Original Article

Does the Number of Vacant Beds in General Wards Affect the Time to ICU Admission of Medical Patients from the Emergency Department?: A Prospective Observational Study

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Background: The time to intensive care unit (ICU) admission of new critically-ill patients presenting at the emergency department (ED) is affected by the ICU scarcity. The number of vacant beds in general wards could affect the ICU admission via the mechanism of outflow limitation.

Objective: The present study aimed to find whether the bed vacancy in general wards affected the time to ICU admission of new medical patients from the ED. This could suggest whether an expansion of the beds in general wards would hasten ICU admission processes.

Materials and Methods: The present study was a prospective, observational study. The medical patients presenting at the ED with indication for ICU admission were consecutively enrolled. The primary outcome was the correlation between the time to ICU and the number of available bed in general wards at admission time. When the ICU bed was immediately available, the correlation between the time to ICU and the number of vacant ICU beds was also analyzed. The clinical outcomes and other potential factors associated with the time to ICU were collected.

Results: Two hundred fifty-two patients were included. The time to ICU did not correlate with the bed vacancy in general wards but well correlated with the number of immediately available ICU bed. It was also independently associated with the patients' Sequential Organ Failure Assessment (SOFA) score, arterial pH, and the need to wait for ICU vacancy. Longer time to ICU and higher SOFA score were independently associated with higher hospital mortality.

Conclusion: The number of available beds in general wards did not correlate with the time to ICU admission of new patients. The ICU admission time seems to link with the bed management strategies and case triaging. With limited ICU beds, triaging patients by severity and sparing an ICU bed at all times could possibly improve the patients' outcomes.

Keywords: Overcrowded, Time to admission, ICU, Limitation, SOFA

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Overcrowding of the intensive care unit (ICU) is a global issue(1-3). When critically ill patients arrive at the emergency department (ED), they often have to board in the emergency room due to unavailable ICU bed(4,5). The ICU admission delay has been shown to be associated with higher ICU mortality(6-9), in-hospital mortality(6,9-12), and hospital length of stay (LOS)(8,9). One report demonstrated that every hour of ICU admission delay may increase the risk of death by 1.5%(7). One major factor that contributes to ICU admission delay is the lack of available ICU bed(13-15). While expanding the number of ICU beds seems to

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be a direct solution, it is not always possible. The cost of running ICUs can be as high as 15% to 20% of the hospital budgets[1,16] and every additional ICU bed would mean an extra expenditure.

The lack of ICU bed can also result from the ICU outflow limitation[14,15,17]. This is the situation when there is a limit number of vacant beds in general wards to accommodate the already-improved patients moving out from the ICU[14,15]. In the authors' hospital, the bed demand always exceeds the supply as seen in internal surveys done in 2010 and 2011 where the average demand to supply ratio was 2.8 to 3.4. Furthermore, the median time from the diagnosis of sepsis to the ICU admission was considerably long, which was 6.7 hours in 2012[18]. The patients who cannot be admitted had to receive the treatments while boarding in the ED and sometimes admitted to the general wards or even discharged home if there were satisfying clinical improvements.

The present study aimed to confirm if the bed vacancy of the general medical wards correlated with the time to ICU admission of the critical medical patients presenting at the ED. The authors hypothesized that when there are fewer available beds, the time to ICU admission would be longer and probably affect the outcome of the critical patients. If the hypothesis was true, some future strategies to increase the number of available beds in general wards (e.g., an expansion of the units, a policy to "borrow" the bed quota from other departments) might be able to hasten the time to ICU admission of the new critical patients.

Materials and Methods

Study design

The present study was a prospective, observational study performed between July and December 2014 at Ramathibodi Hospital, a tertiary care and university hospital in Bangkok, Thailand. The study was approved by the Ethics Committee of Ramathibodi Hospital, Mahidol University (approval No. MURA2014/474). Written informed-consent process had been performed, and the study was undertaken in compliance with the Helsinki Declaration.

Settings and population

The department of medicine can maximally hold 98 general in-patients in four medical wards with an additional 10 to 15 shared beds in the common observe wards. There are 26 beds in the medical ICU and the intermediate ward to accommodate critical patients (collectively called "ICU" in the present study). For ICU admission, the pre-defined criteria have been routinely used, i.e., requirement of endotracheal tube, need of inotropic or vasopressor drugs, hemodynamic instability, hypertensive emergency, or other conditions requiring close monitoring care.

