IDSA/ATS minor criteria aid pre-intensive care unit resuscitation in severe community-acquired pneumonia

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ABSTRACT The effect of employing severity scores to identify severe community-acquired pneumonia (SCAP) cases for early aggressive resuscitation is unknown. Optimising pre-intensive care unit (ICU) care may improve outcomes in patients at risk of SCAP.

We conducted a before-and-after study of patients classified into control and intervention groups (January 2004 to December 2007 and January 2008 to December 2010, respectively). Our intervention was two-pronged, using the 2007 Infectious Diseases Society of America (IDSA)/American Thoracic Society (ATS) minor criteria to identify SCAP for aggressive emergency department resuscitation. Patients with SCAP, defined as those with three or more IDSA/ATS minor criteria, were targeted. Differences in mortality, triage and compliance with emergency department resuscitation were compared between the groups.

The hospital mortality rate was lower in the intervention *versus* the control group (5.7% *versus* 23.8%, $p<0.001$). On multivariate analysis, the intervention group was associated with lower mortality (OR 0.24, 95% CI 0.09–0.67). ICU admission rates decreased from 52.9% to 38.6% ($p=0.008$) and inappropriately delayed ICU admissions decreased from 32.0% to 14.8% ($p<0.001$). There was increased compliance with the aggressive resuscitation protocol after the intervention.

A combined intervention, using a pneumonia score to identify those at risk of SCAP early and an aggressive pre-ICU resuscitation protocol may reduce mortality and ICU admissions.

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Introduction

Severe community-acquired pneumonia (SCAP) is associated with a high mortality rate (23–50%) and can result in significant healthcare costs [1–3]. It is usually defined as community-acquired pneumonia (CAP) that requires intensive care unit (ICU) admission or mechanical ventilation/vasopressor support. However, ICU admission rates can vary between 3% and 39% in different centres [2], due to differences in local ICU admission criteria, subjective physician assessments and availability of ICU resources. In addition, mechanical ventilation or vasopressor support is not required in all cases. Moreover, there is a category of ''at-risk SCAP'', which may be under-recognised because patients may initially have subtle findings. Thus, the 2007 Infectious Disease Society of America (IDSA)/American Thoracic Society (ATS) pneumonia guidelines proposed a set of minor criteria to help identify this group (table 1) [4]. Fulfilment of three out of the nine minor criteria is defined as SCAP. Other pneumonia severity scores such as the SMART-COP (low systolic blood pressure, multilobar chest radiography involvement, low albumin level, high respiratory rate, tachycardia, confusion, poor oxygenation and low arterial pH), CURXO-80 (altered mental status, blood urea nitrogen >30 mg·dL^{-1}, respiratory rate >30 breaths·min^{-1}, systolic blood pressure <90 mmHg, arterial pH <7.30, multilobar/bilateral lung affectation, oxygen arterial pressure <54 mmHg or ratio of arterial oxygen tension to fraction of inspired oxygen <250 mmHg and age >80 years) and risk of early admission (REA)-ICU index were also created with the same intention [5–7]. They perform equally well in predicting subsequent need for ICU admission in validation studies [8–12], but none has been tested in clinical practice for its ability to reduce treatment delays and improve outcomes [13].

Delays in treatment and ICU admission for SCAP can lead to a disproportionate increase in mortality [14–17]. We showed in a validation study [9] that the 2007 IDSA/ATS minor criteria were accurate in predicting ICU admission in patients who did not initially require mechanical ventilation/vasopressor support. Subsequently, other well-conducted studies have reported similar results [10, 12, 18]. We also showed in another retrospective study that a delay in ICU admission was associated with less aggressive resuscitation in the emergency department [15], and that the presence of three or more minor criteria was associated with increased mortality. This suggested that admission decisions based on the minor criteria for SCAP might prevent treatment delay and reduce mortality [15, 17].

The impact of more aggressive treatment guided by pneumonia scores on clinically important outcomes in SCAP has not been evaluated previously. Hence, we conducted the present study to determine the effect of employing the IDSA/ATS 2007 minor criteria to guide emergency department triage and resuscitation, on all-cause hospital mortality, ICU admission rate and compliance with emergency department resuscitation.

Methods

Study design

This before-and-after study was divided into a control group (January 2004 to December 2007) and an intervention group (January 2008 to December 2010), and performed in our 1000-bed university-affiliated hospital. It was reviewed and approved by our research ethics committee (National Healthcare Group Domain Specific Review Board). Patient consent was not required as it was a retrospective observational study.

