Original Article
Yonsei Med J 2022 May;63(5):470-479
https://doi.org/10.3349/ymj.2022.63.5.470
Yonsei Medical Journal
YMJ
pISSN: 0513-5796 · eISSN: 1976-2437

Effect of a Boarding Restriction Protocol on Emergency Department Crowding

Ji Hwan Lee[1]*, Ji Hoon Kim[1,2]*, Incheol Park[1], Hyun Sim Lee[3], Joon Min Park[4], Sung Phil Chung[1], Hyeon Chang Kim[2], Won Jeong Son[5], Yun Ho Roh[5], and Min Joung Kim[1]

Departments of [1]Emergency Medicine and [2]Preventive Medicine and Public Health, Yonsei University College of Medicine, Seoul;
[3]Department of Emergency Nursing, Yonsei University Health System, Seoul;
[4]Department of Emergency Medicine, Inje University Ilsan Paik Hospital, Goyang;
[5]Biostatistics Collaboration Unit, Department of Biomedical Systems Informatics, Yonsei University College of Medicine, Seoul, Korea.

Purpose: Access block due to the lack of hospital beds causes crowding of emergency departments (ED). We initiated the "boarding restriction protocol" that limits the time of stay in the ED for patients awaiting hospitalization to 24 hours from arrival. The purpose of this study was to determine the effect of the boarding restriction protocol on ED crowding.

Materials and Methods: The primary outcome was ED occupancy rate, which was calculated as the ratio of the number of occupying patients to the total number of ED beds. Time factors, such as length of stay (LOS), treatment time, and boarding time, were investigated.

Results: The mean of the ED occupancy rate decreased from 1.532±0.432 prior to implementation of the protocol to 1.273±0.353 after (p<0.001). According to time series analysis, the absolute effect caused by the protocol was -0.189 (-0.277 to -0.110) (p=0.001). The proportion of patients with LOS exceeding 24 hours decreased from 7.6% to 4.0% (p<0.001). Among admitted patients, ED LOS decreased from 770.7 (421.4–1587.1) minutes to 630.2 (398.0–1156.8) minutes (p<0.001); treatment time increased from 319.6 (198.5–482.8) minutes to 344.7 (213.4–519.5) minutes (p<0.001); and boarding time decreased from 298.9 (109.5–1149.0) minutes to 204.1 (98.7–545.7) minutes (p<0.001). In pre-protocol period, boarding patients accumulated in the ED during the weekdays and resolved on Friday, but this pattern was alleviated in post-period.

Conclusion: The boarding restriction protocol was effective in alleviating ED crowding by reducing the accumulation of boarding patients in the ED during the weekdays

Key Words: Emergency department, crowding, hospitalization, quality of healthcare

INTRODUCTION

Crowding in the emergency department (ED) is a critical public health problem.[1,2] Research has shown that crowding in the ED elicits many adverse effects, including increased mortality, medical errors, return visits, ambulance diversion, and costs, as well as decreased patient satisfaction.[3-6] Accordingly, numerous studies have been conducted to solve crowding in the ED over the past decade.[7-9] One of main contributors to crowding in the ED is access block, which refers to an inability to transfer patients from the ED to hospital beds, such that the patients remain in the ED even after emergency treatment has been completed.[10] Access block occurs when hospital bed occupancy increases.[11-13] Forster, et al.[14] reported that the length of stay (LOS) of admitted patients in the ED increased by 18 min for every 10% increase in hospital bed occupancy and increased greatly when bed occupancy exceeded 90%.

In order to solve this situation, several countries have imple-

Received: August 18, 2021 **Revised:** December 29, 2021
Accepted: January 13, 2022
Corresponding author: Min Joung Kim, MD, PhD, Department of Emergency Medicine, Yonsei University College of Medicine, 50-1 Yonsei-ro, Seodaemun-gu, Seoul 03722, Korea.
Tel: 82-2-2228-2460, Fax: 82-2-2227-7908, E-mail: boringzzz@yuhs.ac

*Ji Hwan Lee and Ji Hoon Kim contributed equally to this work.
•The authors have no potential conflicts of interest to disclose.

mented a mandatory national policies limiting the staying time of patients in the ED. In 2004, the UK's National Health Service first introduced the "4-hour target" requiring 98% of patients who visit the ED to leave within 4 hours of arrival.[15,16] Since then, similar national policies have been initiated in several countries: the Australian government applied the National Emergency Access Target, which limited ED LOS to 4 hours, as in the UK; New Zealand adopted a longer 6-hour target.[17,18] The governments of these countries had a strong will to improve the crowding of ED and demanded the improvement from hospitals rather than ED alone, and this mandatory policies have had a great effect on improving the indicators of ED crowding.[15,16,19] In Korea, crowding in the ED has been a serious public issue for a long time; however, there are no national regulations on staying time in the ED: the Korean government only recommends keeping patients who stay for more than 24 hours below 5%. Addressing access block requires changing rules on hospital bed arrangement; however, hospital leadership is not easily motivated without government policies.[20,21]

We initiated a new protocol, the so-called "boarding restriction protocol", to control the situation in which patients who needed to be hospitalized was waiting in the ED without any time limit due to hospital crowding. The core content was to limit the staying time of each patient waiting for hospitalization to 24 hours from ED arrival. The hypothesis of this study was that the boarding restriction protocol would alleviate ED crowding. We conducted this study to confirm this protocol's effect on ED crowding.

