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Association between long boarding time in the emergency department and hospital mortality: a single-center propensity score-based analysis

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Abstract

Once diagnostic work-up and first therapy are completed in patients visiting the emergency department (ED), boarding them within the ED until an in-hospital bed became available is a common practice in busy hospitals. Whether this practice may harm the patients remains a debate. We sought to determine whether an ED boarding time longer than 4 h places the patients at increased risk of in-hospital death. This retrospective, propensity score-matched analysis and propensity score-based inverse probability weighting analysis was conducted in an adult ED in a single, academic, 1136-bed hospital in France. All patients hospitalized via the adult ED from January 1, 2013 to March 31, 2018 were included. Hospital mortality (primary outcome) and hospital length of stay (LOS) were assessed in (1) a matched cohort (1:1 matching of ED visits with or without ED boarding time longer than 4 h but similar propensity score to experience an ED boarding time longer than 4 h); and (2) the whole study cohort. Sensitivity analysis to unmeasured confounding and analyses in pre-specified cohorts of patients were conducted. Among 68,632 included ED visits, 17,271 (25.2%) had an ED boarding time longer than 4 h. Conditional logistic regression performed on a 10,581 pair-matched cohort, and generalized estimating equations with adjustment on confounders and stabilized propensity score-based inverse probability weighting applied on the whole cohort showed a significantly increased risk of hospital death in patients experiencing an ED boarding time longer than 4 h: odds ratio (OR) of 1.13 (95% confidence interval [95% CI] 1.05–1.22), $P = 0.001$; and OR of 1.12 (95% CI 1.03–1.22), $P = 0.007$, respectively. Sensitivity analyses showed that these findings might be robust to unmeasured confounding. Hospital LOS was significantly longer in patients exposed to ED boarding time longer than 4 h: median difference 2 days (95% CI 1–2) ($P < 0.001$) in matched analysis and mean difference 1.15 days (95% CI 1.02–1.28) ($P < 0.001$) in multivariable unmatched analysis. In this single-center propensity score-based cohort analysis, patients experiencing an ED boarding time longer than 4 h before being transferred to an in-patient bed were at increased risk of hospital death.

Keywords Emergency service · Hospital · Crowding · Hospital mortality · Propensity score · Data interpretation · Statistical

Introduction

Overcrowding of hospital emergency departments (ED) is increasingly challenging hospital managements and public health policy makers worldwide [1, 2]. ED overcrowding potentially has a number of harmful consequences, foremost among which stand low patient satisfaction [3, 4] sub-optimal and delayed care delivery [5–10], and undue over-mortality [11–14].

ED overcrowding has many causes among which shortage of in-patient beds that need to be rapidly available for those patients visiting the ED and who need admission is by far the most important and among the most difficult to resolve [11,

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15]. Many patients intended to be rapidly hospitalized still remain in the ED for long periods of time after diagnostic work-up and initial therapy have been completed. This waiting time for an in-patient bed is often referred to as the ED "boarding" time [2, 16]. For the moment, sufficiently sized studies that have examined, at the individual level, the association between long ED boarding time and adverse events such as in-hospital death have given inconsistent results [17–20]. This lack of definitive knowledge does not help to convince the hospital community and the policy makers how urgently should the boarding phenomenon be alleviated.

Studying the impact of ED boarding time is difficult because, for obvious ethical reasons, it is not possible to randomly allocate long or short boarding times to patients. In the present study aimed at examining the effect of ED boarding time on hospital mortality, propensity-matched cohort and propensity-based inverse probability weighting analyses were conducted, to draw as unbiased as possible estimates of the effect of ED boarding time despite the lack of random allocation.

Methods

Study design

This retrospective longitudinal cohort study included consecutive patients who visited the adult ED at the Centre Hospitalier Régional, Orléans, France (a 1136-bed public, regional and teaching hospital), between January 1, 2013 and March 31, 2018, and were then admitted to an in-patient setting. The adult ED has an annual census of 59,000 (in 2017). It is staffed 24 h a day, 7 days a week with seven or nine (only seven at night) nurses, and six auxiliary nurses. There were no non-physician advanced care providers. Five certified emergency physicians and four residents are present during day hours (08:30–18:30) during weekdays. Three certified emergency physicians and three residents cover night hours (18:30–08:30) and weekend days. All urgent, unplanned in-hospital admissions first pass via the ED with the exception of out-of-hospital cardiac arrests that are directly admitted to the medical intensive care unit (ICU), and acute coronary syndromes, suspected or proven during pre-hospital phase, that are directly admitted to the cardiac catheterization service.

The study complied with French law requirements related to personal health data protection. The Ethical Committee of the French Society of Intensive Care approved the study protocol (#CE SRLF 18-31) and waived the need for individual informed consent.

Patients admitted to an in-patient unit without passing via the ED, patients who died in the ED, patients under 15 years and 3 months of age (local administrative threshold below which a patient is considered a pediatric patient), and patients presenting to the pediatric or to the gynecologic/obstetric EDs of the hospital were not included.