TABLE 1 Definition of severe community-acquired pneumonia according to the 2007 Infectious Disease Society of America/American Thoracic Society community-acquired pneumonia guidelines

Minor criteria: three or more of
Respiratory rate ⩾30 breaths·min^{-1}
P_{aO_2}/F_{IO_2} ratio ⩽250
Multilobar infiltrates
Confusion/disorientation
Uraemia (BUN level ⩾20 mg·dL^{-1})
Leukopenia (WBC count <4000 cells·mm^{-3})
Thrombocytopenia (platelet count <100 000 cells·mm^{-3})
Hypothermia (core temperature <36°C)
Hypotension requiring aggressive fluid resuscitation
Major criteria: one or more of
Invasive mechanical ventilation
Septic shock with the need for vasopressors

P_{aO_2}: arterial oxygen tension; F_{IO_2}: inspiratory oxygen fraction; BUN: blood urea nitrogen; WBC: white blood cell. Information from [4].

Target patient population and subgroups

We defined CAP as an acute pulmonary infection, presenting with an acute infiltrate on chest radiography and at least two of the following: fever ($\geqslant 38^{\circ}C$), hypothermia ($<36^{\circ}C$), rigors, new cough or change in colour of respiratory secretions, and chest discomfort or dyspnoea [3]. Patients who were hospitalised within 14 days of symptom onset, were immunocompromised or had tuberculosis were excluded.

Our target SCAP population was defined as CAP that fulfilled at least three IDSA/ATS minor criteria at emergency department presentation [4]. This group is at risk of deterioration, especially if the initial treatment or site of care was inappropriate. Patients with two or fewer minor criteria admitted to the ICU or the general ward, any IDSA/ATS major criteria and ''do not resuscitate'' (DNR) orders were excluded.

The target population was further divided into subgroups for analysis: direct ICU admissions (from emergency department to ICU), delayed ICU admissions (from emergency department to general ward to ICU) and general ward admissions (from emergency department to general ward).

Intervention

Before January 2008, the identification and management of SCAP was based on the clinical discretion of the individual physician. From January 2008, we implemented the intervention, a workflow that standardised the management of SCAP patients in the emergency department (fig. 1). The 2007 IDSA/ATS minor criteria were used to identify SCAP early and to guide a resuscitation bundle that was modified from the 2008 Surviving Sepsis Campaign guidelines [19]. The minor criteria did not dictate ICU admission as a default, but helped identify patients for aggressive treatment and consultations between the emergency department and ICU teams. Physicians were encouraged to exercise clinical judgement.

The entire resuscitation bundle had to be completed within 6 h of emergency department presentation. Empirical antibiotics were administered within the first 3 h and provided coverage for SCAP organisms specific to the local context, such as *Burkholderia pseudomallei* [20]. We did not routinely insert central venous catheters for all SCAP patients at the emergency department unless vasopressors were required. Hence, central venous pressure and central venous oxygen saturation targets were excluded in the default resuscitation bundle. Patients who deteriorated and required intubation/vasopressors while receiving aggressive resuscitation in the emergency department were excluded.

Indication for ICU admission

Admission to the ICU *versus* the general ward was based on the ICU physician's discretion. Briefly, patients with borderline physiological parameters after initial resuscitation, who might require intubation or vasopressors, were admitted to the ICU. Patients with three or more minor criteria who stabilised after initial resuscitation might be transferred to the general ward, with a nurse/patient ratio of 1/12 and managed by respiratory physicians. Patients with two or fewer minor criteria who were designated ''at risk'' by the emergency department physician received similar aggressive initial treatment and were then reviewed by the ICU physician. The decision for ICU admission was as described earlier, depending on the response to treatment. The medical ICU was a closed unit with a nurse/patient ratio of 1/2 and manned 24 h by intensivists.

Multidisciplinary collaboration

The intervention was designed and sustained by a multidisciplinary team, comprising representatives from both the respiratory–critical care medicine and emergency departments. The core group remained constant throughout the 7 years. The educational programme was supported by local champions in these departments, who trained nursing staff and physicians on the definitions and management of SCAP. All new staff underwent orientation tutorials on SCAP triage and sepsis guidelines. Posters and forms were designed and displayed prominently to facilitate compliance. Data on compliance were obtained by clinician nurses and reviewed every 2–4 weeks during business meetings and email discussions. Regular feedback was obtained to improve the workflow.

Data collection

All CAP admissions were prospectively recorded in an electronic database. Information gathered included demographics, comorbid illnesses, vital signs at the emergency department, initial laboratory and radiological findings, culture results, DNR orders, route of ICU admission and outcomes. Severity scores (Pneumonia Severity Index (PSI), 2007 IDSA/ATS minor criteria and Acute Physiology and Chronic Health Evaluation (APACHE) II) were calculated from these data. Data from the control group were collated from our earlier studies [9, 15] using medical record review by nurses, medical students and doctors. Similar methods were used for the intervention group.