A team of medical residents managed the admission of all medical patients, either the appointed elective cases, or those arrived at the ED. The out-patient cases whose conditions required hospital admission were also sent to the ED to be triaged and considered for admission. The same team managed the admission of critical cases who met the ICU criteria, which are the new patients from the ED and the already admitted patients in hospital wards who deteriorated, and the discharge or the step-down transfer of critical patients from the ICU. A patient would be considered ready for ICU discharge if the initial condition(s) fulfilling the ICU admission criteria had been resolved and judged to be stable enough by the attending clinicians. The critical patients awaiting ICU admission and boarding in the ED were looked after by another team of emergency medicine and medical residents. The ED team could temporarily take care the patients who were on mechanical ventilation (MV) or vasopressors, but there were no physicians and nurses specialized in critical care on duty at the site. There was also no protocol for managing patients on MV or vasopressors, and the sepsis protocol had not been developed at the time the present study took place. The two teams communicated with each other to update the situation and the priorities of patients in the admission queue.

The target population of the present study were all new medical patients presenting at the ED and required admission to the ICU. The inclusion criteria were older than 15 years, met with pre-defined criteria for ICU, and were admitted into the medical ICU. The exclusion criteria were surgical patients, patients with do-not-attempt-resuscitation order, and the patients appointed for an elective admission. The authors also excluded the patients admitted to the cardiac care unit due to the presence of a specialized fast-track system for cardiac conditions.

Protocol and data collection

The authors collected the medical data directly from the chart and the hospital medical informatics system, including demographic data, arrival time (ED and ICU), laboratory results, the primary diagnosis and indication for ICU, and the hospital outcomes.

Since the hospital computer system was not capable of performing admission management in real-time, the surveys for bed demand and supply were manually carried out by the admission team and updated twice daily (at 8.00 a.m., the start of morning shift, and at 4.00 p.m., the start of afternoon shift). The bed vacancy (supply of general beds) included all the vacant beds in the wards and the number of cases expecting discharge within that day. The bed demand was the sum of the number of cases with elective appointment, the patients boarding in the ED, and the patients in the ICU awaiting stepping-down transfer. The most recent data were used as a surrogate for the demand or supply at the time a new patient required ICU admission.

Primary and secondary outcome

The primary outcome was the correlation between the bed vacancy in general wards and the time to ICU of patients requiring ICU in that period. The time to ICU was defined as the duration from the patients' first presentation at the ED to their arrival at the ICU. The authors also analyzed the same correlation in a specific situation when there was no ICU bed available at the beginning of the shift, forcing any new admission to rely mainly on the step-down transfer of existing patients (a "bed-shuffle" process).

The secondary outcomes were the associations between the other factors and the time to ICU. These included both the administrative factors, which are the bed demand to supply ratio, the number of patients boarding in the ED, and the need for a bed-shuffle; and the patients' severity factors which are the Sequential Organ Failure Assessment (SOFA) score at the ED, MV use, hypotension, vasopressor use, septic shock, lactate of more than 2 mmol/L, and arterial pH. In the situation with one or more ICU beds available at the beginning of the shift, a correlation between the time to ICU and the number of vacant ICU beds was analyzed. The authors also explored the association between the time to ICU and the clinical outcomes, which are the in-hospital mortality and the LOS; and the other factors associated with the hospital mortality.

Statistical analysis

This was the first study that tried to demonstrate the correlation between the bed vacancy and the time to ICU thus, no previous data was available for the sample size calculation. Instead, the authors used a time-frame of six months to consecutively enroll the cases into the present study.

Spearman's rank correlation was used to analyze the association between any two continuous parameters with non-parametric distributions, where Mann-Whitney U test was used to detect the outcome differences between each pair of categorical factors. For mortality outcome, Mann-Whitney U test or chi-square was used to test its association with independent parameters. Factors associated with the time to ICU admission and hospital mortality ($p<0.10$) were entered into the forward-stepwise linear regression and the binary logistic regression analyses, respectively. All analyses were performed using PASW Statistics software, version 18.0 (SPSS Inc., Chicago, Ill, USA) with two-tails for all tests. A p-value less than 0.05 was considered to be statistically significant.

