there was a significant correlation between high BUN/albumin ratio and mortality time. These results are in line with the current study and support the use of the BUN/albumin ratio as a good and independent biomarker to stratify risk in CAP.

Further, Ginwala et al¹² evaluated the prognostic value of BUN/albumin ratio in CAP and found that the BUN/albumin ratio is a useful predictor of both disease severity and mortality and gave a sensitivity of 79% at a cut off of 10.66 and an exceptionally high sensitivity of 99% at a higher cut off. It could be, however, that the relative reduced sensitivity to mortality prediction in the current study can be attributed to the differences in patient sample, study design and distribution of severity with the authors including a cohort that may be more likely to have a heavy burden of severe illness.

Additional evidence of these results, Jyothi et al¹³ detailed in their observational study of 63 hospitalized CAP patients that higher BUN/ albumin ratios and

lower serum albumin levels were significantly related to an increased need of ICU stay and poorer prognosis and found an optimal cut-off value of 12.94 to be significant in predicting the need to stay in ICU, sensitivity was 9 Also, low serum albumin levels were identified as a non-dependent risk factor towards ICU admission. Findings of these studies are consistent with the current study, but the relative low specificity of their results as compared to the current study can be explained by variations in the sample size, patient attributes, and the distribution of disease severity.

Although the general conclusion was in line with the earlier research, some differences were noted. In the current study, the sensitivity of prediction of mortality was lower as compared to that of Ginwala et al¹² who reported a near-perfect sensitivity. In addition, different studies have different optimal thresholds as higher cut-offs were indicated by Jyothi et al¹³, indicating that the effectiveness of BUN/albumin ratio is patient-dependent and reliant on the clinical setting. Although CURB-65 had a high sensitivity to predict mortality in the current study, its specificity was relatively lower leading to an increase in a false-positive rate. Conversely, the BUN/albumin ratio showed a more balanced diagnostic profile that was more specific and thus a good supplement in establishing the severity of the disease. Since the study population had an upper age limit of 65 years, the age factor did not play a significant role in the overall CURB-65 score.

In recent past, there has been increasing interest to incorporate the novel biomarkers to enhance the accuracy of prognostic information instead of conventional diagnostic practices. Unal Cetin et al¹⁴ compared the fibrinogen-to-albumin ratio (FAR) and CURB-65, PSI, and CT severity scores in patients who had CAP in ICUs. Their analysis revealed that greater FAR, CURB-65, PSI, and CT severity scores were independently predictive of increased mortality and that the addition of FAR had a significant augmentation of the predictive power of conventional models. These results reveal the drawbacks of the use



of traditional scoring systems and promote the increasing significance of biochemical markers. The BUN/albumin ratio is also an important aspect that is supported by the present study as a simple and effective biomarker that does not replace the currently used clinical tools.

Increased studies on larger critical care groups also lend some biological plausibility to the BUN/albumin ratio as a prognostic variable. A large sample of patients with acute respiratory failure, consisting of 9,734 individuals was analyzed by Xiao et al¹⁵ who found that high BUN/albumin ratio was considerably linked to high mortality within 30 days. Their analysis also revealed that there was a non-linear correlation between the ratio and the mortality and an established threshold beyond which the mortality risk would increase. These results support the use of BUN/albumin ratio as an indicator of renal dysfunction, dehydration, and systemic inflammation as the mechanisms of severe CAP.

Similarly, Wu et al¹⁶ studied the relationship between the BUN/albumin ratio and mortality in patients with sepsis and obtained a non-linear relationship with a value that is significantly high than the ones of CAP studies. This difference in threshold values in comparison to the current study can be attributed to the differences in the severity and systemic involvement of the disease since sepsis is a more severe state of inflammation. These results highlight the significance of disease-specific validation and imply that optimum cut-off values of the BUN/albumin ratio can be different across clinical settings.

On the whole, the results of the current study, along with other those published by authors¹⁰⁻¹⁶ provide substantial evidence that the BUN/albumin ratio is a simple, cost-effective, and reliable biomarker to predict severity and mortality in CAP. It has a unique advantage in relation to the traditional scoring systems because it can indicate the renal and nutritional/inflammatory status. It can be used together with clinical instruments like CURB-65 to

improve early risk stratification and make clinical decisions in a timely manner.

There are some limitations to the current research. To begin with, it was a one-center research that was carried out in a tertiary care hospital, which can be a limitation when it comes to the generalizability of the results to other populations and healthcare environments. Second, the sample size was sufficient to make statistical inferences, but larger multicenter studies would offer more valid and robust findings. Last, the study design i.e. cross-sectional decreases the possibility of developing causal relationships between the BUN/albumin ratio and clinical outcomes

Moreover, the study population was also limited to patients between the age of 18 and 65 years, which might have diminished the role of the age factor in the CURB-65 score. The second limitation is that the BUN/albumin ratio was measured only at one point at admission, and the dynamics of the changes in these parameters during the period of illness were not investigated. Moreover, other pertinent biomarkers like procalcitonin, C-reactive protein and lactate were not incorporated in the comparative study. Lastly, it cannot be fully eliminated that there is residual confounding as a result of unmeasured variables.

According to the results of the current research, the BUN/albumin ratio can be regarded as a cheap and easy to obtain, but still a simple, biomarker of early risk stratification in patients with community-acquired pneumonia. Its application in combination with known scoring systems like CURB-65 can help improve accuracy of predicting ICU admission and mortality and help make timely clinical decisions.

Further studies should be done on a large-scale and multicentric prospective studies to confirm the studies on various populations. Also, investigations on serial measurements of the BUN/albumin ratio might give some information on its dynamic prognostic use. It is also advisable that comparative studies that consider other emerging biomarkers and incorporated integrated predictive models should also be carried out in order to enhance risk stratification. It would be



beneficial to define the standardized cut-off values specific to particular populations and severity of diseases, which would increase their clinical applicability.

CONCLUSION

We found blood urea nitrogen to serum albumin (BUN/albumin ratio) as a trustworthy and efficient biomarker while evaluating the severity of community-acquired pneumonia. It demonstrated a high level of diagnostic accuracy to identify patients who need to be admitted to the ICU and high levels of predictability 30 day mortality. The BUN/albumin ratio showed a more balanced diagnostic picture, especially with increased specificity, when compared with the CURB-65 scoring system and, therefore, could be used as a valuable addition to confirm the disease severity.

Even though CURB-65 is more sensitive in predicting mortality, it has a lower specificity than the other, which can result in an overestimation of the severity of the disease. Conversely, BUN/albumin ratio, which is an indicator of renal dysfunction as well as the nutritional or inflammatory conditions, is an extra prognostic indicator that supplements standard clinical scoring systems.

Integrating the BUN/albumin ratio with traditional clinical assessment tools, including CURB-65, can help improve the early risk classification process, decision-making around ICU admission, and eventually lead to better clinical outcomes and better resource utilization in patients with the community-acquired pneumonia.

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