MATERIALS AND METHODS

Study design and setting

This study was a pre-post comparative study conducted in the ED of a tertiary university hospital located in an urban area. The hospital operates about 2200 beds, with an average annual bed utilization rate of 80%. The ED was divided into an adult ED and a pediatric ED, and the adult ED, in which this study was conducted, consisted of a monitoring area (13 beds), a bed area (29 beds), a chair area (20 recliners), and a fast track area. The adult ED treated patients over 16 years of age, and the number of visiting patients was about 90000 per year. 20% of visiting patients were hospitalized, and the average waiting time for hospitalization was 10 hours. About 5% of patients stayed in the ED for more than 24 hours. An emergency physician or emergency medicine trainee began the treatment for all patients who came to the ED, and if hospitalization was deemed necessary, consultation with a relevant specialist was conducted to determine whether the patients ought to be hospitalized. When hospitalization was decided, the attending physician became the subject of treatment for the patient, and treatment continued in the ED until the hospital bed was ready. When transferring a patient to another hospital, the hospital was arranged by requesting to the ED coordinator. The boarding restriction protocol began in November 2019; however, coronavirus disease (COVID-19) infection began to spread in Korea from February 2020, which greatly affected the treatment process of the ED.[22-24] Therefore, the duration of this study was set for 9 weeks starting from the first week of December 2019, and we compared the same period 1 year previous in consideration of seasonal variations in ED crowding. All data were collected by the hospital information system and processed anonymously, and this study was exempt from the obligation to obtain patient informed consent from the Institutional Review Board of Severance hospital (approval number: 4-2020-1164).

Boarding restriction protocol

The boarding restriction protocol is directed for patients requiring hospitalization, and the purpose of the protocol is to move these patients out of the ED within 24 hours from ED arrival (Fig. 1). The strategy seeks to allocate hospital beds as much as possible within 18 hours from ED arrival. If bed assignment is not made within 18 hours, a text message is sent to the attending physician informing that the patient could not be admitted due to the absence of a hospital bed. When the attending physician decides to transfer the patient to another hospital, the ED coordinator arranges an appropriate hospital according to the patient's condition and dispatches the patient within 24 hours. If the patient cannot be transferred to another hospital for a severe condition or patient disagreement with the transfer, the attending physician can decide to keep the patient in this hospital. Patients who decide to keep waiting for hospitalization are given priority bed allocation over other waiting patients at the attending physician's outpatient clinic.

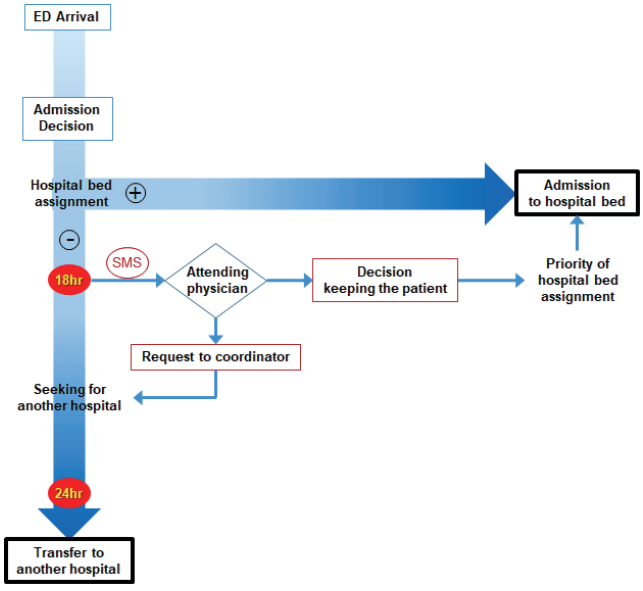

Fig. 1. Boarding restriction protocol. ED, emergency department; SMS, short message service.

Crowding indicators

As the primary outcome of this study, we investigated ED occupancy rate. The definition of ED occupancy rate was the ratio of the number of occupying patients to the total number of beds in the ED.[25] Although there is no universally accepted tool to measure ED crowding, ED occupancy rate is one reliable method that has been used in many previous studies.[26,27] To obtain ED occupancy rate, we reconstructed the dataset of the number of ED occupying patients at 10-minute intervals from the time of arrival and departure of each patient. A total of 9072 ED occupancy rate values were generated for the pre- and post-period, and the difference in crowding between the two periods was examined. Time series analysis of ED occupancy rate at 10-minute intervals from January 2018 was performed to confirm whether there was a significant change in crowding trends after implementation of the boarding restriction protocol.

The secondary outcome was the proportion of patients who stayed longer than 24 hours and ED LOS. Time factors were also investigated according to the ED treatment process. The treatment time was the time taken from ED arrival to the decision of disposition (admission, discharge, or transfer). The decision time of transferred patients was based on the time when doctors requested the arrangement of proper hospital to the coordinator. Boarding time was defined as the time from the decision of disposition to the time of leaving the ED.

Since the target of this protocol is boarding patients, their LOS and occupancy in the ED were analyzed in more detail. ED occupancy by patients who were deemed to require hospitalization but remained in the ED was reconstructed at 10-minute intervals using each patient's admission decision time and ED departure time. Since hospitalization patterns vary between weekdays and weekends, the number of patients admitted to hospital beds and ED LOS were analyzed according to the day of the week.