Data extracted from the hospital electronic health record to constitute the final study dataset were: demographic characteristics, survival status at hospital discharge, length of hospital stay, diagnosis most responsible for the hospitalization and comorbidities as coded according to the 10th edition of the International Classification of Diseases (ICD-10) by the hospital specialists who admitted the patient in their units; diagnosis most responsible for the ED visit as coded by the emergency physician according to the ICD-10; score on the Classification Clinique des Malades aux Urgences (CCMU) 5-point scale, which ranks the severity of illness from stable situation with no need for diagnostic or therapeutic action (CCMU1) to critical illness with need for resuscitation (CCMU5) [21]; timestamp data related to the ED visit, including time spent before seeing a doctor, duration of the examination and diagnostic work-up phase, and ED boarding time before transfer to an in-patient unit. The time of arrival for each patient was systematically recorded by an administrative employee at the ED entrance. The time of departure from the ED (either discharge from the hospital or transfer to an in-patient unit) was systematically and timely recorded by the ED nurses. The emergency physicians were trained, at least since 2013, to record the result of their first physical examination and their diagnostic hypotheses as soon as possible after having seen a patient for the first time. After having completed the diagnostic work-up, having administrated urgent therapy if needed, and possibly after talks with different hospital specialists, the emergency physicians also systematically updated the patient's electronic medical records, indicated if hospitalization was necessary, and declared the precise moment at which the patient in question was ready to be transferred to an in-patient setting. These time-stamped data were used to calculate the ED boarding time, i.e., the time elapsed between the decision to hospitalize in an inpatient unit and the physical departure of the patient from the ED [16].

Comorbidities as coded at hospital discharge according to the ICD-10 classification were reorganized based on the Elixhauser classification system [22], which was slightly modified to comprise 40 distinct conditions. In particular, two comorbidity categories, dementia and dependency (i.e., immobility [ICD-10 Codes: R26.3-, G82.3–G82.5] or care provider dependency [Codes Z74.0–Z74.9, Z76.4]) were added.

Outcome measures

Hospital mortality (i.e., in-hospital all-cause mortality) and the hospital length of stay (LOS) (including the time spent in the ED) were the primary and secondary outcome measures, respectively, and were compared between patients with and without ED boarding time longer than 4 h.

Analytic strategy

The chosen primary analytic strategy was to assess the outcome measures in a matched cohort where patients with an ED boarding time longer than 4 h were matched to patients with an ED boarding time ≤ 4 h according to a propensity score to experience an ED boarding time longer than 4 h. Analyses in the entire cohort of patients and sensitivity analyses were then conducted.

Statistical analysis

Propensity score calculation

A propensity score [23], i.e., the probability, to experience an ED boarding time > 4 h, was calculated for each patient using multivariable logistic regression and using all individual demographic, timestamp, and clinical data available as independent covariables.

Matching procedure

This procedure attempted at matching each patient with an ED boarding time > 4 h with one patient with an ED boarding time ≤ 4 h but similar propensity score. It was performed without replacement and using a maximum caliper distance of 0.05 SD of the logit, i.e., the output of the logistic regression from which the propensity score was calculated [24]. In addition, exact matching was performed on the order number of admission of each patient, so that different visits in a same given patient could not be matched.

In the event the matching did not result in a satisfactory balance of confounders between exposed and unexposed patients, it was rerun using exact matching on those confounders. A satisfactory balance was defined as a standardized difference (of means or of proportions) between exposed and unexposed patients of less than 0.1 [25].

Matched analysis

Association between emergency department boarding time and hospital mortality

The association of an ED boarding time > 4 h with hospital mortality was assessed in the matched cohort through two distinct analyses: (1) McNemar's χ^2 test was used to compare the mortality rates between patients exposed or unexposed to an ED boarding time > 4 h; (2) odds ratios (OR) (and 95% confidence interval [95% CI]) obtained using conditional logistic regression, in which each pair of patients was handled as a distinct stratum.

Association between ED boarding time and hospital length of stay

The association of an ED boarding time > 4 h with hospital LOS was examined in the matched cohort using (1) a paired Wilcoxon test and calculation of difference in medians using bootstrapping (2000 bootstrap samples); (2) a linear mixed-effects model, in which pairs of patients were entered as random effect (random intercept), that compared estimated marginal mean of LOS between patients exposed and unexposed to an ED boarding time > 4 h.

Analyses in the entire study cohort

Generalized estimating equations (GEE) [26] with robust standard errors were applied, using a correlation structure that took into account the repeated visits of patients, and stabilized or not stabilized propensity score-based inverse probability weighting [27, 28]. The GEE analyses were adjusted for confounders, i.e., time data and clinical characteristics showing an imbalance between patients exposed or unexposed to an ED boarding time longer than 4 h (imbalance was defined as a weighted [29] standardized difference above 0.1) and associated with the dependent variable with $P < 0.2$ using "bivariable" analysis (GEE with only one independent covariable but still using a within-patient correlation structure). For hospital mortality, a binary outcome, a binomial distribution was assumed and a logit link function was used to produce ORs and their robust 95% CI. For hospital LOS, a continuous outcome, a Gaussian distribution was assumed and an identity link was used to derive regression coefficients and their 95% CI (from which estimated mean difference was calculated).