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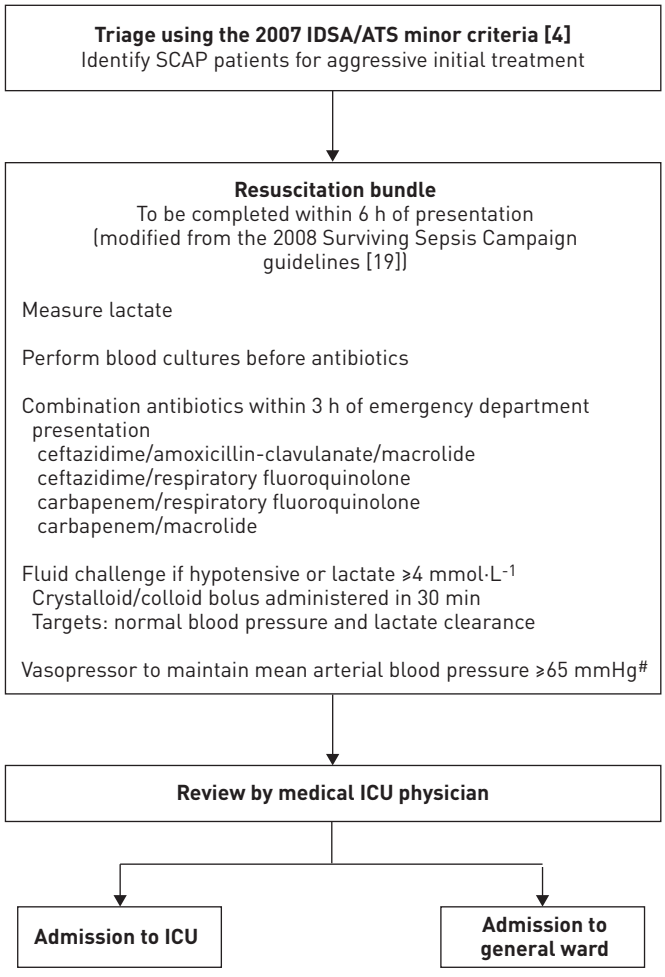

FIGURE 1 Workflow for managing severe community-acquired pneumonia (SCAP). IDSA: Infectious Diseases Society of America; ATS: American Thoracic Society; ICU: intensive care unit. #: patients who required vasopressors in the emergency department fulfilled major IDSA/ATS criteria for SCAP and were excluded from the main analysis.

Details of emergency department resuscitation were only collected for ICU admissions, because this information was unavailable for general ward admissions from our earlier studies. Antibiotic use was considered appropriate if the organism isolated was susceptible to the antibiotic used and the appropriate antibiotic combination was used in culture-negative cases.

Statistical analysis

We used the statistical software SPSS version 20 (SPSS Inc., Chicago, IL, USA). We compared categorical data using the Chi-squared or Fisher's exact test and continuous data using the Mann–Whitney U-test or paired t-test where appropriate. Statistical significance was assumed at $p<0.05$.

To determine the independent predictors for mortality, univariate analyses comparing survivors with nonsurvivors were first performed on the following variables: study group, disposition (direct ICU admission/delayed ICU admission/general ward admission), age, sex, nursing home residency, comorbid illnesses, vital signs, laboratory and radiological findings, antibiotic appropriateness, PSI and APACHE II. Variables with $p<0.10$ and not used to calculate PSI were then entered into a forward logistic regression model for multivariate analysis: study group, disposition, diabetes mellitus, platelet count, antibiotic appropriateness and PSI. To determine whether disposition affected mortality, we repeated the logistic regression analysis in both the direct and delayed ICU admission subgroups using the same variables, except disposition was excluded and APACHE II was included to adjust for severity on ICU admission.

Results

3173 CAP patients were admitted from 2004 to 2010. We targeted 348 SCAP patients with three or more minor criteria for main analysis (fig. 2).

