Research

Risk stratification of early admission to the intensive care unit of patients with no major criteria of severe community-acquired pneumonia: development of an international prediction rule

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Abstract

Introduction To identify risk factors for early (< three days) intensive care unit (ICU) admission of patients hospitalised with community-acquired pneumonia (CAP) and not requiring immediate ICU admission, and to stratify the risk of ICU admission on days 1 to 3.

Methods Using the original data from four North American and European prospective multicentre cohort studies of patients with CAP, we derived and validated a prediction rule for ICU admission on days 1 to 3 of emergency department (ED) presentation, for patients presenting with no obvious reason for immediate ICU admission (not requiring immediate respiratory or circulatory support).

Results A total of 6560 patients were included (4593 and 1967 in the derivation and validation cohort, respectively), 303 (4.6%) of whom were admitted to an ICU on days 1 to 3. The Risk of Early Admission to ICU index (REA-ICU index) comprised 11 criteria independently associated with ICU admission: male gender, age younger than 80 years, comorbid conditions, respiratory rate of 30 breaths/minute or higher, heart rate of 125 beats/minute or higher, multilobar infiltrate or pleural effusion, white blood cell count less than 3 or 20 G/L or above, hypoxaemia (oxygen saturation < 90% or arterial partial pressure of oxygen (PaO2) < 60 mmHg), blood urea nitrogen of 11 mmol/L or higher, pH less than 7.35 and sodium less than 130 mEq/L. The REA-ICU index stratified patients into four risk classes with a risk of ICU admission on days 1 to 3 ranging from 0.7 to 31%. The area under the curve was 0.81 (95% confidence interval (CI) = 0.78 to 0.83) in the overall population.

Conclusions The REA-ICU index accurately stratifies the risk of ICU admission on days 1 to 3 for patients presenting to the ED with CAP and no obvious indication for immediate ICU admission and therefore may assist orientation decisions.

ATS: American Thoracic Society; CAP: community-acquired pneumonia; CI: confidence interval; ED: emergency department; EDCAP: Emergency Department Community-Acquired Pneumonia; ICU: intensive care unit; IRVS: intensive respiratory or vasopressor support; OR: odds ratio; PORT: Patient Outcomes Research Team; PSI: Pneumonia Severity Index; REA-ICU: risk of early admission to ICU; ROC: receiver operating characteristics; SCAP: severe community-acquired pneumonia.
Introduction

Approximately 10% of patients hospitalised for community-acquired pneumonia (CAP) are admitted to an intensive care unit (ICU), and these patients account for about 10% of all medical admissions to ICUs [1,2]. Although some patients with CAP have an obvious reason for ICU admission on the day of presentation to the emergency department (ED), a substantial proportion of others will develop organ failure within a few days [3]. Transfer to the ICU for delayed respiratory failure or delayed onset of septic shock is associated with increased mortality [4]. Hence, a major challenge in the management of CAP is to identify patients at risk for rapidly developing adverse medical outcomes among those presenting to the ED with no obvious reason for immediate ICU admission.

Since the publication of the American Thoracic Society (ATS) guidelines in 1993, several prediction rules have been derived to identify ED patients with severe CAP, defined by adverse outcomes (including ICU admission, shock requiring vasopressors, acute respiratory failure requiring mechanical ventilation or death). Most of these prediction rules were derived in populations including patients presenting with an obvious reason for immediate ICU admission. However, a prediction rule is essentially relevant to help management decisions for patients not requiring immediate respiratory or circulatory support at presentation to the ED [5]. Additionally, previous rules were designed to predict endpoints occurring within 30 days of ED presentation, which may be an excessively remote perspective, when considering both the viewpoint of the ED and ICU physicians’ orientation decisions, and the potential relatedness of a late ICU transfer to physiological alterations caused by pneumonia itself.

Therefore, our goals were to identify risk factors for ICU admission within three days of hospital stay for patients initially presenting without respiratory failure or shock, and to derive and validate a prediction rule to stratify the risk of ICU admission on days 1 to 3.