Results

Demographic data

During the study period of 183 days, there were 440 ICU admissions, where 266 (60%) were new admissions from the ED. The data were available for analyses in 252 patients (95%). Demographic data is shown in Table 1.

The most common primary provisional diagnosis was acute respiratory failure (34.5%), followed by septic shock (29%). Regarding the main indication for ICU admission, the most common was the need of MV, followed by the need of inotropic or vasopressor drugs.

Hospital courses and outcomes

The median time to ICU admission was 8.63 hours (Table 2). The hospital mortality was 27.8%. The most common cause of death was acute respiratory failure (34.8%), followed by septic shock (29%) and upper gastro-intestinal tract bleeding (11.6%).

Bed supply, demand, and ICU occupancy

The mean number of bed vacancy (available beds in general wards) was 9.5±4.5 beds per shift. The total bed demand was 39.6±7.8 beds per shift. The medical cases boarding in the ED was 30.7±5.9 cases per shift. The median ratio of bed demand to supply was 4.42 (IQR 3.29 to 6.26).

The median number of available ICU beds was 0 (0 to 0.5) bed per shift. On average, 96.7% of the ICUs capacity were occupied. One-fifth of the occupants were patients who had improved conditions awaiting discharge to the general wards (Figure 1).

Factors associated with the time to ICU

The analysis of primary outcome found no significant correlation between the bed vacancy and the time to ICU (Figure 2). No significant correlation

Table 1. Demographic data of the patients (n=252)

Parameters	n (%)
Age (year); mean±SD	63.6±16.87
Sex: female	118 (46.8)
Vital signs; mean±SD	
Body temperature (°C)	37.0±3.5
Heart rate (bpm)	106.1±28.9
Respiratory rate (/minute)	25.4±7.1
Systolic BP (mmHg)	129.4±40.9
Diastolic BP (mmHg)	71.6±22.5
Mean BP (mmHg)	91±28.3
Glasgow Coma Score; median (IQR)	15 (11 to 15)
Primary provisional diagnosis	
Acute respiratory failure	87 (34.5)
Septic shock	73 (29.0)
Alteration of consciousness	22 (8.7)
DKA/HHS	18 (7.1)
Severe acidosis	10 (4.0)
Hypertensive emergency	9 (3.6)
Acute renal failure	3 (1.2)
Other*	30 (11.9)
Main indication for ICU admission	
ETT/mechanical ventilator	136 (54.0)
Use of inotropic/vasopressor drug	66 (26.2)
Need close monitoring	23 (9.1)
Metabolic disturbance (DKA/HHS)	17 (6.7)
Hypertensive crisis	6 (2.4)
Requirement of hemodialysis	4 (1.6)
Other	2 (0.8)
SOFA score; median (IQR)**	5 (3 to 8)
Serum lactate (mmol/L); median (IQR)***	2.8 (1.5 to 5.4)
Start of vasopressor at the ED	84 (33.3)

SD=standard deviation; IQR=interquartile range; BP=blood pressure; DKA=diabetic ketoacidosis; HHS=hyperosmolar hyperglycemic state; ICU=intensive care unit; ETT=endotracheal tube; SOFA=Sequential Organ Failure Assessment; ED=emergency department

* Including: sepsis patients without shock state but required close observation, cases with anaphylaxis and upper gastro-intestinal bleeding, ** Data available in 211 cases, *** Data available in 225 cases

Table 2. Hospital courses and outcomes

	Median (IQR)
Time to ICU admission (hour)	8.63 (4.95 to 20.09)
ICU LOS (day)	6 (3 to 11.75)
Hospital LOS (day)	12 (7 to 21)
Hospital mortality; n (%)	70 (27.8)

IQR=interquartile range; ICU=intensive care unit; LOS=length of stay

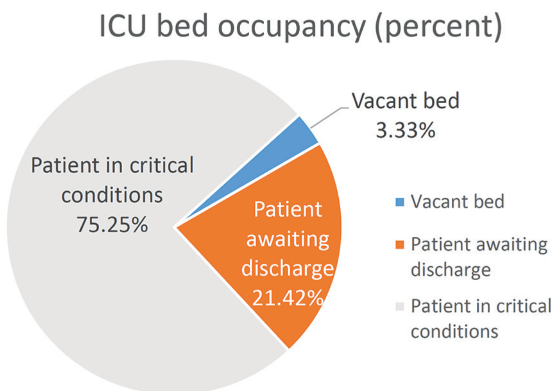

Figure 1. An overview of ICU bed occupancy, averaged from the twice daily data of the 2 ICUs over 183 days during the study period. The total numbers of the beds in the 2 ICUs were 26 beds.