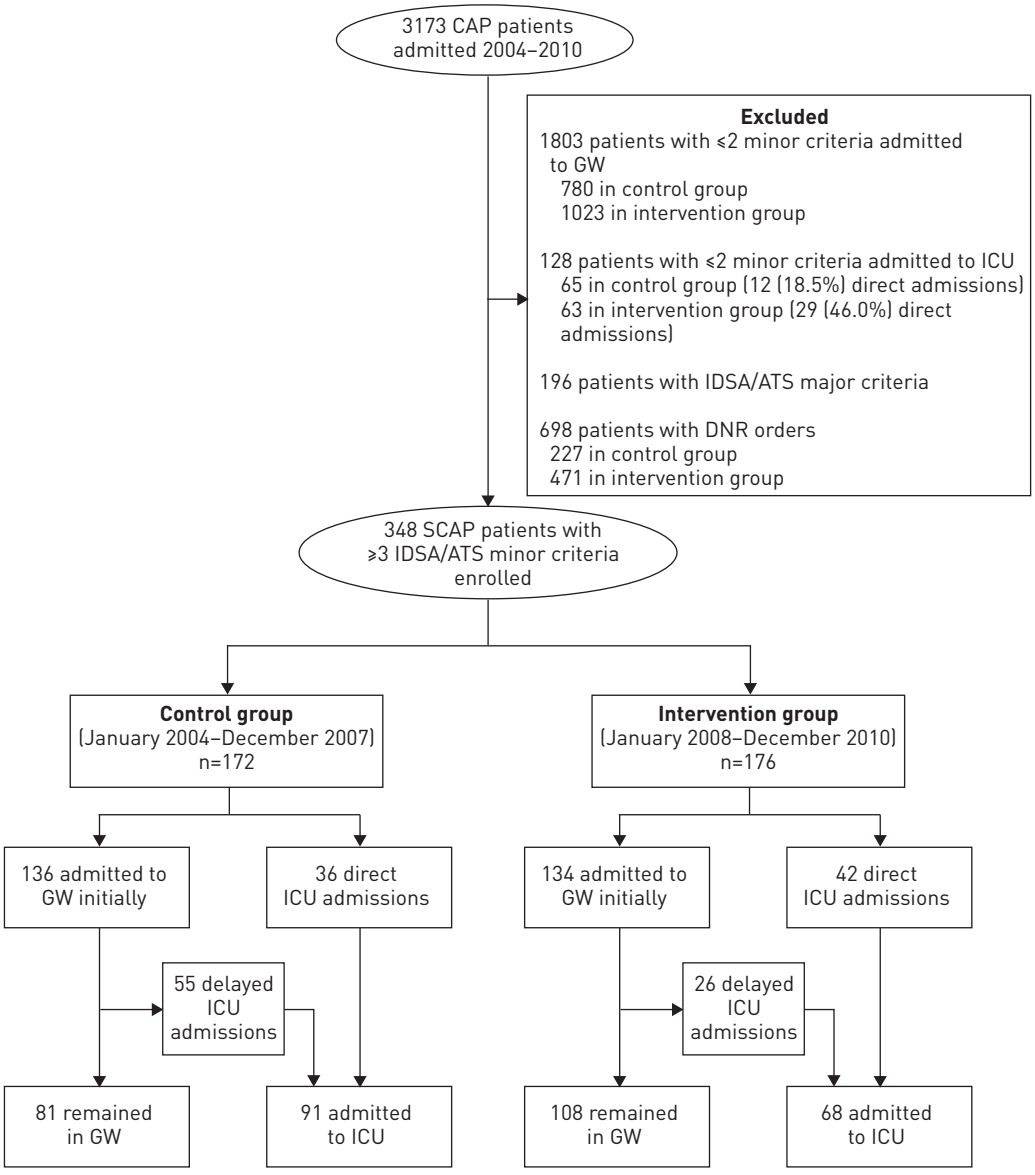

FIGURE 2 Differences in site of care and route of intensive care unit (ICU) admission between the study groups. CAP: community-acquired pneumonia; GW: general ward; IDSA: Infectious Disease Society of America; ATS: American Thoracic Society; DNR: do not resuscitate; SCAP: severe CAP.

Baseline characteristics

Differences in baseline characteristics are shown in table 2. The PSI was slightly lower in the intervention group. Patients in the control group had more comorbid conditions, such as heart failure and chronic renal disease; mean urea levels were higher in the intervention group. The proportion of patients meeting each IDSA/ATS minor criterion was similar between groups. Microbiological aetiologies are summarised in table 3; fewer patients were culture-positive in the intervention group.

Effect on mortality and other improvements

Hospital mortality was lower in the intervention group compared with the control group (table 4). Multivariate analysis showed that the intervention group was associated with lower mortality (table 5).

In the intervention group, fewer patients required mechanical ventilation and vasopressor support; hospital length of stay was also shorter (table 4).