Materials and methods

Study design

This study was based on data obtained from four prospective, multicentre studies in adults with pneumonia. Two were from North America, the Pneumonia Patient Outcomes Research Team (PORT) cohort study and the Emergency Department Community-Acquired Pneumonia (EDCAP) trial, and the two other cohorts were from Europe (Pneumocom-1 and Pneumocom-2). The methods used for the Pneumonia PORT, EDCAP and Pneumocom studies have been reported previously [6-9]. With the exception of the EDCAP cluster randomised trial, all studies were observational. The study protocols were approved by the institutional review boards of the participating institutions. We received permission to use the data from the four original multicentre studies and the need for informed consent for the specific purpose of this study was waived.
mated the area under the ROC curve of our score within each original cohort. All analyses were performed using Stata version 8.0 (Stata Corporation, College Station, TX, USA).

**Results**

**Patient characteristics**
Overall, 6560 patients were retained in our analysis, including 4593 (70%) in the derivation and 1967 (30%) in the validation cohort (Figure 1). The characteristics of the two cohorts are compared in Tables 1 and 2.

**Outcomes measures**
During the 28-day follow-up, 378 patients were admitted to an ICU (5.6% and 6.0%, respectively in the derivation and validation cohort; Table 2). More than 80% of ICU admissions occurred within three days of ED presentation. Conversely, nearly 80% of the 262 deaths occurred after three days, whereas about 20% (53) of the deaths occurred within three days of presentation.

**Factors associated with ICU admission on days 1 to 3**

**Baseline characteristics associated with ICU admission on days 1 to 3**
Patients admitted to the ICU on days 1 to 3 were more likely to be elderly men with comorbidities, and to have more vital sign abnormalities (altered mental status, tachypnoea and hypotension), radiographic or laboratory abnormalities (hypoxaemia, hyponatraemia, acidosis, high blood urea nitrogen level, and pleural effusion or multilobar infiltrates; Tables 3 and 4).

**Independent risk factors**
In multivariable analysis, we identified 11 independent predictors of ICU admission on days 1 to 3, including male gender, age under 80 years and at least one comorbid condition; all...
other independent risk factors were physical or laboratory findings (Table 5).

### Discussion

In this study, we identified 11 baseline characteristics that were independently associated with ICU admission on days 1 to 3 in a broad range of patients presenting with CAP and no obvious reason for immediate ICU admission (i.e. not requiring immediate respiratory or circulatory support). These characteristics included male gender, age younger than 80 years, the risk of admission to the ICU on days 1 to 3 increased significantly from risk class I to risk class IV within each of the four original cohorts ($P < 0.001$ for each cohort). The area under the ROC curve of the score for predicting admission to an ICU on days 1 to 3 ranged from 0.76 (95% CI = 0.72 to 0.90) in the EDCAP cohort to 0.82 (95% CI = 0.85 to 0.90) in the Pneumocom-2 cohort.

The risk of admission to the ICU on days 1 to 3 increased significantly from risk class I to risk class IV within each of the four original cohorts ($P < 0.001$ for each cohort). The area under the ROC curve of the score for predicting admission to an ICU on days 1 to 3 ranged from 0.76 (95% CI = 0.72 to 0.90) in the EDCAP cohort to 0.82 (95% CI = 0.85 to 0.90) in the Pneumocom-2 cohort.

The REA-ICU score yielded a higher area under the ROC curve than the PSI (0.75, 95% CI = 0.73 to 0.78), CURB-65 (0.69, 95% CI = 0.66 to 0.72) and Espana Severe CAP (SCAP) (0.74, 95% CI = 0.71 to 0.76) for predicting ICU admission on days 1 to 3 for patients not requiring immediate circulatory or ventilatory support ($P < 0.001$ for all pairwise comparisons involving the REA-ICU score).

### Risk of admission to the ICU

The risk of admission to the ICU on days 1 to 3 increased significantly from risk class I to risk class IV within each of the four original cohorts ($P < 0.001$ for each cohort). The area under the ROC curve of the score for predicting admission to an ICU on days 1 to 3 ranged from 0.76 (95% CI = 0.72 to 0.90) in the EDCAP cohort to 0.82 (95% CI = 0.85 to 0.90) in the Pneumocom-2 cohort.