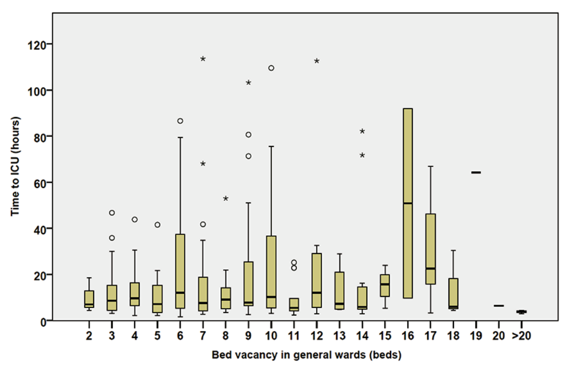

Figure 2. A box plot depicting the primary outcome. There was no significant correlation between the time to ICU and the bed vacancy (Spearman's rho 0.028, p=0.655).

between the bed vacancy and the time to ICU was found, even when the authors analyzed only the situation when there was no ICU bed available at the beginning of the shift (Spearman's rho 0.041, p=0.599).

When one or more ICU beds were immediately available at the beginning of the shift, the authors found a correlation between the time to ICU and the number of vacant ICU beds. In this situation, more vacant ICU beds correlated with less time to the ICU of the new patients (Figure 3).

Further analyses found that factors associated with the time to ICU were the SOFA score at the ED (p=0.08), hypotension (p=0.012), hyperlactatemia (p=0.065), arterial pH (p=0.004), and the need for a bed-shuffle (p=0.01). The factors with p<0.10 were

Table 3. Factors independently associated with the time to ICU (multivariate analysis)

Factors	Coefficient (B)	SE	95% CI for coefficient	Beta	p-value
SOFA score	–1.11	0.42	–1.93 to –0.29	–0.18	0.008
Arterial pH	23.80	9.04	5.99 to 41.61	0.18	0.009
The need to wait for ICU discharge	7.27	3.67	0.05 to 14.50	0.14	0.048

SE=standard error; CI=confidence interval; SOFA=Sequential Organ Failure Assessment; ICU=intensive care unit

Table 4. Factors independently associated with hospital mortality (multivariate analysis)

Variable	Survivors (n=182) Median (IQR)	Non-survivors (n=70) Median (IQR)	Coefficient (B)	SE	Adjusted OR (95% CI)	p-value
Time to ICU (hour)	7.58 (4.93 to 18.25)	10.00 (5.69 to 31.73)	0.02	0.01	1.02 (1.01 to 1.04)	0.002
SOFA score	5 (3 to 8)	6 (4 to 9)	0.12	0.04	1.12 (1.03 to 1.22)	0.009

SE=standard error; OR=odds ratio; CI=confidence interval; SOFA=Sequential Organ Failure Assessment; ICU=intensive care unit

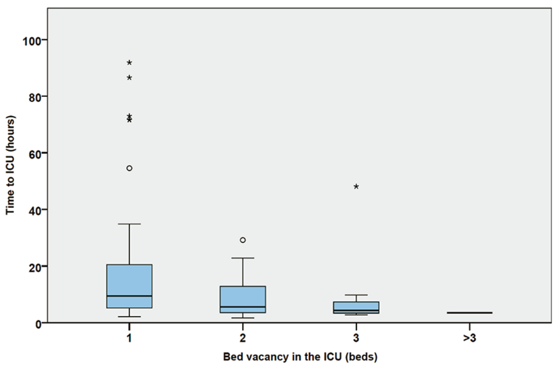

Figure 3. A box plot showing the correlation between the time to ICU and the number of vacant bed in the ICU at the beginning of the shift (when one or more ICU beds were immediately available). The Spearman's rho was –0.037, p=0.004.

