Observational Study

Medicine®

OPEN

Impact of nighttime and weekends on outcomes of emergency trauma patients

A nationwide observational study in Japan

Tomoya Hirose, MD, PhD[a,b,*], Tetsuhisa Kitamura, MD, DrPH[c], Yusuke Katayama, MD, PhD[a], Junya Sado, PhD[d], Takeyuki Kiguchi, MD, PhD[e], Tasuku Matsuyama, MD, PhD[f], Kosuke Kiyohara, DrPH[g], Hiroki Takahashi, MD[h], Jotaro Tachino, MD[a], Yuko Nakagawa, MD, PhD[a], Yasuaki Mizushima, MD, PhD[b], Takeshi Shimazu, MD, PhD[a]

Abstract

The impact of time of day or day of week on the survival of emergency trauma patients is still controversial. The purpose of this study was to evaluate the outcomes of these patients according to time of day or day of week of emergency admission by using data from the nationwide Japan Trauma Data Bank (JTDB).

This study enrolled 236,698 patients registered in the JTDB database from 2004 to 2015, and defined daytime as 09:00 AM to 16:59 PM and nighttime as 17:00 PM to 08:59 AM, weekdays as Monday to Friday, and weekends as Saturday, Sunday, and national holidays. The outcome measures were death in the emergency room (ER) and discharge to death.

In total, 170,622 patients were eligible for our analysis. In a multivariable logistic regression adjusted for confounding factors, both death in the ER and death at hospital discharge were significantly lower during the daytime than at nighttime (623/76,162 [0.82%] vs 954/94,460 [1.01%]; adjusted odds ratio [AOR] 0.79; 95% confidence interval [CI] 0.71–0.88 and 5765/76,162 [7.57%] vs 7270/94,460 [7.70%]; AOR 0.88; 95% CI 0.85–0.92). In contrast, the weekdays/weekends was not significantly related to either death in the ER (1058/114,357 [0.93%] vs 519/56,265 [0.92%]; AOR 0.95; 95% CI 0.85–1.06) or death at hospital discharge (8975/114,357 [7.85%] vs 4060/56,265 [7.22%]; AOR 1.02; 95% CI 0.97–1.06).

In this population of emergency trauma patients in Japan, both death in the ER and death at hospital discharge were significantly lower during the daytime than at night, but the weekdays/weekends was not associated with outcomes of these patients.

Abbreviations: AIS = Abbreviated Injury Scale, AOR = adjusted odds ratio, CI = confidence interval, ER = emergency room, IQR = interquartile range, ISS = Injury Severity Score, JTDB = Japan Trauma Data Bank, MTCs = major trauma centres, ORs = odds ratios, Ps = probability of survival, TRISS = Trauma Injury Severity Score, UK = United Kingdom.

Keywords: mortality, night, registry, trauma, weekend

1. Introduction

In many previous studies, worse outcomes have been shown for patients admitted to hospital during the weekend, and this is called the "weekend effect".[1–3] The weekend effect has been reported in various settings such as acute stroke,[4] myocardial infarction,[5] lower extremity ischemia,[6] emergency general surgery,[7] sepsis,[8] and cardiopulmonary arrest.[9] Some studies also evaluated survival outcome by time of day and reported poor survival outcomes for patients with out-of-hospital cardiac arrest[9,10] or trauma[11–13] treated at night.

However, some studies found the weekend effect to be controversial in trauma patients.[14–16] In major trauma centres (MTCs) in the United Kingdom (UK), major trauma admissions

Editor: Ediriweera Desapriya.

This study was supported by a medical research grant on traffic accident from The General Insurance Association of Japan.

We certify that the authors declare no ethical or financial conflicts of interest in relation to this manuscript.

[a] Department of Traumatology and Acute Critical Medicine, Osaka University Graduate School of Medicine, [b] Emergency and Critical Care Center, Osaka Police Hospital, [c] Division of Environmental Medicine and Population Sciences, Department of Social and Environmental Medicine, [d] Medicine for Sports and Performing Arts, Department of Health and Sport Sciences, Osaka University Graduate School of Medicine, [e] Kyoto University Health Services, [f] Department of Emergency Medicine, Kyoto Prefectural University of Medicine, Kyoto, [g] Department of Food Science, Faculty of Home Economics, Otsuma Women's University, Tokyo, [h] Department of Emergency and Critical Care Medicine, Kansai Medical University, Osaka, Japan.

[*] Correspondence: Tomoya Hirose, Department of Traumatology and Acute Critical Medicine, Osaka University Graduate School of Medicine, 2-15 Yamadaoka, Suita, Osaka 565-0871, Japan (e-mail: htomoya1979@hp-emerg.med.osaka-u.ac.jp).

How to cite this article: Hirose T, Kitamura T, Katayama Y, Sado J, Kiguchi T, Matsuyama T, Kiyohara K, Takahashi H, Tachino J, Nakagawa Y, Mizushima Y, Shimazu T. Impact of nighttime and weekends on outcomes of emergency trauma patients: A nationwide observational study in Japan. Medicine 2020;99:1(e18687).