At this hospital, every morning, the administrative team counted the number of patients who were hospitalized and discharged the previous day, as well as the number of occupying patients at 8:00 am to calculate the hospital bed occupancy rate. The hospital bed occupancy rate was the number of occupying patients out of the total number of hospital beds. We used this data to compare hospital crowding between the pre- and post-periods.

Study variables

Patient data were extracted from the hospital information system and electric medical records. We checked whether the patient was transferred from another hospital and whether the patient arrived via emergency medical service. The result of triage by Korean Triage and Acuity Scale (KTAS), a five-point classification scale (1=resuscitation, 5=non-emergent), was investigated.[28] The complaint category was the organ system that corresponded to the main symptom of which the patient complained. Non-medical problems referred to visits due to external reasons, such as trauma, poisoning, or environmental factors. Severe disease corresponded to diagnosis of a disease that has been designated with a severe diagnosis code by the Central Emergency Medical Center under the Ministry of Health and Welfare (Supplementary Table 1, only online).[29] We investigated whether the emergency physician treated and the area where the treatment started. Time of ED arrival and weekend were classified based on the time the patient arrived at the ED. Laboratory study, imaging study (x-ray, computed tomography, magnetic resonance imaging), and specialty consultation performed during the stay in the ED were also confirmed.

Statistical analysis

Nominal variables of the pre- and post-periods were compared using the chi-square test and presented as numbers with percentages. Continuous variables were analyzed using Student's t-test and presented as means and standard deviations. Time factor variables were analyzed using Mann-Whitney U test considering the positive skewness of the data distribution and are presented as medians and interquartile ranges. The time-series analysis of the ED occupancy rate was analyzed using a Bayesian structural time series model.[30] A logistic regression for patients staying longer than 24 hours and a generalized linear regression for ED LOS were performed by selecting influencing variables with p-value less than 0.05 in univariable analysis. Data reconstruction and statistical analysis were performed using SAS (version 9.4, SAS Inc., Cary, NC, USA). The time series analysis was performed with the R package, version 4.0.1 (R Foundation for Statistical Computing, Vienna, Austria). A p value less than 0.05 was deemed to be statistically significant.

RESULTS

Patient characteristics

12498 patients during the pre-period and 13050 patients during the post-period were treated in the ED (Table 1). The sex and age of both groups were similar, and the proportion of patients who were transferred from other hospitals decreased from 12.9% in the pre-period to 10.8% in the post-period (p<0.001). The proportion of less urgent patients with KTAS 4 and 5 decreased during the post-period, and the proportion of patients diagnosed with severe disease increased from 17.8% to 18.9% (p=0.031). The rates of laboratory study and specialty consultation were similar between the two periods; however, among imaging studies, computed tomography was performed more in the post-period (37.5% vs. 38.9%, p=0.020). As a result of treatment, the number of hospitalized patients decreased from 2853 (22.8%) to 2793 (21.4%), and the number of patients who were sent to other hospitals increased from 347 (2.8%) to 399 (3.1%) (p=0.013).

https://doi.org/10.3349/ymj.2022.63.5.470

Table 1. Comparison of Patient Characteristics between the Pre- and Post-Period

Variable	Pre-period (n=12498)	Post-period (n=13050)	*p*-value
Age			0.976
<40	3897 (31.9)	4151 (31.8)	
40–65	4502 (36.0)	4697 (36.0)	
>65	4009 (32.1)	4202 (32.2)	
Female	6719 (53.8)	6930 (53.1)	0.293
Transfer in	1612 (12.9)	1404 (10.8)	<0.001
EMS	2995 (24.0)	3144 (24.1)	0.811
KTAS			<0.001
1	200 (1.6)	201 (1.5)	
2	960 (7.7)	1172 (9.0)	
3	2651 (21.2)	3798 (29.1)	
4	6857 (54.9)	6508 (49.9)	
5	1830 (14.6)	1371 (10.5)	
Complaint category			0.806
Gastrointestinal	2498 (20.0)	2538 (19.5)	
General	2086 (16.7)	2242 (17.2)	
Neurological	1815 (14.5)	1844 (14.1)	
Cardiovascular	1290 (10.3)	1388 (10.6)	
Musculoskeletal	1084 (8.7)	1119 (8.6)	
Respiratory	993 (8.0)	1014 (7.8)	
ENT	818 (6.6)	845 (6.5)	
Skin	794 (6.4)	843 (6.5)	
Other	1120 (9.0)	1217 (9.3)	
Severe disease	2234 (17.8)	2469 (18.9)	0.031
Emergency physician	5433 (43.5)	5238 (40.1)	<0.001
Area			<0.001
Monitoring area	1000 (8.0)	922 (7.1)	
Bed area	2101 (16.8)	2497 (19.1)	
Chair area	2093 (16.8)	2754 (21.0)	
Fast track	7304 (58.6)	6877 (52.7)	
Time of ED arrival			0.347
0–6	2265 (18.1)	2329 (17.9)	
6–12	3531 (28.3)	3807 (29.2)	
12–18	3786 (30.3)	3858 (29.6)	
18–24	2916 (23.3)	3056 (23.4)	
Weekend	4131 (33.1)	4061 (31.1)	0.001
Laboratory study	8892 (71.2)	9237 (70.8)	0.520
Imaging study			
X-ray	9428 (75.4)	9955 (76.3)	0.114
CT	4680 (37.5)	5071 (38.9)	0.020
MRI	679 (5.4)	688 (5.3)	0.568
Specialty consultation	6960 (55.7)	7275 (55.8)	0.925
Treatment result			0.013
Admission	2853 (22.8)	2793 (21.4)	
Discharge	9298 (74.4)	9858 (75.5)	
Transfer	347 (2.8)	399 (3.1)	

EMS, emergency medical services; KTAS, Korean Triage and Acuity Scale; ENT, ear, nose, and throat; ED, emergency department; CT, computed tomography; MRI, magnetic resonance imaging.
Data are presented as n (%).