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comorbid condition of 1 or higher, tachypnoea, tachycardia, leukopenia or leukocytosis, multilobar infiltrates or pleural effusion, hypoxaemia, acidosis, hyperuraemia and hyponatraemia. From this set of variables, we derived a prediction rule, REA-ICU score, that demonstrated a consistent discriminatory power for predicting ICU admission occurring within three days of ED presentation for patients with CAP not requiring immediate ICU transfer.

The British Thoracic Society advocates using a set of only four variables (CURB-65) and suggests considering ICU referral when three or more criteria are present [13]. The ATS rule, modified in 2001 [16], appears to have a slightly better predicting accuracy than the CURB-65 or the PSI; however, it still results in a substantial proportion of patients misclassified with regard to ICU admission [17]. Moreover, the two major criteria of the ATS rule – requirements for mechanical ventilation and the occurrence of shock – are obvious reasons for ICU admission. Espana and colleagues derived the SCAP prediction rule that was shown to discriminate better than previous prediction rules between ED patients with and without CAP-related adverse medical outcomes, including 30-day mortality and ICU referral [12]. Narrowing the criteria for severe CAP needing ICU admission to the requirement for intensive respiratory or vasopressor support (IRVS), Charles and colleagues recently developed the SMART-COP, which demonstrated interesting characteristics to predict IRVS requirement during the whole hospital course of patients [18]. We took a different perspective and focused on patients not presenting to the ED with a need for IRVS, but subsequently transferred to the ICU within the first three days of admission; thus, our index might be especially useful for emergency physicians to assess the potential risk of ICU requirement within the next few days among those patients presenting with none of the ATS major severity criteria. As a result, the REA-ICU performed significantly better than existing prediction rules (PSI, CURB-65, PRISM).

### Table 2

| Characteristics                                      | Derivation sample (n = 4593) | Validation sample (n = 1967) | P value |
|------------------------------------------------------|------------------------------|-----------------------------|---------|
| Laboratory and x-ray findings                        |                              |                             |         |
| Arterial pH, median (IQR)                            | 7.45 (7.41 to 7.47)          | 7.44 (7.41 to 7.47)         | 0.59    |
| Arterial partial pressure of oxygen, median (IQR), mmHg | 63 (55 to 74)                | 64 (55 to 73)               | 0.62    |
| BUN, median (IQR), mEq/L                             | 6 (4 to 9)                   | 6 (4 to 9)                  | 0.81    |
| Sodium, median (IQR), mEq/L                          | 137 (134 to 139)             | 137 (134 to 139)            | 0.63    |
| Glucose, median (IQR), %                             | 7 (6 to 9)                   | 7 (6 to 9)                  | 0.97    |
| Multilobar infiltrates                               | 39 (35 to 42)                | 39 (36 to 42)               | 0.48    |
| WBC, median (IQR), G/L                               | 11.7 (8.5 to 15.8)           | 11.2 (8.1 to 15.3)          | 0.04    |
| Pleural effusion, n (%)                              | 503 (10.9)                   | 206 (10.5)                  | 0.57    |
| Pneumonia Severity Index, n (%)                      |                              |                             | 0.80    |
| Class I, n (%)                                       | 1259 (27.4)                  | 538 (27.3)                  |         |
| Class II, n (%)                                      | 1075 (23.4)                  | 479 (24.3)                  |         |
| Class III, n (%)                                     | 877 (19.1)                   | 372 (18.6)                  |         |
| Class IV, n (%)                                      | 1104 (24.0)                  | 451 (22.9)                  |         |
| Class V, n (%)                                       | 278 (6.0)                    | 127 (6.5)                   |         |
| Outcomes                                             |                              |                             |         |
| ICU admission ≤ 3 days, n (%) (n = 3350)              | 201 (4.4)                    | 102 (5.2)                   | 0.15    |
| 3-day mortality, n (%)                               | 41 (0.9)                     | 12 (0.6)                    | 0.24    |
| 28-day ICU admissions, n (%) (n = 2573)               | 259 (5.6)                    | 119 (6.0)                   | 0.51    |
| 28-day mortality, n (%)                              | 184 (4.0)                    | 78 (4.0)                    | 0.94    |