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TABLE 2 Differences in baseline characteristics

	Control group	Intervention group	p-value
Subjects[#]	172	176	
Demographics			
Age years	68.2±16.8	67.3±18.6	0.626
Female	52 (30.2)	65 (36.9)	0.186
Nursing home resident	24 (14.0)	14 (8.0)	0.076
Comorbid illness			
Neoplastic disease	13 (7.6)	21 (11.9)	0.169
Liver disease	6 (3.5)	7 (4.0)	0.810
Heart failure	37 (21.5)	19 (10.8)	0.007
Cerebrovascular disease	51 (29.7)	46 (26.1)	0.465
Renal disease	34 (19.8)	18 (10.2)	0.013
Diabetes mellitus	67 (39.0)	52 (29.5)	0.064
Vital signs at emergency department			
Altered mental status	55 (32.0)	68 (38.6)	0.194
Heart rate beats·min^{-1}	107.0±23.1	103.4±22.6	0.142
Respiratory rate breaths·min^{-1}	23.1±5.6	24.0±7.4	0.203
Systolic blood pressure mmHg	119.4±29.8	119.2±29.8	0.968
Diastolic blood pressure mmHg	62.1±16.7	61.4±15.5	0.687
Temperature °C	37.6±1.2	37.2±3.1	0.073
P_{aO_2}/F_{IO_2} ratio %	175.5 (92.3–279.3)	192.4 (114.0–282.1)	0.224
S_{pO_2}/F_{IO_2} ratio %	271.0 (99.0–426.2)	281.1 (186.8–433.3)	0.217
Laboratory and radiological findings at the emergency department			
Blood urea nitrogen mmol·L^{-1}	5.8 (3.6–8.9)	9.0 (3.8–13.9)	<0.001
Sodium mmol·L^{-1}	135.2±6.4	133.9±7.0	0.705
Glucose mmol·L^{-1}	10.0±7.3	9.4±5.1	0.384
Haematocrit %	36.4±6.0	36.9±6.6	0.524
White blood cells per mm^3	12.5±6.6	12.5±7.3	0.977
Platelets per mm^3	266 (198–345)	226 (174–318)	0.003
Arterial pH	7.41 (7.31–7.46)	7.42 (7.37–7.47)	0.052
Pleural effusion	37 (21.5)	52 (29.5)	0.086
Multilobar infiltrates	128 (74.4)	145 (82.4)	0.071
Pneumonia Severity Index points	123.8±33.5	116.0±35.7	0.038
IDSA/ATS minor criteria score	3.45±0.651	3.54±0.834	0.251
Fulfilment of individual IDSA/ATS criterion for severe CAP			
Respiratory rate ⩾30 breaths·min^{-1}	30 (17.4)	32 (18.2)	0.857
P_{aO_2}/F_{IO_2} ratio ⩽250	109 (63.4)	103 (58.5)	0.354
Multilobar infiltrates	128 (74.4)	145 (82.4)	0.071
Confusion/disorientation	55 (32.0)	68 (38.6)	0.194
Uraemia[¶]	130 (75.6)	118 (67.0)	0.079
Leukopenia[+]	14 (8.1)	21 (11.9)	0.240
Thrombocytopenia [§]	14 (8.1)	13 (7.4)	0.793
Hypothermia[ƒ]	8 (4.7)	12 (6.8)	0.385
Hypotension requiring aggressive fluid resuscitation	105 (61.0)	111 (63.1)	0.698

Data are presented as n, mean±SD, n (%) or median (interquartile range), unless otherwise stated. P_{aO_2}: arterial oxygen tension; F_{IO_2}: inspiratory oxygen fraction; S_{pO_2}: arterial oxygen saturation measured by pulse oximetry; IDSA: Infectious Diseases Society of America; ATS: American Thoracic Society; CAP: community-acquired pneumonia.[#]: data were complete for all patients except P_{aO_2}/F_{IO_2} ratio (37.1% missing), arterial pH (34.5% missing) and glucose (19.8% missing); [¶]: blood urea nitrogen ⩾20 mg·dL^{-1}; [+]: white blood cell count <4000 cells per mm^3; [§]: <100 000 platelets per mm^3; [ƒ]: core temperature <36°C.

Effect on ICU admission rates, route of ICU admission and compliance with emergency department resuscitation

The ICU admission and delayed ICU admission rates were reduced in the intervention group (table 4). Of those who required ICU admission, direct ICU admission rates increased from 39.6% to 61.8% (p=0.006). Of those who were admitted to the general ward initially, the proportion of delayed ICU admissions dropped from 40.4% to 19.5% in the intervention group (p<0.001).

Improvements were achieved in the emergency department resuscitation performance measures in the intervention group; more lactate checks, more fluid boluses and more timely and appropriate antibiotics were given (table 6).