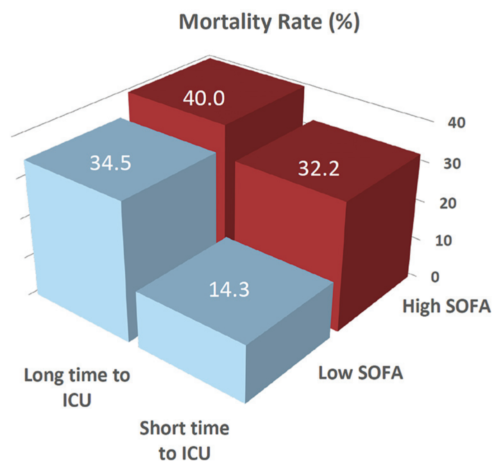

Figure 4. Interaction between the two independent parameters determining hospital mortality, i.e., the time to ICU and the SOFA score. The cut-point for subgroups were the median of each parameter (SOFA ≤5 vs. >5 and the time to ICU ≤8.63 vs. >8.63 hours).

entered into a multivariate analysis (linear regression). It revealed that three factors were independently associated with longer time to ICU, which were lower SOFA score, higher arterial pH, and the need for a bed-shuffle (Table 3).

The time to ICU and clinical outcomes

The time to ICU was significantly associated with mortality. The median (IQR) time to ICU was 7.58 (4.93 to 18.25) hours in survivors and 10.01 (5.69 to 31.73) hours in non-survivors (p=0.017 by Mann-Whitney U test). The time to ICU was not correlated with either ICU LOS or hospital LOS (p=0.077 and 0.253, respectively, Spearman's rank correlation).

Other factors associated with hospital mortality

In addition to the time to ICU already mentioned, factors associated with mortality and a p-value of less than 0.10 by univariate analyses included SOFA score (p=0.032), hypotension (p=0.041), initiation of MV at the ED (p=0.079), and septic shock (p=0.062). The binary logistic regression revealed the time to ICU and the SOFA score were both independently associated with mortality (Table 4).

By categorizing the patients into 2×2 subgroups of high versus low SOFA and long versus short time to ICU, using the median of each parameter as a cut-point, the authors could demonstrate the interaction between the time to ICU and SOFA score that determined the mortality rate in each subgroup (Figure 4).

Discussion

In the present observational study, the authors found the time to ICU admission of the new medical patients presenting at the ED was independently associated with the need for a bed-shuffle, the patients' SOFA score, and the arterial pH. The bed vacancy in general wards did not affect the time to ICU. However, if any ICU bed was immediately available, the time to ICU correlated well with the number of vacant ICU beds. Furthermore, the time to ICU and the patients' SOFA score were found to be independently associated with the hospital mortality.

The ICU occupancy rate was 97% while one-fifth were patients awaiting ICU discharge. Therefore, the study hospital had a problem with ICU outflow limitation. However, the authors could not find any correlation between the time to ICU of new patients and the number of available general beds expected to affect the severity of the outflow limitation. Some possible explanations are 1) the bed-shuffle process of an existing ICU patient might vary in different situations. Thus, the same number of bed vacancy might not reflect the same amount of the time delay in each situation. 2) Due to technical restrictions, the bed supply could not be updated in a real-time manner. This might obscure the real effect of the bed vacancy. 3) The conditions of the patients boarding in the ED were not static. This affected the rank of admission priority in a particular patient when there were more than one cases competing for the ICU. An arrival of new critical case might also affect the existing admission queue.

Furthermore, in an additional analysis regarding situations with lower versus higher number of bed vacancy in general wards using the median as a cut-point, the frequency of the admissions of those needed a bed-shuffle was 78.9% when the bed vacancy was low, and 72.7% when the bed vacancy was high ($p=0.256$ by chi-square). In other words, more vacant bed in general wards did not result in a significantly less frequent need to await ICU discharge when the new admission was requested. That means the outflow limitation of the ICU could not always be alleviated by increasing the available destination beds, as these beds were not exclusively reserved for ICU stepping-down. The decision to initiate a discharge of an improving patient to open a vacancy in the ICU could be influenced by several factors more than just the number of available beds in the wards. These include the conditions of the ICU patient(s) in the discharge queue, the number of patients expecting elective admission for pre-scheduled treatments, and the delay of the patients' home-discharge process, etc. This data suggested that, in addition to the availability of post-ICU facilities, which was proposed earlier by Levin et al[14,15], the administrative process may play a big role in the outflow limitation of the ICU. A strategy to keep at least one ICU-bed opened at all-time to avoid the need for a bed-shuffle might be a way to improve the time to ICU and the patients' outcome.