Missing values were assumed to be normal for arterial pH (n = 4247, 65%), arterial partial pressure of oxygen or oxygen saturation (n = 1029, 15%), BUN (n = 1685, 26%), sodium (n = 1565, 24%), glucose (n = 1637, 25%), haematocrit (n = 1205, 18%), WBC (n = 1185, 18%). BP = blood pressure; BUN = blood urea nitrogen; ICU = intensive care unit; IQR = interquartile range; WBC = white blood cell.
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Table 3

Association of patient demographic characteristics, comorbid conditions and baseline physical examination findings with intensive care unit admission within three days of presentation

| Characteristics                          | Derivation cohort | Validation cohort | P value | Derivation cohort | Validation cohort | P value* |
|------------------------------------------|-------------------|------------------|---------|-------------------|------------------|---------|
|                                          | Admission to ICU ≤ 3 days | Admission to ICU ≤ 3 days |         | No (4392) | Yes (201) | No (1865) | Yes (102) |
| Demographic factors                      |                   |                  |         |                   |                  |         |
| Male gender, %                           | 52.4              | 63.7             | 0.002   | 52.5             | 59.8             | 0.15    |
| Age, mean (SD) years                     | 59 (21)           | 67 (15)          | < 0.001 | 60 (21)          | 65 (16)          | 0.01    |
| Comorbid conditions, %                   |                   |                  |         |                   |                  |         |
| Cancer                                   | 5.0               | 5.5              | 0.75    | 5.8              | 11.8             | 0.01    |
| Cerebrovascular disease                  | 6.8               | 8.9              | 0.15    | 6.9              | 6.5              | 0.87    |
| Liver disease                            | 1.5               | 2.0              | 0.60    | 1.4              | 3.9              | 0.04    |
| Congestive heart failure                 | 11.2              | 25.9             | < 0.001 | 11.4             | 21.6             | 0.002   |
| Renal disease                            | 4.9               | 14.4             | < 0.001 | 5.4              | 10.8             | 0.02    |
| Coronary artery disease                  | 16.6              | 30.8             | < 0.001 | 15.9             | 20.6             | 0.21    |
| Chronic pulmonary disease                | 24.8              | 31.3             | 0.04    | 23.9             | 28.4             | 0.29    |
| Diabetes mellitus                        | 14.3              | 21.4             | 0.006   | 13.7             | 27.4             | < 0.001 |
| Physical examination findings, %         |                   |                  |         |                   |                  |         |
| Altered mental status                    | 5.5               | 15.9             | < 0.001 | 5.7              | 12.7             | 0.004   |
| Respiratory rate ≥ 30 breaths/minute     | 12.3              | 33.8             | < 0.001 | 11.5             | 35.3             | < 0.001 |
| Systolic BP < 90 mmHg                    | 1.5               | 5.0              | < 0.001 | 1.2              | 2.0              | 0.48    |
| Temperature < 35 or ≥ 40°C               | 5.6               | 9.4              | 0.02    | 5.8              | 12.7             | 0.005   |
| Pulse ≥ 125 beats/minute                 | 8.8               | 18.4             | < 0.001 | 7.5              | 23.5             | < 0.001 |
| Oxygen saturation, < 90%                 | 13.6              | 44.4             | < 0.001 | 14.0             | 46.4             | < 0.001 |

Admission to ICU ≤ 3 days refers to patients who were admitted to an ICU within 3 days of presentation at the emergency department. * P value refers to the variables associated with admission to ICU within 3 days of presentation.

BP = blood pressure; ICU = intensive care unit; SD = standard deviation.

Espana SCAP) in predicting ICU admission on days 1 to 3 of ED presentation in these patients.

Indeed, the criteria for inclusion in our analysis have several distinctive features from previous attempts at predicting CAP severity. First, contrasting with previous prediction rules, we focused on the more challenging subgroup of patients presenting with moderately severe CAP and no requirement for immediate ICU admission [11]; hence, we excluded patients with obvious respiratory or haemodynamic failure at presentation. Indeed, including such clinically apparent features in a prediction rule is likely to improve its operative characteristics, but is of limited value in assisting physicians in triaging patients [19,20].