TABLE 3 Summary of microbiological aetiologies

	Control group	Intervention group
Subjects[#]	172	176
Acinetobacter baumanii	2 (1.16)	1 (0.57)
Burkholderia pseudomallei	1 (0.58)	1 (0.57)
Escherichia coli	0 (0)	2 (1.14)
Haemophilus influenzae	0 (0)	3 (1.70)
Klebsiella pneumoniae	16 (9.3)	9 (5.11)
Methicillin-resistant *Staphylococcus aureus*	1 (0.58)	3 (1.70)
Mycoplasma pneumoniae	2 (1.16)	0 (0)
Pseudomonas aeruginosa	11 (6.40)	1 (0.57)
Staphylococcus aureus	13 (7.56)	3 (1.70)
Streptococcus pneumoniae	12 (6.98)	5 (2.84)
Influenza A virus subtype H1N1 (2009)	NA	3 (1.70)
Others	16 (9.30)	9 (5.11)
Total culture-positive cases	74 (43.02)	40 (22.73)

Data are presented as n or n (%). NA: not applicable. [#]: 67.2% culture-negative or missing.

Subgroup analysis

Table 7 shows the outcomes between subgroups. In the direct ICU admission subgroup, fewer patients required vasopressor support in the intervention group. In the delayed ICU admission subgroup, the hospital mortality rate dropped by 43%; being in the intervention group was associated with lower mortality on multivariate analysis (table 5). In the general ward admissions subgroup, hospital length of stay dropped from 5 days to 4 days.

The baseline characteristics for the subgroups are presented in online supplementary table S1. There were some interesting findings in the delayed ICU admission subgroup. First, the patients in the control arm were more hypoxaemic, with a median (interquartile range) PaO_2/FIO_2 ratio of 153.8 (80.3–207.9), much lower than the minor criteria threshold of 250. Secondly, the PSI (at initial emergency department presentation) was similar in both the control and intervention arms, but the APACHE II score (on ICU day 1) was significantly lower in the latter group.

Effect on the entire CAP population

For the entire CAP population (table 8), we found a higher DNR rate in the intervention group. No differences were apparent between the two groups in hospital mortality, ICU admission rate, or proportion of patients with two or fewer minor criteria requiring ICU admission. After excluding patients with DNR orders, there was a statistical difference in mortality. In patients with two or fewer minor criteria requiring ICU admission, there was a higher rate of direct ICU admissions.

TABLE 4 Differences in clinical outcomes

	Control group	Intervention group	p-value
Subjects	172	176	
Hospital mortality	41 (23.8)	10 (5.7)	<0.001
Need for mechanical ventilation	75 (43.6)	47 (26.7)	0.001
Need for vasopressors	67 (39.0)	25 (14.2)	<0.001
Hospital length of stay days	7 (4–12)	6 (3–9)	0.013
ICU admission required	91 (52.9)	68 (38.6)	0.008
Disposition			
Direct ICU admission[#]	36 (20.9)	42 (23.9)	0.523
Delayed ICU admission[¶]	55 (32.0)	26 (14.8)	<0.001
General ward admission[+]	81 (47.1)	108 (61.4)	0.001
ICU length of stay days	4 (2–8)	4 (2–8)	0.659

Data are presented as n, n (%) or median (interquartile range), unless otherwise stated. ICU: intensive care unit. [#]: from emergency department to ICU; [¶]: from emergency department to general ward to ICU; [+]: from emergency department to general ward.

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TABLE 5 Variables associated with hospital mortality on multivariate analysis

	Variables associated with mortality	OR (95% CI)	p-value
All patients with three or more minor criteria	Intervention group	0.24 (0.09–0.67)[#]	0.006
Subgroup analysis			
Direct ICU admissions	APACHE II (per point)	1.16 (1.01–1.27)[¶]	0.031
Delayed ICU admissions	Intervention group	0.14 (0.03–0.69)[¶]	0.016

ICU: intensive care unit; APACHE: Acute Physiology and Chronic Health Evaluation. [#]: variables significantly associated with hospital mortality and included in the logistic regression model were study group, disposition (direct ICU admission/delayed ICU admission/general ward admission), diabetes mellitus, platelet count, antibiotic appropriateness and Pneumonia Severity Index; [¶]: disposition was excluded and APACHE II included in the model.

Overall data on all SCAP patients, defined as those with 1) three or more minor criteria, 2) one or more major criteria, and 3) two or fewer minor criteria, admitted to the ICU are summarised in online supplementary tables S2 and S3. For the entire SCAP cohort, there was a reduction in hospital mortality, need for vasopressors, hospital length of stay and ICU length of stay in the intervention group.

Discussion

Using the 2007 IDSA/ATS minor criteria to identify at-risk SCAP patients for aggressive initial emergency department resuscitation was associated with a reduction in hospital mortality, fewer ICU admissions and shorter length of stay. This may be related to better recognition (fewer delayed ICU admissions) and compliance with the resuscitation protocol. We found no evidence that the intervention harmed patients outside the study group: there were no differences in mortality for the entire CAP cohort and the proportion of ''milder'' SCAP cases (two or fewer minor criteria requiring ICU admission) were similar. The higher DNR rate in the intervention group may have led to fewer futile ICU admissions and partly, thus, to the mortality reduction. The intervention might allow the emergency department–ICU team to pick up cases in which aggressive care may be inappropriate. We enrolled SCAP patients with three or more IDSA/ATS minor criteria because we wanted to determine whether their excess risk might be mitigated by early aggressive treatment. Targeting this at-risk group specifically may have contributed to the mortality reduction, as early intervention benefited them the most.