When at least one ICU bed was available, the time to ICU of the new patients inversely correlated with the number of vacant ICU beds, i.e., the time was shorter if more ICU beds were available. This might be the result of triaging processes and the "wait-and-see" action of the ED staff and the admission team. If there were more than one vacant ICU beds, the team would be less reluctant to immediately admit a case from the ED. On the other hand, in a situation where there were more candidates than the number of available ICU bed, they might tend to await the treatment responses until it was clear which patients would benefit the most from the ICU admission.

Another important result from the present study was that the SOFA and the time to ICU were both independently associated with mortality. A patient with high SOFA is likely to have higher risk of death compare to another patient with lower SOFA, and the risk will be even higher if the admission has been delayed. However, in a patient with an initially low SOFA, the mortality can also increase if the admission was delayed for too long. This points out that the "triaging" of patients by their severity is the cornerstone to set the priorities of ICU admissions. The triaging system can be some objective tools such as SOFA or simply the clinical judgments such as "gut feeling", which has been reported to be useful[19]. The present study seems to support this finding, as the clinicians in the present ED never routinely calculated the SOFA, but the patients with higher SOFA, which was separately calculated for the purpose of the study, had relatively shorter time to ICU. In other words, the clinicians could already predict the severity of the patients without having to calculate the exact SOFA, and naturally used that feeling to set the priorities of critical patients' admissions.

Limitation

The present study had some limitations. The study period was rather short and performed in a single center. The authors did not include the patients whose ICU admission were delayed and, in the end, were admitted to general wards or discharged home due to clinical improvements. The authors also omitted the ICU transfer from general wards that occurred in 40% of all ICU admission as the onset of the events leading to ICU transfer might be hard to be pinpointed. Nevertheless, the authors expected that the effects of the bed vacancy should be the same, regardless of the origin of patients. The SOFA score was available for only 80% of the cases, and the present study did not measure the Acute Physiology and Chronic Health Evaluation (APACHE) II score at the ED. As SOFA was not intentionally developed to predict mortality[20], it was arguable that its association to the mortality might not be perfect. However, several studies demonstrated that the ability to predict mortality was similar between these two scores[21-24] and a short report suggested SOFA as a triaging tool for overcrowded ED[25].

In terms of generalizability of the results, it is also important to recognize that the various ratio between the numbers of ICU beds and general beds might generate different outcomes. With the ratio of ICU beds/general beds at about 26/100 in the present center, the authors could not find the effect of outflow limitation. Whether the effect will be detectable in a hospital with lower number of general beds is unknown. The ratio between the ICU beds and general wards varies a lot from place to place[26,27]. Determining the best ratio will require multiple metrics to be considered and most of them are hard to define and measure[28], which is far beyond the scope of the present study.

Lastly, in terms of analytic process, the authors assumed a linear correlation between each factor and the time to ICU. Linear regression was used for multivariate analysis, which might not reflect the real pattern of correlation.

Conclusion

The present study did not find any correlation between the bed vacancy in general wards and the time to ICU admission of the critical medical patients presenting at the ED. The present study implies that an expansion of the general wards' capacity with an aim to relieve the ICU outflow limitation might not always improve the ICU admission time. The time to ICU seems to link with the bed management and the patients' severity, which might affect the clinicians' judgment to set the admission priority accordingly. The SOFA score can be a tool for triaging patients. Keeping an ICU bed opened at all-time might be a good strategy to reduce the waiting time. While admission delay might not always be avoidable, good managing strategies could probably improve the overall quality of critical-patient care in situations with limited resources.

What is already known on this topic?

The ICU outflow limitation is one major cause of ICU scarcity, which in turn, cause an ICU admission delay and bad clinical outcomes of the critical cases arrived at the ED.

What this study adds?

Bed vacancy in the ward was not found to directly correlate with ICU admission time of new patients, which seems to be modified by the bed management strategies. Furthermore, the ICU admission delay was found to be associated with higher hospital mortality, but this could be balanced by a good triaging practice to get the most out of the limited resources.

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Ethical approval and consent to participate

This study was approved by the Ethics Committee of Ramathibodi Hospital, Mahidol University (approval no. MURA2014/474; Chairman, Pratak O-Prasertsawat, MD), and written informed consent was obtained from all participating patients or the next-of-kin where appropriates.

Conflicts of interest

The authors declare no conflict of interest.

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