Second, we focused on admission to ICU within three days of ED presentation, instead of including all 28-day outcomes. Pneumonia is the most common cause of severe sepsis, and severe CAP should be seized in the overall context of sepsis from pulmonary infection with organ dysfunction(s) potentially requiring intensive care [5,21]. Indeed, most sepsis-related organ failures in this setting occur early [3,22]. Accordingly, our findings in a large sample of patients presenting with CAP confirm that admission to ICU mostly occurred within the first three days of ED presentation. In addition, late ICU admissions may be associated with other factors than the severity of pneumonia itself (e.g. decompensated comorbidity or an intercurrent event), and not be influenced by its initial management [23-25]. Moreover, the REA-ICU score was based on data readily available at patient presentation to the ED and did not include results from ED monitoring, which would be less relevant to triaging patients in the ED setting [12,26]. Accordingly, we could not include laboratory tests that were not evenly collected across the four original studies (e.g. albuminaemia).
Third, we considered that adequate ICU admission should not be restricted to patients requiring IRVS [19]. Indeed, ICU care has been demonstrated to improve outcome in severely ill and unstable patients, and these patients require intensive monitoring and may potentially need immediate intervention [27]. Therefore, given the characteristics of the REA-ICU (Additional data file 2), we suggest that intensive care physicians be informed of those patients with the highest risk of three-day ICU admission. This could be achieved by requesting the advice of an intensivist for such patients, who would then help decide on the most appropriate site of care for providing them adequate management and close monitoring, possibly in the ICU or an intermediate-care unit as deemed appropriate.

Fourth, despite substantial differences across the four original cohorts in patient characteristics and outcomes (Tables 1 and 2) [6-9], the overall discriminatory power of the REA-ICU score in predicting ICU admission on days 1 to 3 was quite high across the four original cohorts, reflecting the robustness of this score [28].

Several potential limitations of our study must be acknowledged. First, there were slight methodological differences and exclusion criteria across the four cohorts analysed. However, the definitions used in EDCAP, Pneumocom-1 and Pneumocom-2 were all based on the Pneumonia PORT study. Second, our findings do not take into account processes of care or causative pathogens, which may have confounded the relation between risk class and patient outcomes. As these data were not collected in a standardised manner across the four studies, we could not adjust for these variables. Third, the REA-ICU score includes 11 variables, which might limit its applicability to clinical use. However, the 20-variable PSI has been successfully implemented in various settings, including routine practice [7,9,29-31]. Fourth, our findings are based solely on hospital admission data and patient monitoring data were not recorded during the initial hospital course, so we

| Characteristics                  | Derivation cohort | Validation cohort |
|----------------------------------|-------------------|-------------------|
|                                  | Admission to ICU  | $P$ value         | Admission to ICU  | $P$ value*     |
|                                  | $\leq$ 3 days     |                   | $\leq$ 3 days     |                   |
| No (4392)                        |                   |                   | No (1865)         |                   |
| Yes (201)                        |                   |                   | Yes (102)         |                   |
| Laboratory and x-ray findings, % |                   |                   |                   |                   |
| Arterial pH $< 7.35$             | 2.3               | $< 0.001$         | 2.6               | $< 0.001$        |
| BUN $\geq 10$ mmol/L             | 13.0              | $< 0.001$         | 12.9              | $< 0.001$        |
| Sodium $< 130$ mEq/L             | 3.9               | $< 0.001$         | 3.0               | $< 0.001$        |
| Glucose $\geq 14$ mmol/dL        | 4.8               | 0.001             | 5.1               | 0.02             |
| Haematocrit $< 30\%$             | 4.5               | $< 0.001$         | 4.7               | 0.002            |
| WBC $< 3$ or $\geq 20$ G/L       | 9.1               | $< 0.001$         | 8.4               | $< 0.001$        |
| PaO$_2$ $< 60$ mmHg              | 21.9              | $< 0.001$         | 18.9              | $< 0.001$        |
| Pleural effusion                 | 10.4              | $< 0.001$         | 10.1              | 0.01             |
| Multilobar infiltrates           | 22.0              | $< 0.001$         | 22.2              | $< 0.001$        |
| Pneumonia Severity Index, %      |                   |                   |                   |                   |
| Class I                          | 28.4              | $< 0.001$         | 28.6              | $< 0.001$        |
| Class II                         | 24.0              | 10.9              | 24.9              | 13.7             |
| Class III                        | 19.1              | 17.9              | 18.7              | 22.5             |
| Class IV                         | 23.0              | 46.8              | 22.2              | 35.3             |
| Class V                          | 5.4               | 19.4              | 5.5               | 23.5             |