Aggressive pre-ICU treatment may lead to better outcomes. Recently, a multicentre observational study by MILLER *et al.* [21] reported that after implementing a resuscitation bundle, hospital mortality for severe sepsis and septic shock declined from 21.2% to 8.7% over 7 years. Better compliance to resuscitation bundles reduced the subsequent need for other organ support. Similarly, we report a decline in hospital mortality from 23.8% to 5.7% over the same timeframe. Other improvements suggest that our intervention was effective. First, ICU admission rates dropped from 52.9% to 38.6%, and this may have been due to better treatment and prevention of multiorgan dysfunction necessitating ICU care. Secondly, in the delayed ICU admission subgroup, despite both study arms having similar disease severity at emergency department presentation (similar PSI), by the time of ICU admission, the intervention group was notably less sick (lower APACHE II score), implying that the intervention may have prevented subsequent deterioration. As a result, this subgroup experienced the largest absolute mortality risk reduction of 43%; fewer patients required mechanical ventilation and vasopressors. Thirdly, those who were successfully treated in the general ward similarly benefited from a shorter hospital length of stay. Thus it is not delayed ICU admission [14–16] but delayed treatment that may contribute to additional mortality in SCAP. Better recognition and emergent management of borderline SCAP patients may reduce mortality and the need for ICU care [22].

Our intervention comprised two components to minimise treatment delays: 1) early identification of at-risk SCAP patients using the IDSA/ATS minor criteria; and 2) a resuscitation protocol. Effectively, this linked recommendations from both pneumonia [3, 4] and sepsis guidelines [19]. The minor criteria score was chosen as it had been widely validated for SCAP and is easy to use. We showed that this score might improve triage accuracy in clinical practice because it reduced delayed ICU admission rates. However, contrary to the IDSA/ATS recommendation [4], we did not admit all cases having three or more minor criteria into the ICU. LIAPIKOU *et al.* [18], in their validation study, showed that ICU admission based on the IDSA/ATS minor criteria alone would require further investigation. This might also increase the number of inappropriate ICU admissions, as 50% of patients with three or more minor criteria may not require ICU admission [9]. Interestingly, we found that by using the minor criteria to guide aggressive treatment and not to determine ICU admission, we managed to reduce ICU admissions. Another concern was that SCAP patients with two or fewer minor criteria could be deprived of appropriate treatment, since its sensitivity

TABLE 6 Differences in compliance to emergency department resuscitation performance measures for intensive care unit admissions

Resuscitation component	Control group	Intervention group	p-value
Subjects	91	68	
Lactate checked in emergency department	55 (60.4)	54 (79.4)	0.011
Blood culture performed in emergency department[#]	69 (97.2)	65 (95.6)	0.614
Fluid bolus given	17 (23.9)	33 (49.3)	<0.001
Fluid bolus not required[¶,+]	16 (23.9)	29 (43.3)	<0.001
Antibiotics given in emergency department	37 (84.1)[§]	66 (100)[f]	0.001
Organisms susceptible to emergency department antibiotics	35 (79.5)[§]	62 (95.4)[##]	<0.001

Data are presented as n or n (%), unless otherwise stated. [#]: data missing for 12.6%; [¶]: data missing for 13.2%; [+]: when patient was not hypotensive and lactate was >4 mmol·L^{-1}; [§]: data missing for 51.6%; [f]: data missing for 2.9%; [##]: data missing for 4.4%.

was only 57% (95% CI 46–68%) in a systematic review by MARTI *et al.* [8]. However, the proportion of patients with two or fewer minor criteria who required ICU admission did not drop. Instead, there was an increase in direct ICU admissions, similar to those with three or more minor criteria. Rather than searching for the "ideal score" to guide ICU admission, we should focus on how to use SCAP severity scores effectively to identify at-risk SCAP patients for timely management.

The second component of the intervention was a resuscitation bundle initiated in the pre-ICU setting. Currently, pneumonia guidelines do not emphasise the importance of achieving time-sensitive resuscitation targets in SCAP, although sepsis studies [21, 23, 24] have consistently demonstrated this to be effective in reducing mortality. Conflicting evidence also exists regarding the usefulness of early antibiotics for SCAP [1, 25]. Logically, to achieve outcome improvements, identifying SCAP patients early would not suffice; thus, the pragmatic incorporation of a resuscitation bundle might have improved the outcomes significantly.