Sensitivity analyses

The sensitivity to unmeasured confounding of the association of ED boarding time > 4 h with hospital mortality was assessed (1) through *E* value calculation [30] for the unadjusted relative risk on the matched cohort; (2) on the entire study cohort by generating sequences of GEE models in which an unmeasured confounder hypothetically present in 50% of the population but with varying association with ED boarding time and hospital mortality was added at random (10,000 random samples) as a covariable.

The analyses of the association of ED boarding time longer than 4 h with hospital mortality conducted on the entire study cohort were rerun in pre-specified cohorts: (1) patients admitted or not admitted to an ICU after the ED visit. For this purpose, patients admitted either to the medical or surgical ICUs, or to the medical or surgical intermediate care units were considered ICU patients; intermediate care units in our hospital are units adjacent to the ICUs, staffed with a nurse/patient ratio three times higher than in general wards, equipped with multi-parameter bedside monitors and under the responsibility of one on-call critical care physician and resident. They are intended to admit and care for fragile patients at risk of developing organ failure(s). Of note, ICU patients, as soon as they were identified as critically ill patients, were cared for by ICU staff members within the ED until an ICU bed became available; (2) in the subsets of patients who underwent surgical procedures or not during hospital stay, for traumatic injuries or for other diseases, the reason for dichotomizing the surgical cohort was that, most of the time, non-critically ill trauma patients (at very low risk of hospital death) who needed rapid surgical intervention were waiting within the ED for admission to the operating room, even when beds were available in in-hospital surgical wards; (3) in the population of non-surgical patients; and (4) in a population restricted to the first hospitalization via the ED of each patient during the study period, using mixed-effect logistic regression with patients entered as random effect.

The unit of analysis was the ED visit, unless otherwise specified. Sample size considerations are available in Supplement 1. A two-tailed $P < 0.05$ was considered statistically significant. The R software version 3.5.1 (R Foundation for Statistical Computing) was used for all analyses.

Results

Among the 251,760 adult ED visits that occurred during the study period, 68,876 were followed by admission to an in-hospital setting (i.e., an admission rate of 27.4%), of which 68,632 (99.6%), corresponding to 48,208 patients, were included (Fig. 1). The characteristics of the study population (mean [SD] age, 63.8 [22.0] years; 50.7% men) are set out in eTable1 and eTable2 in Supplement 1.

Overall, the median ED boarding time was 90 [IQR 40–243] minutes. Visits with ED boarding time longer than 4 h represented 25.2% (17,271/68,632) of the total number of visits that resulted in in-hospital admission. Patients with or without ED boarding time longer than 4 h differed for a number of characteristics as evidenced by a standardized difference above 0.1 (eTable1 and eTable2 in Supplement 1). Dependency, dementia, severe malnutrition and mental or behavioral disorders were by far more prevalent in patients with ED boarding time longer than 4 h. Conversely, traumatic injuries and surgery during hospital stay were more prevalent in patients with ED boarding time shorter than 4 h.