ED crowding

As a result of analyzing ED occupancy rate at 10-minute intervals, the mean ED occupancy rate decreased from 1.532±0.432 in the pre-period to 1.273±0.353 in the post-period (p<0.001). Fig. 2 shows the distribution of ED occupancy rates according to the day and time of the week. Overall, ED occupancy rates in the post-period decreased throughout the week, compared to the pre-period. The pattern of crowding resolved at dawn and worsening in the afternoon was observed in both periods. Crowding gradually worsened from Monday to Thursday in the pre-period, although this feature was not observed in the post-period. Fig. 3 shows the results of the time series analysis of the ED occupancy rate. During the post-period, the mean (95% confidence interval) ED occupancy rate predicted by the time series model was 1.462 (1.383–1.550). However, after implementation of the protocol, the mean ED occupancy rate was 1.273, which was lower than the predicted value, resulting in an absolute effect of the protocol of -0.189 (-0.277 to -0.110). (p=0.001).

The number of patients leaving the ED beyond the goal of this protocol of 24 hours decreased from 951 (7.6%) to 525 (4.0%) (p<0.001). The results of logistic regression analysis for the proportion of patients with LOS exceeding 24 hours are shown in Table 2. After correcting for influencing factors, the effect of the protocol on LOS over 24 hours was statistically significant with an odds ratio (OR) of 0.433 (0.384–0.489). Among admitted patients, the post-period had an adjusted OR of 0.428 (0.372–0.492) for patients staying over 24 hours (Supplementary Table 2, only online).

The ED LOS of all patients was 238.2 (134.0–465.2) minutes in the pre-period and 238.3 (136.9–451.2) minutes in the post-period (Table 3). After adjusting for influencing factors, the post-period was a significant factor for ED LOS, with an adjusted OR of -99.3 (-113.1 to -85.4) (Supplementary Table 3, only online). Among admitted patients, ED LOS decreased from 770.7 (421.4–1587.1) minutes to 630.2 (398.0–1156.8) minutes (p<0.001), with an adjusted OR of -310.9 (-360.6 to -261.3) (Supplementary Table 4, only online). Treatment time increased 7.9% from 319.6 (198.5–482.8) minutes to 344.7 (213.4–519.5) minutes (p<0.001), while boarding time decreased 31.8% from 298.9 (109.5–1149.0) minutes to 204.1 (98.7–545.7) minutes (p<0.001). The ED LOS of transferred patients increased from 379.1 (255.8–695.5) minutes to 443.8 (278.3–695.5) minutes, and the boarding time increased 50.2% from 93.3 (55.1–164.6) minutes to 140.1 (89.4–226.9) minutes.

Weekly boarding pattern

Fig. 4 shows the distribution of the arrival and departure days of the admitted patients by day of the week. During the pre-period, the number of patients admitted to hospital beds was smaller than the number of patients who arrived at the ED from Monday to Thursday, maintaining a positive difference, and from Friday, more patients could be hospitalized. During

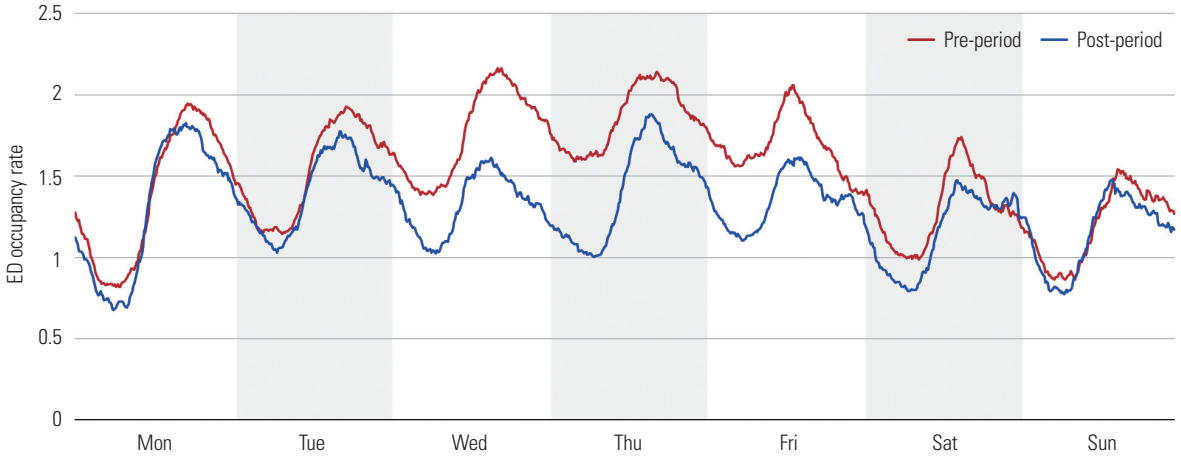

Fig. 2. Distribution of the ED occupancy rate according to day of week and time. The occupancy rate during the day is the lowest during early morning and then increases in the afternoon. Crowding gradually worsened from Monday to Thursday in the pre-period, but this feature was not observed in the post-period. ED, emergency department.