Admission to ICU $\leq$ 3 days refers to patients who were admitted to an ICU within three days of presentation to the emergency department. $P$ value refers to the variables associated with admission to ICU within 3 days of presentation. BUN = blood urea nitrogen; ICU = intensive care unit; PaO$_2$ = arterial partial pressure of oxygen; WBC = white blood cell.
could not analyse the adequacy of secondary ICU admission (e.g. requirement for mechanical ventilation or vasopressor, or other reason for ICU admission). Fifth, all laboratory tests were performed at the discretion of the attending physicians and missing values were assumed to be normal. This strategy is widely used in the clinical application of prediction rules and reflects the methods used in the original derivation and validation of the PSI [15]. Indeed, patients with less severe illness were more likely to have missing values for laboratory findings. Finally, prediction scores often perform better in their derivation and internal validation cohorts than in external validation studies; therefore, external independent validation is required.

### Conclusions

In summary, using a large database combining four prospective cohorts of patients with CAP, we derived and validated the REA-ICU index to predict ICU referral within the first three days of hospital admission in patients without overt circulatory or respiratory failure at ED presentation. This index demonstrates valuable characteristics for stratifying the risk of admission to ICU on hospital days 1 to 3. Using this combination of

### Table 5

| Characteristics                              | \( \beta \) parameter | 95% CI (\( \beta \) parameter) | OR    | 95% CI (OR) | Points assigned |
|----------------------------------------------|------------------------|---------------------------------|-------|-------------|-----------------|
| Male                                         | 0.39                   | (0.08 to 0.70)                  | 1.47  | (1.08 to 2.01) | 1               |
| Comorbid condition \( \geq 1 \)              | 0.45                   | (0.11 to 0.78)                  | 1.57  | (1.12 to 2.19) | 1               |
| Respiratory rate \( \geq 30 \) breaths/minutes| 0.53                   | (0.18 to 0.88)                  | 1.70  | (1.20 to 2.41) | 1               |
| White blood cell count < 3 or \( \geq 20 \) G/L | 0.54                   | (0.14 to 0.94)                  | 1.71  | (1.15 to 2.55) | 1               |
| Heart rate \( \geq 125 \) beats/minute      | 0.55                   | (0.14 to 0.95)                  | 1.73  | (1.15 to 2.60) | 1               |
| Age \( < 80 \) years                        | 0.57                   | (0.18 to 0.95)                  | 1.76  | (1.19 to 2.59) | 1               |
| Multilobar infiltrates or pleural effusion   | 0.79                   | (0.48 to 1.09)                  | 2.19  | (1.62 to 2.97) | 2               |
| Oxygen saturation \( < 90\% \) or \( \text{PaO}_2 < 60 \) mmHg | 0.85                   | (0.53 to 1.17)                  | 2.35  | (1.71 to 3.23) | 2               |
| Arterial pH \( < 7.35 \)                     | 0.91                   | (0.38 to 1.44)                  | 2.49  | (1.47 to 4.22) | 2               |
| Blood urea nitrogen \( \geq 11 \) mmol/L    | 0.94                   | (0.61 to 1.28)                  | 2.56  | (1.84 to 3.58) | 2               |
| Sodium \( < 130 \) mEq/L                    | 1.06                   | (0.58 to 1.53)                  | 2.88  | (1.79 to 4.63) | 3               |

CI = confidence interval; OR = odds ratio; \( \text{PaO}_2 \) = arterial partial pressure of oxygen.