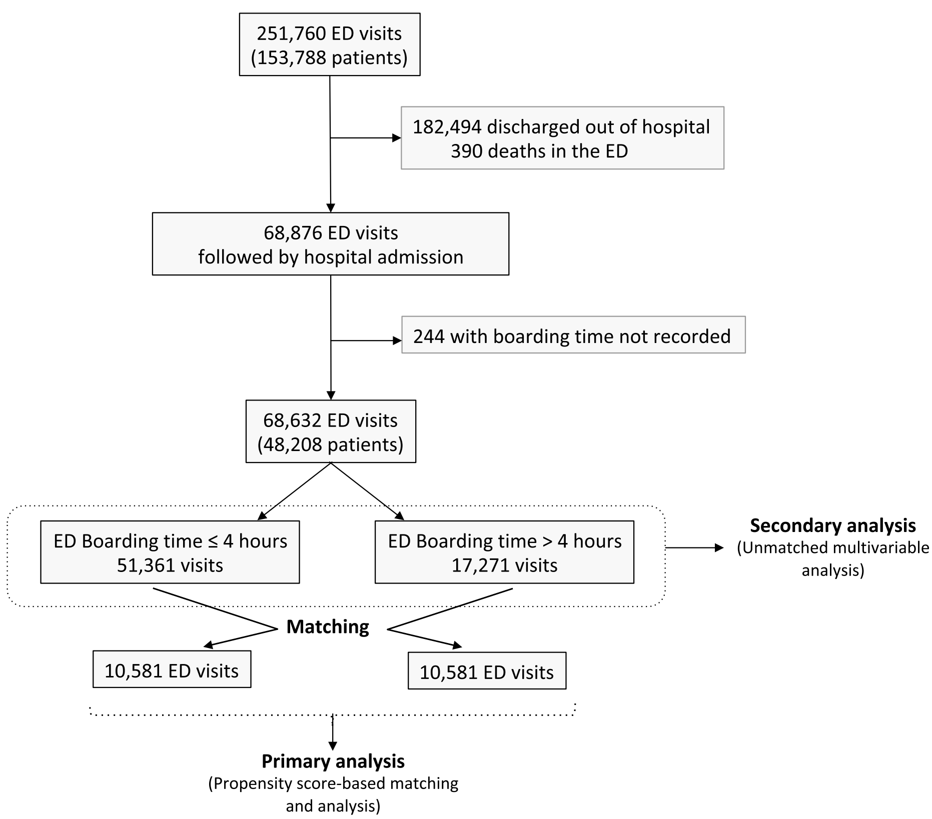


Fig. 1 Flow diagram. *ED* emergency department

Result of matching

As planned, the matching procedure has needed, in addition to propensity score matching, to also match patients according to some illnesses to obtain well-matched cohorts: exact matching on the existence of dementia, dependency (see "Methods" for definition), weight loss or severe malnutrition, and chronic alcoholism was used. The procedure yielded 10,581 pairs of ED visits that were well balanced regarding clinical characteristics and timestamp data other than ED boarding time (Table 1 and eTable 3). All variables examined showed a standardized difference between the paired cohorts of less than 0.1 (in fact, all were < 0.05 except the comorbidity "hypertension" and the time spent for initial diagnostic work-up) (Table 1).

Association between emergency department boarding time and hospital mortality

In the matched cohort, hospital mortality was significantly higher for visits with ED boarding time > 4 h (758/10,581 [7.16%]) than for their matched counterparts (669/10,581 [6.32%]) ($P < 0.001$).

All planned analyses, summarized in Table 2, on the matched cohort or on the whole study population, showed a statistically significant increased risk of hospital death in patients exposed to an ED boarding time > 4 h. Based on the OR of 1.13 (95% CI 1.02–1.26) yielded by conditional logistic regression performed on the propensity-matched cohort, boarding patients in the ED longer than 4 h would result in 1 additional death in every 129 exposed patients (95% CI 67–806), i.e., an estimated number needed to harm 129 patients.

Association between ED boarding time and hospital length of stay

In the matched cohort, the median hospital LOS was longer in patients with ED boarding time > 4 h (8 days [IQR 4–13]) than in patients with shorter ED boarding time (6 days [IQR 3–11]) (median difference: 2 days (95%CI 1–2); $P < 0.001$). All planned analyses (Table 3) showed a statistically significant and positive link between ED boarding time > 4 h and hospital LOS.

Sensitivity analyses

Analysis of the sensitivity to a hypothetical unmeasured confounder performed on the matched cohort (E value = 1.52 [95% CI 1.18–1.82]) and on the whole study population (random sequences of GEE models, see eFigure1 in Supplement 1), showed that such a confounder should be 1.5 times more frequent in patients exposed to ED boarding time > 4 h and also associated with 1.5 times more deaths to explain away the association between ED boarding time and mortality.

An analysis of pre-specified cohorts showed that an ED boarding time > 4 h seemed to preferentially harm non-critically ill patients with non-surgical diseases, i.e., the majority of patients (Fig. 2).

Discussion

In this single-center retrospective cohort study, propensity-matched and propensity score-based inverse probability weighting analyses showed that boarding patients longer than 4 h in the ED was significantly associated with an increased risk of hospital death and a longer hospital LOS.

To our knowledge, the association between ED boarding time and outcomes of hospitalized patients had never been examined through propensity score-based analysis until now. For analyzing the effect of exposures like ED boarding time that cannot be randomly allocated, propensity-based analyses may satisfactorily balance confounders, thereby allowing drawing causal inference with lowered risk of bias [23]. Risk of bias is particularly important when studying the effects of ED boarding time. Old patients with high complexity diseases, who hospital wards are sometimes reluctant to admit in a timely manner [31], play a growing part in ED overcrowding [32]. Disentangling the correlated effects of ED boarding time on hospital mortality and that of the naturally high risk of death of these patients is not straightforward. Meanwhile, in crowding conditions, even patients with intermediate severity of illness (as those classified in the CCMU class 2 in the current study) are exposed to long ED boarding time. No or small increase in the risk of death due to ED boarding in these patients at low basal risk may confound analyses.

Previous studies have given inconsistent results. Recently, a study involving 31,219 patients hospitalized in a medical ward via the ED of a single hospital showed that patients exposed to an ED boarding time > 4 h were at increased risk of serious adverse events (transfer to ICU, death) [19]. In another single-center study, an ED boarding time > 6 h was found to increase the risk of hospital death in 41,256 ED visits with an OR of 1.24 (95% CI 1.00–1.54) [17]. In a recent bi-center study involving 39,781 hospitalizations via the ED, non-survivors at hospital discharge were shown to have experienced a longer ED boarding time than survivors [20]. In counterpart, a multicenter study (involving 13 EDs) that included 208,706 ED visits did not show such an association [18]. Of note, none of the above-cited studies, though having used sophisticated case-mix adjustments, has taken into account the patient's probability to be boarded a long time in the ED, which depends not only on comorbidities but also