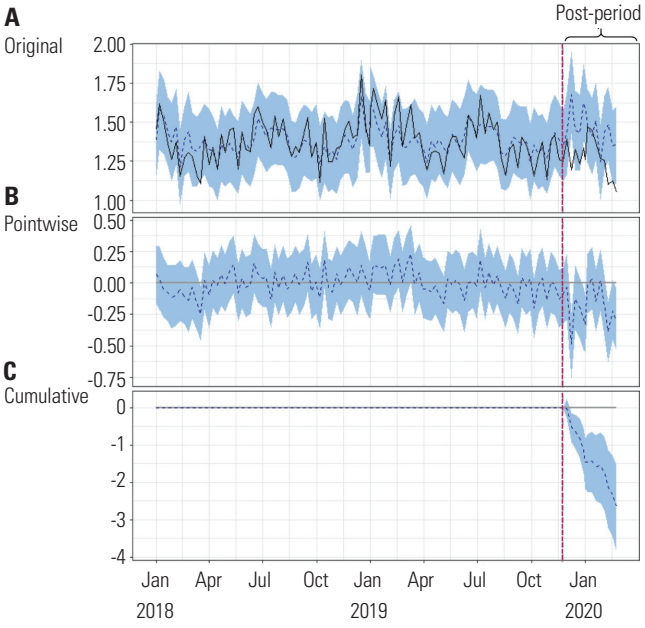

Fig. 3. Time series analysis of the ED occupancy rate. (A) The solid black line is the observed value of the ED occupancy rate, and the dotted blue line is the predicted value through the Bayesian structural time series model. The sky blue zone indicates the values between the upper and lower 95% CIs. During the post-period, the mean of the observed values was 1.273 and the mean (95% CI) of the predicted values was 1.462 (1.383–1.550), and the absolute effect, the difference between the two values, was -0.189 (-0.277 to -0.110) (p=0.001). (B) The line shows the difference between the observed and predicted values (observed-predicted value) at each time point. (C) The line indicates the cumulative difference between the observed and the predicted value, and the slope of the line shows a negative direction in the post-period. ED, emergency department; CI, confidence interval.

the post-period, the number of patients arriving and leaving on Tuesday and Wednesday remained similar, and hospitalization was less concentrated on Friday, compared to the pre-period. In the pre-period, the ED LOS of patients arriving from Tuesday to Thursday was significantly delayed, although this feature was alleviated in the post-period.

The median number of boarding patients measured at 10-minute intervals was 21.0 (12.0–37.0) in the pre-period and 10.0 (7.0–19.0) in post-period, a decrease of 52.4% (p<0.001). In the distribution of boarding patients, the number of patients continuously increased from Monday to Thursday and then rapidly decreased on Friday in the pre-period (Fig. 5). The number of boarding patients during the post-period was also higher on weekdays than on weekends, although the difference was much less than that in the pre-period.

The total number of patients admitted to this hospital was 21626 in the pre-period and 21258 in the post-period. Among them, 2839 (13.1%) and 2794 (13.1%) patients were admitted via ED, respectively, and there was no statistically significant difference between the two periods (p=0.962). The hospital bed occupancy rate in both groups was similar to 0.863 (0.812–0.876) in the pre-period and 0.838 (0.792–0.888) in the post-period (p=0.361).

DISCUSSION

In this study, we confirmed that the boarding restriction protocol significantly reduces ED occupancy rates by reducing the LOS of admitting patients. It is well known that the main driver of ED crowding is obstruction of outflow.[13,31,32] Since access block is caused by crowding of the entire hospital, the solution should not be limited to the ED to be effective, and bed capacity must be increased in consideration of patient flow throughout the whole hospital.[20,33,34] However, there is still not much leadership in recognition the ED crowding as a whole hospital problem, and it can be also related to the hospital's profits, making it difficult to change hospitalization policies for the entire hospital to solve ED crowding.[20,21] For this reason, we could not apply the boarding protocol to the entire hospital and had to start targeting only emergency patients inside the ED, even