The successful implementation of the intervention depended on a close-knit emergency department–medical ICU collaboration. The workflow was facilitated by the same core team over the entire 7 years. Thus we managed to ensure sustainability, one of the challenges encountered in many sepsis studies [23, 26]. We demonstrated that an interdisciplinary collaboration can facilitate initiation of timely emergent treatment in the pre-ICU setting [22, 27] and lead to an improvement in clinically important outcomes over time.

This study suffers from many important limitations. The "true" mortality reduction is probably lower. First, the intervention group may comprise "milder cases", as the PSI score and the incidence of culture-positive

TABLE 7 Differences in subgroup outcomes

	Control group	Intervention group	p-value
Direct ICU admissions	36	42	
Hospital mortality	11 (30.6)	7 (16.7)	0.147
Need for mechanical ventilation	25 (69.4)	30 (71.4)	0.848
Need for vasopressors	26 (72.2)	17 (40.5)	0.005
Hospital length of stay days	9 (3.3–16.8)	8 (6–16)	0.595
ICU length of stay days	3 (2–6.5)	4.5 (2–8)	0.524
Delayed ICU admissions	55	26	
Hospital mortality	30 (54.5)	3 (11.5)	<0.001
Need for mechanical ventilation	50 (90.9)	17 (65.4)	0.005
Need for vasopressors	41 (74.5)	6 (23.1)	<0.001
Hospital length of stay days	11 (6–19)	10.5 (6–17.3)	0.584
ICU length of stay days	5 (4–9)	4 (3–8)	0.346
General ward admissions	81	108	
Hospital mortality	0 (0)	0 (0)	NA
Need for mechanical ventilation	0 (0)	0 (0)	NA
Need for vasopressors	0 (0)	2 (1.9)	0.218
Hospital length of stay days	5 (3–8)	4 (3–6)	0.024

Data are presented as n, n (%) or median (interquartile range), unless otherwise stated. ICU: intensive care unit; NA: not applicable.

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TABLE 8 Effect of on the entire community-acquired pneumonia population

Outcome	Control group	Intervention group	p-value
Subjects	1310	1863	
DNR rates	227 (17.3)	471 (25.3)	<0.001
Hospital mortality	204 (15.6)	278 (14.9)	0.62
After excluding DNR cases[#]	82 (7.6)	73 (5.2)	0.018
Overall ICU admission rates	214 (16.3)	261 (14.0)	0.071
After excluding DNR cases[#]	214 (19.8)	261 (18.8)	0.527
SCAP with two or fewer minor criteria admitted to ICU	65 (7.7)	63 (5.8)	0.097
Direct ICU admission[¶]	12 (18.5)	29 (46.0)	0.001

Data are presented as n, or n (%), unless otherwise stated. DNR: do not resuscitate; ICU: intensive care unit; SCAP: severe community-acquired pneumonia. [#]: n=1083 in control group and n=1392 in intervention group; [¶]: reported as proportion of cases with two or fewer minor criteria admitted to ICU.

cases were lower. However, the lower PSI score may be related to the lower comorbid burden in this group, as the mean IDSA/ATS scores in the two groups were similar. The significant reduction in mortality cannot be fully explained by the mild difference in PSI scores, which was apparent even after including PSI in the multivariate analysis. In addition, the relationship between culture positivity and disease severity is controversial [28]. Secondly, the mortality reduction may be spuriously lowered by bias and confounders that cannot be adjusted fully by statistical tools. Nonetheless, the mortality reduction signal is strong, the multidisciplinary team had remained constant, and information bias was limited using the same definitions and auditing process throughout the study. Thus, we felt that the improvement is less explained by minor differences in microbiological aetiologies, staff changeover and the introduction of new antibiotics and equipment. Thirdly, due to the study design, we could not assess whether the reduction of hospital mortality was related to early identification of at-risk SCAP cases, an aggressive resuscitation protocol or both. Fourthly, we did not compare data for compliance with emergency department resuscitation for general ward admissions because we did not collect this information in our previous studies [9, 15], which made up the control group. Lastly, the study period may be considered long. However, the study period is similar that used by MILLER *et al.* [21]; a shorter study period may not yield sufficient numbers to demonstrate statistical significance. SCAP is also a complex problem and the sustained improvement in outcomes supports the clinical feasibility of our intervention.

In conclusion, the main strength of this study is its novel yet pragmatic approach of a combined intervention using the IDSA/ATS minor criteria to identify at-risk SCAP patients for timely emergent treatment with a resuscitation protocol. Despite the methodological limitations, we believe that the intervention may improve outcomes. More multidisciplinary collaboration and prospective trials are needed to critically evaluate this intervention in the pre-ICU setting.

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