Table 1 Characteristics of patients included in the matched cohort analysis

	ED boarding time ≤ 4 h $N = 10{,}581$ visits	ED boarding time > 4 h $N = 10{,}581$ visits	Standardized difference[a]
Boarding time in the ED, median [IQR] (min)	64 [33–117]	645 [346–1103]	
Female gender[b]	5378 (50.8)	5420 (51.2)	0.008
Age[c], mean (SD) (year)	69.0 (20.5)	69.1 (20.5)	< 0.001
Surgery during hospital stay[c]	599 (5.7)	599 (5.7)	< 0.001
Surgical trauma patients[c]	223 (2.1)	223 (2.1)	< 0.001
Score 1 or 2 in CCMU[c,d] classification	2575 (24.3)	2575 (24.3)	< 0.001
Score 3 in CCMU [c,d] classification	7234 (68.4)	7234 (68.4)	< 0.001
Score 4 or 5 in CCMU [c,d] classification	772 (7.3)	772 (7.3)	< 0.001
Individual order number of hospitalization[c] during the study period, median [IQR]	1 [1–2]	1 [1–2]	< 0.001
Previous hospitalization via the ED within 90 days	1083 (10.2)	1021 (9.6)	0.020
No of patients present in the ED at admission, median [IQR]	42 [33–52]	43 [34–52]	0.017
No of patients boarding in the ED at admission, median [IQR]	17 [11–25]	17 [10–24]	0.014
Waiting time before being seen by Emergency Physician, median [IQR], min	132 [68–225]	133 [72–226]	0.020
Time needed for diagnostic work-up and initial treatment, median [IQR], min	127 [38–282]	160 [47–365]	0.096
Morning admission (07:00–13:59)	3591 (33.9)	3609 (34.1)	0.004
Evening admission (14:00–20:59)	4506 (42.6)	4440 (42.0)	0.013
Night admission (21:00–06:59)	2484 (23.5)	2532 (23.9)	0.011
Weekend admission	2705 (25.6)	2727 (25.8)	0.005
Palliative care during hospital stay[e]	281 (2.7)	318 (3.0)	0.021
Principal diagnosis category of ICD-10 as coded at hospital discharge			
Bacterial infectious diseases (excluding non-tuberculosis lung infections)	463 (4.3)	485 (4.6)	0.001
Neoplasms	273 (2.6)	298 (2.8)	0.015
Diseases of the blood and blood-forming organs	482 (4.6)	422 (4.0)	0.028
Endocrine, nutritional and metabolic diseases	336 (3.2)	358 (3.4)	0.012
Mental and behavioral disorders	557 (5.3)	505 (4.8)	0.023
Diseases of the nervous system	399 (3.8)	429 (4.1)	0.015
Diseases of the circulatory system	1665 (15.7)	1668 (15.8)	0.001
Diseases of the respiratory system (including non-tuberculosis infections)	1395 (13.2)	1537 (14.5)	0.039
Diseases of the digestive system	1105 (10.4)	1165 (11.0)	0.018
Diseases of the musculoskeletal system and connective tissue	630 (6.0)	603 (5.7)	0.011
Diseases of the genitourinary system	640 (6.0)	535 (5.1)	0.043
Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified	954 (9.0)	900 (8.5)	0.018
Traumatic injuries	594 (5.6)	619 (5.9)	0.010
Poisoning and certain other consequences of external causes	387 (3.7)	391 (3.7)	0.002
Factors influencing health status and contact with health services	319 (3.0)	355 (3.4)	0.019
Comorbidities[f]			
Dementia (*)[c]	375 (3.5)	375 (3.5)	< 0.001
Paralysis	427 (4.0)	444 (4.2)	0.008
Including sequella of ischemic or hemorrhagic stroke (*)	131 (1.2)	144 (1.4)	0.011
Other neurological disorders	386 (3.6)	464 (4.4)	0.038
Dependency (*)[c,g]	714 (6.7)	714 (6.7)	< 0.001
Weight loss, Severe malnutrition[c]	1165 (11.0)	1165 (11.0)	< 0.001
Obesity	453 (4.3)	472 (4.5)	0.009
Chronic alcoholism[c]	103 (1.0)	103 (1.0)	< 0.001
Chronic renal insufficiency	583 (5.5)	628 (5.9)	0.018
Including chronic dialysis (*)	42 (0.4)	29 (0.3)	0.021

Table 1 (continued)