https://doi.org/10.3349/ymj.2022.63.5.470

Table 2. Logistic Regression Analysis for ED Length of Stay over 24 Hours

Variables	Univariable		Multivariable	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Age				
<40	1		1	
40–65	3.737 (3.108–4.493)	<0.001	1.638 (1.344–1.995)	<0.001
>65	5.574 (4.653–6.676)	<0.001	1.448 (1.186–1.768)	<0.001
Female	0.579 (0.520–0.644)	<0.001	0.728 (0.648–0.818)	<0.001
Transfer in	2.398 (2.112–2.724)	<0.001	1.018 (0.882–1.174)	0.811
EMS	2.314 (2.078–2.578)	<0.001	1.120 (0.975–1.286)	0.109
KTAS				
1	1.660 (1.249–2.207)	0.001	1.535 (1.074–2.195)	0.019
2	1.103 (0.939–1.294)	0.233	0.982 (0.809–1.192)	0.855
3	1		1	
4	0.359 (0.318–0.405)	<0.001	0.720 (0.612–0.849)	<0.001
5	0.198 (0.153–0.255)	<0.001	0.688 (0.510–0.927)	0.014
Complaint category				
Gastrointestinal	1		1	
General	0.725 (0.596–0.882)	0.697	1.404 (1.178–1.673)	<0.001
Neurological	0.098 (0.056–0.170)	<0.001	0.233 (0.182–0.298)	<0.001
Cardiovascular	0.970 (0.830–1.133)	0.001	0.552 (0.443–0.687)	<0.001
Musculoskeletal	0.300 (0.223–0.402)	<0.001	0.556 (0.402–0.768)	<0.001
Respiratory	0.526 (0.433–0.639)	<0.001	1.570 (1.313–1.876)	<0.001
ENT	0.349 (0.266–0.457)	<0.001	0.402 (0.225–0.717)	0.002
Skin	2.618 (2.240–3.060)	<0.001	0.928 (0.545–1.582)	0.785
Others	0.130 (0.080–0.212)	<0.001	0.476 (0.355–0.637)	<0.001
Severe disease	4.374 (3.928–4.870)	<0.001	1.545 (1.362–1.754)	<0.001
Emergency physician	3.678 (3.278–4.127)	<0.001	1.150 (0.987–1.341)	0.074
Area				
Monitoring area	4.887 (4.207–5.676)	<0.001	1.396 (1.123–1.736)	0.003
Bed area	3.080 (2.711–3.499)	<0.001	1.276 (1.085–1.500)	0.003
Chair area	0.838 (0.698–1.006)	0.058	0.674 (0.553–0.821)	<0.001
Fast track	1		1	
Time of ED arrival				
0–6	1		1	
6–12	3.369 (2.724–4.167)	<0.001	2.285 (1.796–2.906)	<0.001
12–18	3.893 (3.156–4.802)	<0.001	2.645 (2.080–3.362)	<0.001
18–24	1.512 (1.191–1.920)	0.001	1.283 (0.993–1.658)	0.057
Weekend	0.219 (0.184–0.260)	<0.001	0.248 (0.206–0.298)	<0.001
Laboratory study	329.848 (82.405–>999.999)	<0.001	65.286 (16.112–264.541)	<0.001
Imaging study				
X-ray	19.179 (13.002–28.292)	<0.001	2.408 (1.595–3.633)	<0.001
CT	3.671 (3.282–4.106)	<0.001	1.971 (1.738–2.234)	<0.001
MRI	2.061 (1.722–2.467)	<0.001	2.557 (2.024–3.229)	<0.001
Specialty consultation	5.344 (4.602–6.207)	<0.001	2.114 (1.784–2.505)	<0.001
Period				
Pre	1		1	
Post	0.514 (0.461–0.574)	<0.001	0.433 (0.384–0.489)	<0.001

OR, odds ratio; CI, confidence interval; EMS, emergency medical services; KTAS, Korean Triage and Acuity Scale; ENT, ear, nose, and throat; ED, emergency department; CT, computed tomography; MRI, magnetic resonance imaging.

though our protocol aimed to solve output from the ED. Even so, our protocol likely would have affected patient flow throughout the entire hospital, because we not only moved patients out of the hospital, but also gave the attending physician the authority to decide whether to hospitalize emergency patients over patients in outpatient clinics.

As discharged patients accounted for 75.5% of all patients who were not subject to this protocol, the entire ED LOS was not reduced. Among admitted patients, we were able to see an interesting phenomenon in which ED LOS decreased as boarding time was significantly reduced while treatment time increased. We suspect that it took a longer time to make admission decisions because patients could not board indefinitely in the ED until hospitalization, thereby making the attending physician more cautious with their decision making. This finding is in line with previous studies indicating that increased ED crowding is associated with a decrease in decision making for hospitalization.[35,36] Crowding of the ED is a desperate situation for emergency staff as it hinders providing adequate first aid to new emergency patients; however, attending physicians outside the ED are generally not directly affected by ED crowding. Until this protocol was initiated, the attending physicians made admission decisions without considering the availability of hospital beds, and allocating beds was the responsibility of administrative staff. Since administrative staff could not consider the medical condition of patients, patient safety was inevitably threatened when hospital beds were insufficient. With implementation of this protocol, attending physicians were forced to face the problem of hospital bed shortages and intervene in the assignment of beds. As such, emergency patients were given the opportunity to have bed priority.

Through this study, we could see that patients waiting for hospitalization were congested in the ED on weekdays and resolved on Friday and Saturday, which was resolved considerably after this protocol. A significantly longer ED LOS for admitted patients who arrived at the ED on Tuesday, Wednesday, and Thursday was also resolved. Since scheduled hospitalization is primarily conducted on weekdays, a delay in emergency