### Table 6

| Risk class | Score | Derivation population | Validation population |
|------------|-------|-----------------------|-----------------------|
|            | N     | ICU ≤ 3 days, % (95% CI) | Death ≤ 28 days, % (95% CI) | n  | ICU ≤ 3 days, % (95% CI) | Death ≤ 28 days, % (95% CI) |
| I          | ≤ 3   | 2510 | 1.1 (0.7 to 1.6) | 1.2 (0.8 to 1.8) | 1099 | 1.3 (0.7 to 2.1) | 1.9 (1.2 to 2.9) |
| II         | 4 to 6 | 1498 | 5.5 (4.4 to 6.8) | 6.0 (4.8 to 7.3) | 633 | 7.1 (5.2 to 9.4) | 4.4 (3.0 to 6.3) |
| III        | 7 to 8 | 419 | 11.0 (8.2 to 14.4) | 9.1 (6.5 to 12.2) | 164 | 12.2 (7.6 to 18.2) | 7.9 (4.2 to 13.2) |
| IV         | ≥ 9   | 166 | 27.1 (20.5 to 34.5) | 15.1 (10.0 to 21.4) | 71 | 32.4 (21.7 to 44.5) | 22.5 (13.5 to 34.0) |
| Total      |       | 4593 | 4.4 (6.0 to 7.4) | 4.0 (3.4 to 4.6) | 1967 | 5.2 (5.8 to 8.0) | 4.0 (3.1 to 4.9) |

ICU ≤ 3 days and death ≤ 28 days refer to patients who were admitted to an ICU within three days of presentation to the emergency department or who died within 28 days of presentation, respectively. Results are expressed as percentages of each outcome within each REA-ICU risk class. CI = confidence interval; ICU = intensive care unit.
variables might help ED physicians to more accurately assess the potential need for ICU admission in the challenging group of high-risk patients presenting with no obvious reason for ICU admission [5,32,33].

Key messages

- Among 6560 patients with CAP and no obvious indication for ICU admission at ED presentation, 303 (4.6%) were admitted to the ICU within the three following days.

- Eleven variables – male gender, older age, comorbid conditions, tachypnoea, tachycardia, multilobar infiltrate or pleural effusion, low or high white blood cell count, hypoxaemia, high blood urea nitrogen, acidosis, hyponatraemia – were independently associated with admission to ICU on days 1 to 3, and were used to derive the REA-ICU index.

- The REA-ICU index stratified ED patients with CAP and no obvious indication for ICU admission into four classes of risk for ICU admission on days 1 to 3, ranging from 0.7 to 31%. This index might help ED physicians and intensivists in the disposition decision.

Competing interests

MJF consults for the University of Pennsylvania and GeneSoft Pharmaceuticals Inc. He also received honoraria from Zynx Health Corporation, STA Healthcare Communications Inc., University of Alberta and Maine Medical Center. MJF gives expert testimony for Stephen Lynn Klein, Kellogg & Siegelman, Swanson, Martin, & Bell, William J. Burke, Chad McGowan, Chernett, Wasserman, Yarger and Pasternak, LLC. MJF received grants from Pfizer Inc. BR received grants from GlaxoSmithKline Inc. MJF also received royalties from Up-to-Date.

Authors' contributions

BR, JL, CBB made substantial contributions to conception and design. BR, JL, EC, AS, MG, NC, ER, FH, JH, MS, MJF and CBB made substantial contributions to acquisition of data. BR, JL, EC, AS, MG, MJF, FH, JH and CBB were involved in drafting the manuscript or revising it critically for important intellectual content. BR, JL, EC, AS, MG, NC, ER, FH, JH, MS, MJF and CBB gave their final approval of the version to be published. BR, EC, AS, MG, ER, JH, MS and MJF were involved in acquisition of funding and collection of data. BR, EC, AS, MG, MJF and CBB were involved in general supervision of the research group.

Additional files

The following Additional files are available online:

Additional file 1
Word file containing a table comparing study patient exclusion criteria across the four original study populations.
See http://www.biomedcentral.com/content/supplementary/cc7781-S1.doc

Additional file 2
Word file containing a table that describes the risk of early intensive care unit admission index characteristics.
See http://www.biomedcentral.com/content/supplementary/cc7781-S2.doc

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