	ED boarding time ≤ 4 h N = 10,581 visits	ED boarding time > 4 h N = 10,581 visits	Standardized difference[a]
Diabetes, uncomplicated	703 (6.6)	724 (6.8)	0.008
Diabetes, complicated	534 (5.0)	547 (5.2)	0.006
Chronic heart failure	618 (5.8)	590 (5.6)	0.011
Ischemic cardiomyopathy (with or without chronic heart failure) (*)	582 (5.5)	515 (4.9)	0.029
Cardiac arrhythmias	1460 (13.8)	1412 (13.3)	0.013
Including atrial fibrillation (*)	1170 (11.1)	1150 (10.9)	0.006
Valvular disease	178 (1.7)	185 (1.7)	0.005
Peripheral vascular disease	150 (1.4)	159 (1.5)	0.007
Chronic arterial hypertension	2054 (19.4)	1808 (17.1)	0.060
Chronic pulmonary disease	518 (4.9)	543 (5.1)	0.011
Including chronic obstructive pulmonary disease (*)	247 (2.3)	275 (2.6)	0.017
Chronic respiratory insufficiency (*)	232 (2.2)	241 (2.3)	0.006
Home mechanical ventilation (excluding night positive pressure ventilation for sleep apnea syndrome) (*)	54 (0.5)	66 (0.6)	0.015
Solid tumor (without metastasis)	610 (5.8)	632 (6.0)	0.009
Solid tumor with metastasis	432 (4.1)	474 (4.5)	0.020
Hematologic malignancy	193 (1.8)	177 (1.7)	0.012
Coagulation disease	270 (2.6)	220 (2.1)	0.031
Blood loss anemia	266 (2.5)	266 (2.5)	< 0.001
Deficiency anemias	485 (4.6)	523 (4.9)	0.017
Liver disease	185 (1.7)	256 (2.4)	0.047
Including cirrhosis (*)	119 (1.1)	160 (1.5)	0.034
Peptic ulcer disease excluding bleeding	50 (0.5)	58 (0.5)	0.011
Psychiatric disease	681 (6.4)	747 (7.1)	0.025
Depressive disorder	141 (1.3)	158 (1.5)	0.014
Rheumatoid and collagen diseases	138 (1.3)	132 (1.2)	0.005
Hypothyroidism	193 (1.8)	193 (1.8)	< 0.001
Fluid and electrolyte disorder	833 (7.9)	953 (9.0)	0.041
AIDS	15 (0.1)	24 (0.2)	0.020
Drug abuse	63 (0.6)	62 (0.6)	0.001
Organ transplanted (*)	37 (0.3)	36 (0.3)	0.002

CCMU French acronym for Classification Clinique des Malades aux Urgences, *ED* Emergency Department, *ICD-10* international classification of diseases version 10, *IQR* interquartile range

[a]Standardized differences were calculated according to Austin [25]. A value of less than 0.1 indicates a satisfactory balance of covariates between exposed and unexposed subjects

[b]All categorical variables are expressed as count and (%)

[c]Variable used for matching (exact matching) in addition to the propensity score

[d]Score on the Classification Clinique des Malades aux Urgences (CCMU) 5-point scale ranks the severity of illness: *CCMU1* stable situation with no need of diagnostic or therapeutic action, *CCMU2* stable situation for which diagnostic or therapeutic act are ordered, *CCMU3* situation likely to deteriorate but not life-threatening, *CCMU4* prognosis committed but no need of immediate resuscitation acts, *CCMU5* critical illness with need of resuscitation [21]

[e]As indicated by the ICD-10 code Z51.5 when coded at hospital discharge

[f]The Elixhauser's classification system was used to report comorbidities [22]. Some subcategories identified by an asterisk (*) were added to the original classification

[g]Dependency was defined as immobility [ICD-10 Codes: R26.3-, G82.3 to G82.5] or care provider dependency [Codes Z74.0 to Z74.9, Z76.4])

on crowding conditions. Importantly, in the latter study [18], patients boarded in the ED were systematically cared for by a dedicated additional team (nurses and physicians) provided by in-patient settings. This support to the ED team probably relieved workload and was conductive to better and timely care. Such conditions of mutual help are rarely possible in

Table 2 Association between emergency department boarding time and hospital mortality (primary outcome)

		ED boarding time > 4 h	ED boarding time ≤ 4 h	Odds ratio (95% confidence interval)	*P* value
Propensity-matched cohort analyses	No of deaths (%)	758/10,581 (7.16)	669/10,581 (6.32)		
Bivariable analysis				1.14 (1.03–1.27)	< 0.001[a]
Conditional logistic regression[b]				1.13 (1.02–1.26)	0.001
Whole study population analyses	No of deaths (%)	1432/17,271 (8.29)	2696/51,361 (5.25)		
GEE with adjustment on confounders[c] and propensity score-based IPW				1.14 (1.05–1.24)	0.002
GEE with adjustment on confounders and stabilized propensity score-based IPW				1.12 (1.03–1.22)	0.007

ED emergency department, *GEE* generalized estimating equations, *IPW* inverse probability weighting

[a]Bivariable comparison was performed using McNemar's χ^2 test

[b]In this conditional regressions analysis each pair of patients was handled as a distinct stratum

[c]The unmatched analysis was adjusted for 13 confounders (see the Methods section for method used to select confounders): (1) surgery during hospital stay; (2) score 3 in CCMU classification (a 5-point scale which ranks the severity of illness at presentation to the emergency department from stable situation with no need of diagnostic or therapeutic action [CCMU1] to critical illness with need of resuscitation [CCMU5] [21]); (3) score 4 or 5 in CCMU classification; (4) previous hospitalization within the preceding 90 days; (5) disease of the circulatory system (6) disease of the digestive system (7) traumatic injury as the principal category of diagnosis coded at hospital discharge; (8) weight loss as coded as a comorbidity; (9) disease of the circulatory system (10) disease of the respiratory system (11) disease of the digestive system (12) symptoms not elsewhere classified, and (13) traumatic injury as the principal category of diagnosis coded as the primary cause of the ED visit

Table 3 Association between emergency department boarding time and hospital length of stay (secondary outcome)