Table 3. Comparison of ED LOS and Time Factors between the Pre- and Post-Period

Variable	Pre-period, median (IQR)	Post-period, median (IQR)	*p*-value
Total patients			
ED LOS	238.2 (134.0–465.2)	238.3 (136.9–451.2)	0.286
Treatment time	189.5 (107.5–335.3)	189.9 (110.3–338.7)	0.235
Boarding time	22.0 (9.3–83.8)	23.8 (10.3–83.9)	0.011
Admitted patients			
ED LOS	770.7 (421.4–1587.1)	630.2 (398.0–1156.8)	<0.001
Treatment time	319.6 (198.5–482.8)	344.7 (213.4–519.5)	<0.001
Boarding time	298.9 (109.5–1149.0)	204.1 (98.7–545.7)	<0.001
Discharged patients			
ED LOS	182.0 (115.1–306.3)	186.7 (119.1–305.5)	0.049
Treatment time	158.3 (95.4–278.2)	160.0 (97.5–272.3)	0.782
Boarding time	14.1 (7.5–29.4)	15.5 (8.3–33.3)	<0.001
Transferred patients			
ED LOS	379.1 (255.8–695.5)	443.8 (278.3–695.5)	0.006
Treatment time	267.4 (147.9–432.7)	282.6 (144.4–441.2)	0.479
Boarding time	93.3 (55.1–164.6)	140.1 (89.4–226.9)	<0.001

IQR, interquartile range; ED LOS, emergency department length of stay.

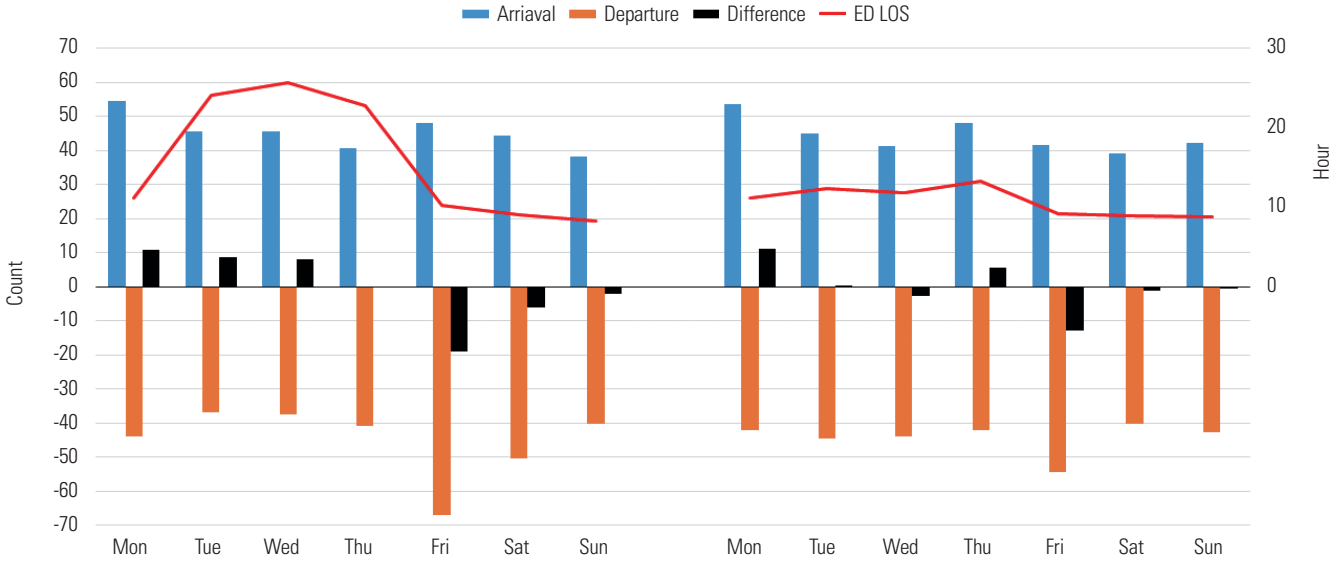

Fig. 4. Distribution of the arrival and departure days of admitted patients and ED LOS by day of the week. The blue bar indicates the mean number of admitted patients according to the arrival day, the orange bar indicates the mean number of admitted patients according to the departure day, and the black bar indicates the difference between the two numbers. During the pre-period, there were more arriving patients than departing patients from Monday to Thursday, and the number of departing patients increased drastically on Friday. This pattern was observed to a lesser degree in the post-period. In the pre-period, the ED LOS (the red line) of admitted patients arriving from Tuesday to Thursday was longer. There was little difference in the ED LOS according to the day of the week in the post-period. ED LOS, emergency department length of stay.