		ED boarding time > 4 h	ED boarding time ≤ 4 h		*P* value
Propensity-matched cohort analyses	Median hospital LOS (IQR), days	8 (4–13)	6 (3–11)		
Bivariable analysis				Median difference (95% CI), days[a] 2 (1–2)	< 0.001[b]
Linear mixed-effect regression				Mean difference (95% CI), days 1.30 (1.18–1.42)	< 0.001
Whole study population analyses	Mean hospital LOS (SD), days	12.0 (11.2)	8.9 (10.4)		
GEE with adjustment on confounders[c] and propensity score-based IPW				Mean difference (95% CI), days 1.16 (0.90–1.43)	< 0.001
GEE with adjustment on confounders and stabilized propensity score-based IPW				1.15 (0.88–1.41)	< 0.001

ED emergency department, *GEE* generalized estimating equations with robust errors calculation, *IPW* inverse probability weighting, *IQR* inter-quartile range, *LOS* length of stay

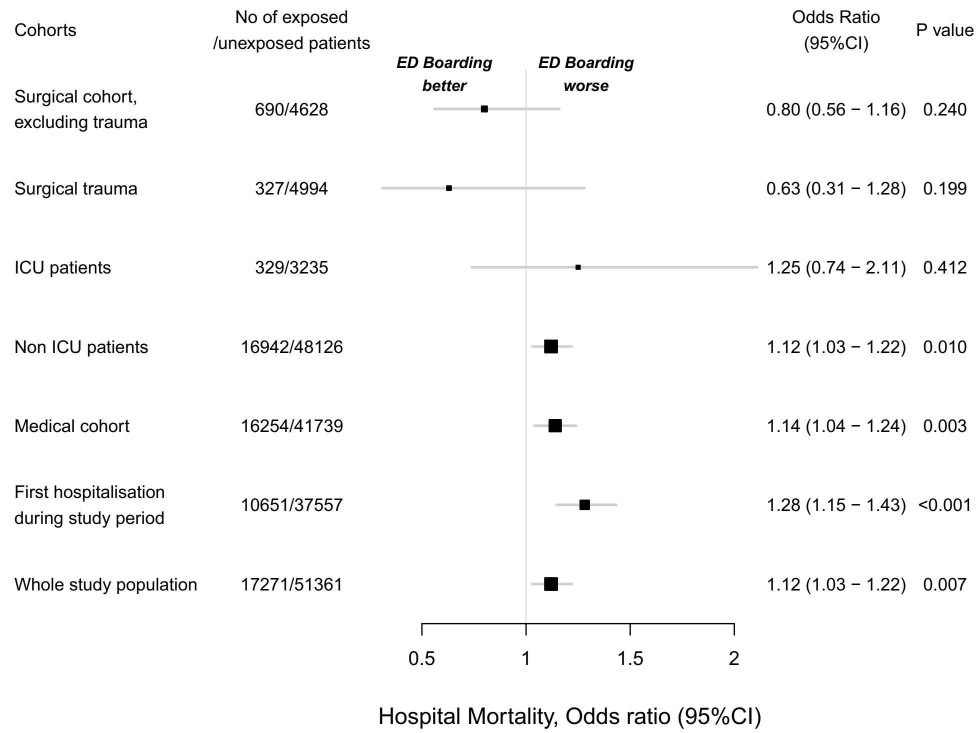
[a]Median difference was calculated using bootstrapping

[b]*P* value obtained using paired Wilcoxon rank test

[c]GEE models were adjusted for covariables that showed imbalance between patients exposed or unexposed to ED boarding time longer than 4 h and associated with hospital LOS with $P < .2$ using bivariable analysis (see Methods section). There were 25 confounders selected to be entered in the GEE models

French hospitals, like in many other countries, where shortage in care providers is a common feature, and were not met in the current study. Nevertheless, in the current study, critically ill patients waiting for an ICU bed were cared for within the ED by ICU physicians and residents. This policy may explain why the effect of boarding on hospital mortality was not found in this specific population. Different policies across hospitals may explain the different degrees of association between ED boarding time and outcome of ICU patients observed in previous studies [33–35]. Also, it is possible that despite careful adjustment for confounders, unbalance between ICU patients boarded shorter or longer than 4 h in our whole study population may have biased our findings. Indeed, significantly more ICU patients with CCMU 4 or 5 (i.e., the patients with the highest risk of death, who logically are often rapidly admitted to the ICU) were observed in patients boarding less than 4 h than in those with boarding time longer than 4 h (2269/3235 [70.1%] vs 179/329

Fig. 2 Odds ratios for hospital mortality associated with emergency department boarding time longer than 4 h in pre-specified cohorts of patients. *ED* emergency department, *ICU* intensive care unit. With the exception of the cohort of first hospitalization of each patient during the study period, analyses were performed using generalized estimating equations with robust standard errors calculation, propensity-based inverse probability weighting, and a correlation structure that took into account the multiple ED visits of patients. In the cohort of first hospitalizations, a mixed-effect logistic regression was used in which patients were handled as random effect



[54.4%], respectively; $P < 0.001$). As already suggested by others [17], this could have further attenuated the supposed protective effect of short boarding time in ICU patients.

In line with previous researches [36–38], the current study showed a strong statistical link between ED boarding time longer than 4 h and hospital LOS. This finding is not surprising as older and more complex patients who will need longer hospital care also are those who tend to remain longer in the ED. However, the adjustments made for the propensity to be boarded in the ED once again suggest that beyond age and disease complexity, sub-optimal and delayed care during ED boarding may have played a role.

The current study does not help in identifying the root causes of worse outcome in patients boarded within the ED. A rich literature stresses the role of multitask workload pressure placed on ED nurses and physicians [39]. When the ED is flooded with patient's arrival waves and crowded with boarded patients, missed diagnoses, therapeutic errors and delayed care are likely to occur [14]. However, ED crowding and flow conditions were very similar in our pair-matched cohorts so that workload pressure was probably similar too. Given our study design that renders the possibility of unmeasured confounder rather unlikely, the main factor explaining the worse outcome of boarding patients remains the time spent boarding in the ED. Sometimes, in crowding conditions, the time left aside on a stretcher with piecemeal surveillance after first therapy has been completed may lead to missed home medications [40], to ignore vital signs deterioration such as low blood pressure [40], hypoxia [40], arrhythmia [40], or ongoing dehydration, bronchial stasis, and beginning pressure sores. In line with a previous study [41] that showed that in boarded patients the frequency of serious complications grew in parallel with boarding time, our findings suggest that more than 4 h in these conditions is deleterious for patients.

This study has several limitations. First, data come from one single hospital particularly affected by the ED boarding phenomenon with one quarter of patients boarded longer than 4 h, a proportion much higher than that observed in other EDs [19]. Despite a slightly lower median ED boarding time than reported, for example, in 723 US EDs (101 min [75–132] vs 90 min [IQR 40–243] in the current study) [42], our admission rate and ED LOS were higher than reported in other French [43] and US EDs [44] of similar annual census. Therefore, our findings are not necessarily generalizable to other hospitals under less pressure. As mentioned earlier, the findings of a recent multicenter US study that did not show the effect of boarding time on hospital mortality [18] can also hardly be transposed to French hospitals. Second, a cutoff value was arbitrarily used to categorize ED boarding time, like done by other researchers who chose a cutoff of either 2 [17], 4 [19], or 6 h [20]. In fact, in the study population, as illustrated in eFigure 2 in Supplement 1, the risk of hospital death grew in parallel with the continuous scale of ED boarding time. Whatever the chosen cutoff value (2, 4, 6, or 8 h), longer ED boarding time still remained significantly associated with hospital mortality in our whole study population (data not shown). However, in the absence of specific propensity score developed for each cutoff value, our analyses do not allow definitively inferring that boarding patients longer than 2 (or 6) h in the ED places them at increased risk of death compared to patients boarded shorter than 2 (or 6) h. This could be the subject of further propensity score-matching analyses. Third, a satisfactory balance of confounders was reached only in the primary, matched cohort analysis, so that the results of the whole cohort analyses should be interpreted with caution. Fourth, the representativeness of the matched cohort might be questioned as it represented only 61.3% of the patients exposed to ED boarding time longer than 4 h and less than one-third of the whole study population. However, with the exception of surgical patients, all categories of patients and comorbidities were well represented and the ED boarding time in the matched cohort covered the entire range observed in the whole population. Fifth, the sensitivity analysis showed that a missed confounder had to be 1.5 more frequent in patients with long boarding time and also be associated with 1.5 more deaths to confound the analysis. This may not be seen so improbable. However, it should be noted that the prevalence of the unmeasured confounder was set as high as 50% in the study population, a very penalizing scenario. Sixth, the retrospective nature of the study did not permit to distinguish groups of vulnerable patients such as very poor persons, migrants or other minorities, who may present at the same time poor health status that places them at risk of hospital death and high propensity to be boarded a long time in the ED. Once again, the results of our sensitivity analysis make it unlikely that the lack of precision in identifying such minorities has biased our main analysis. Seventh, like in all studies relying on health record systems and coding, the accuracy and completeness of data cannot be ascertained. In addition to the fact that missed diagnoses and comorbidities have not been reported to be so frequent [45], the large study size and the analyses of sensitivity to unmeasured confounding suggest that the findings may be robust to imperfect coding.

Conclusion

In this propensity score-based cohort analysis, conducted at one single teaching hospital where the busy adult ED received no external help to care for the patients waiting for an in-hospital bed, patients experiencing an ED boarding time longer than 4 h were at increased risk of hospital death.

Author contributions TB had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Concept and design: TB, AM, OM. Acquisition, analysis, or interpretation of data: TB, AM, OM. Drafting of the manuscript: TB. Critical revision of the manuscript for important intellectual content: TB, AM, OM. Statistical analysis: TB. Obtained funding: TB. Administrative, technical, or material support: TB, AM, OM. Supervision: TB.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no financial or non-financial competing interests relative to this submission.

Ethical approval The Ethical Committee of the French Society of Intensive Care approved the study protocol (#CE SRLF 18-31).

Informed consent For this retrospective study that complied with French law requirements related to personal data protection, informed consent was not required.

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