https://doi.org/10.3349/ymj.2022.63.5.470

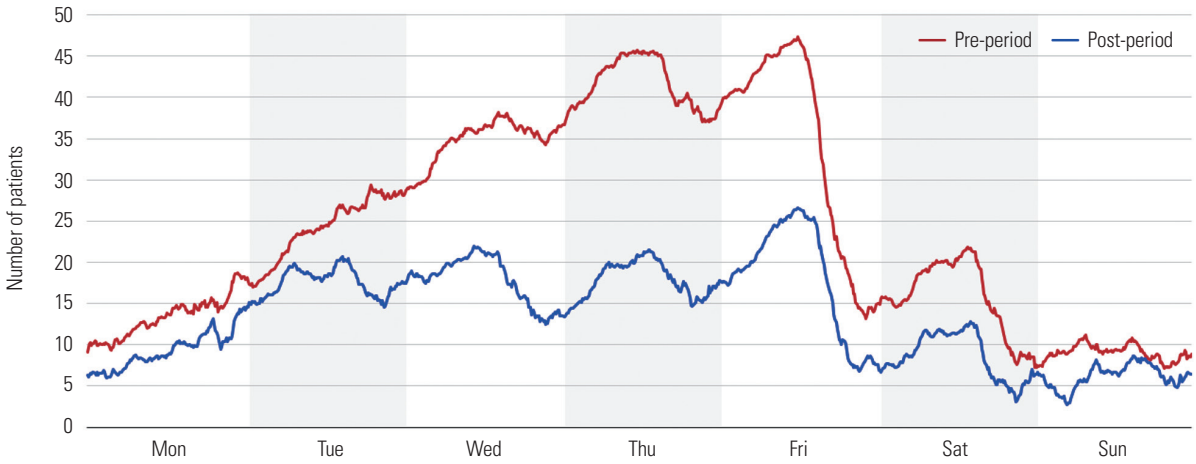

Fig. 5. Distribution of the number of boarding patients in the emergency department according to day of week and time. The number of boarding patients continuously increased from Monday to Thursday and decreased on Friday in the pre-period. In the post-period, the number of boarding patients was higher on weekdays than on weekends, but the difference was small compared to the pre-period.

hospitalization during weekdays has been reported in previous studies.[11,37,38] In most hospitals, medical staff prefer to perform the procedure at the beginning of the week and to discharge the patient before the weekend. This preference is because doctors do not want to work on the weekends; however, if a patient is still in the hospital on the weekends, they will have to take responsibility or continue care.[39] Variations in the hospital's daily inpatient census are the result of a combination of natural variations in emergency hospitalization and an artificial peak and valley of scheduled hospitalizations. A discrepancy between a hospital's available resources and patient demand is a major culprit that degrades the quality of care, impedes access to care, and ultimately threatens the safety of patients.[40,41] In order to efficiently use hospital resources and ensure patient safety, the peaks and valleys of patient demand must be smoothed.[42-44] Interventions introduced in previous studies to smooth demand were accompanied by system changes, such as weekend staffing relocation to alleviate the weekend effect.[20,42,43,45] Although our boarding protocol did not directly intervene in artificial variations, it achieved smoothing of weekly variations in hospitalization through the ED by limiting boarding time in the ED. Further studies should be conducted to determine the effect of smoothing of weekly fluctuations in emergency admission on patient flow throughout the hospital and patient safety. Since it is difficult to cancel scheduled surgeries and procedures, hospitalization of patients who need conservative treatment may be delayed. Excessive delay in scheduled hospitalization, however, may be a factor that hinders patient safety from a long-term perspective, such as delayed chemotherapy. Thus, a system that proactively coordinates overall hospitalizations is essential.

The present study has several limitations. First, because our study has a pre-post comparative design and was performed retrospectively, some confounders may have been unidentified. Second, to avoid the COVID-19 outbreak period, which had a major impact on ED processes, a short study period of 9 weeks was inevitable. Thus, it was impossible to ascertain the long-term effects of this protocol. Finally, this study was conducted at a single tertiary hospital with a high bed occupancy of more than 80% and a significantly long boarding time in the ED. Therefore, the effect of this protocol may be different at hospitals where the degree of crowding and the patterns of patient flow are different.

In conclusion, we confirmed that a boarding restriction protocol was effective in reducing ED crowding. This was possible because weekly variations in emergency hospitalization were alleviated by facilitating hospitalization of emergency patients during weekdays. Further research is needed to study changes brought on patient flow throughout the hospital and their impact on patient safety and hospital revenue.

ACKNOWLEDGEMENTS

We would like to thank Young Ho Lee, deputy general manager of the Department of Planning and Budgeting, for his support in establishing and implementing this protocol.

This work was supported by the National Research Foundation of Korea grant funded by the Korea government (Ministry of Science and ICT) (no. 2017R1C1B5076958).

AUTHOR CONTRIBUTIONS

Conceptualization: Ji Hwan Lee, Ji Hoon Kim, and Min Joung Kim. Data curation: Ji Hwan Lee and Hyun Sim Lee. Formal analysis: Joon Min Park, Min Joung Kim, Won Jeong Son, and Yun Ho Roh. Funding acquisition: Min Joung Kim. Investigation: Hyun Sim Lee. Methodology: Joon Min Park and Min Joung Kim. Project administration: Incheol Park and Min Joung Kim. Resources: Ji Hwan Lee and Hyun Sim Lee. Software: Ji Hwan Lee and Ji Hoon Kim. Supervision: Incheol Park, Sung Phil Chung, and Hyeon Chang Kim. Validation: Ji Hwan Lee and Ji Hoon Kim. Visualization: Min Joung Kim, Won Jeong Son,

and Yun Ho Roh. Writing—original draft: Ji Hwan Lee, Ji Hoon Kim, and Min Joung Kim. Writing —review & editing: Min Joung Kim. Approval of final manuscript: all authors.

ORCID iDs

Ji Hwan Lee https://orcid.org/0000-0002-6908-9459
Ji Hoon Kim https://orcid.org/0000-0002-0070-9568
Incheol Park https://orcid.org/0000-0001-7033-766X
Hyun Sim Lee https://orcid.org/0000-0001-6439-2494
Joon Min Park https://orcid.org/0000-0001-7258-8892
Sung Phil Chung https://orcid.org/0000-0002-3074-011X
Hyeon Chang Kim https://orcid.org/0000-0001-7867-1240
Won Jeong Son https://orcid.org/0000-0002-2973-6615
Yun Ho Roh https://orcid.org/0000-0003-0841-7161
Min Joung Kim https://orcid.org/0000-0003-1634-5209

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