Received: 7 May 2019 / Received in final form: 8 November 2019 / Accepted: 10 December 2019

http://dx.doi.org/10.1097/MD.0000000000018687

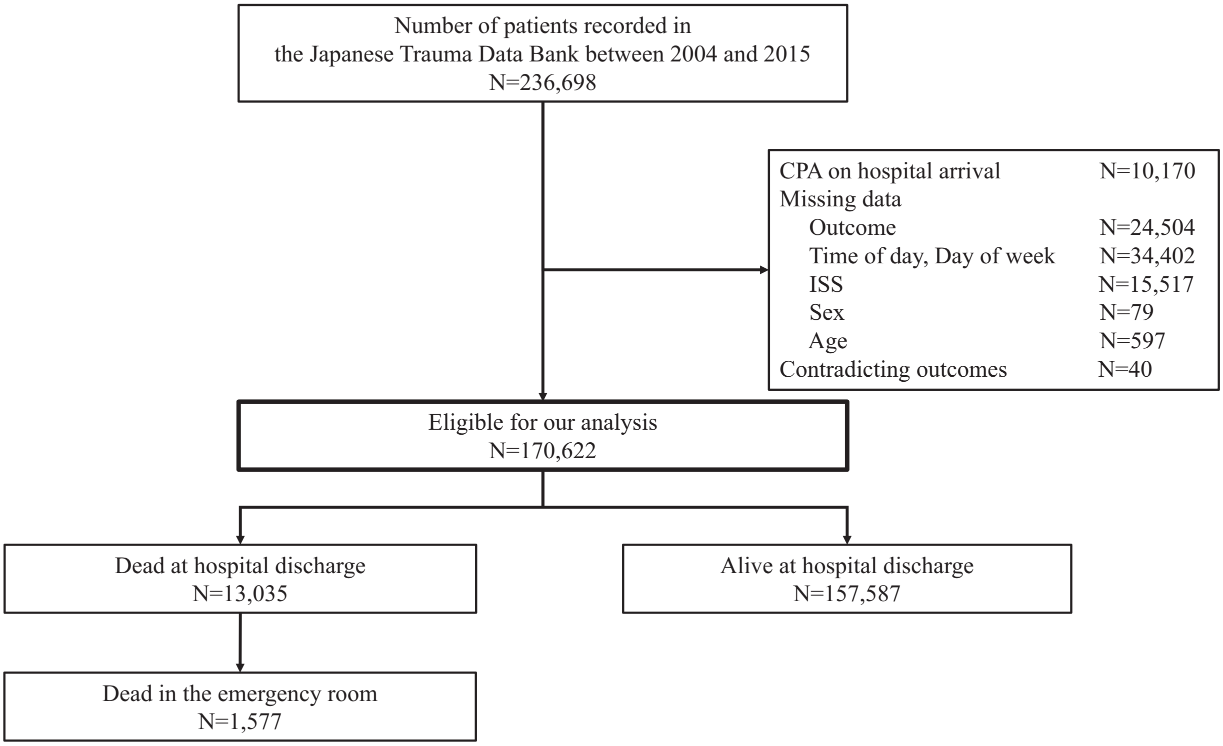

Figure 1. The patient flow in this study.

on the weekend, and at nighttime were not associated with increased mortality.[14] However, an earlier study using the National Trauma Data Bank in the United States showed that patients admitted at night were 1.18 times more likely to die than those presenting within working hours.[12] In a single-center retrospective study in Japan, the mortality in trauma patients requiring subspecialty intervention (open reduction with internal fixation for open fractures of extremities or laparotomy, craniotomy, thoracotomy, or transarterial embolization) was not different between business hours and off hours, but the impact on the outcome of the trauma patients transported urgently according to time of day and day of the week was not evaluated sufficiently.[17]

The Japanese Trauma Data Bank (JTDB) is a nationwide trauma registry that is managed by the Japanese Association for the Surgery of Trauma. Data registration in the JTDB was launched in 2003 and approximately 230,000 emergency patients with trauma were enrolled by 2015. We hypothesized that survival rates of emergency patients with trauma in Japan would be lower in those admitted at night compared with daytime and in those admitted on weekends/holidays compared with weekdays. The aim of the present study was to confirm this hypothesis.

2. Methods

2.1. Study design, population, and setting

This was a retrospective observational study using the JTDB database. The study period spanned 12 years from January 2004 to December 2015. We included all emergency trauma patients registered in the JTDB database. We excluded the following patients:

Those with

1. cardiopulmonary arrest on hospital arrival,
2. missing data (outcome, time of day, day of week, Injury Severity Score [ISS], sex, age),
3. contradicting outcome (patients registered as both "death in emergency room [ER]" and "alive at hospital discharge").

This study was approved by the Ethics Committee of the Osaka University Graduate School of Medicine. Personal identifiers were removed beforehand from the JTDB database, and thus the patients' right to informed consent was waived.

Figure 1 shows the patient flow in this study. During the study period, 236,698 emergency patients were registered in the JTDB. We excluded the following patients: those with cardiopulmonary arrest on hospital arrival (n = 10,170); with missing data on outcome (n = 24,504), time of day or day of week of admission (n = 34,402), ISS (n = 15,517), sex (n = 79), age (n = 597); and with contradicting outcome (n = 40). Finally, 170,622 patients were eligible for our analysis. Among them, 157,587 patients (92.4%) survived to discharge, 1577 (0.92%) died in the ER, and 13,035 (7.6%) died in the hospital.

2.2. Japanese trauma data bank

The JTDB was launched in 2003 by the Japanese Association for the Surgery of Trauma (Trauma Surgery Committee) and the Japanese Association for Acute Medicine (Committee for Clinical Care Evaluation).[18] In 2016, 256 major emergency medical institutions across Japan were registered in the JTDB database. These hospitals have ability equal to Level I trauma centres in the United States. Data were collected via the Internet from the participating institutions. In most cases, physicians and medical assistants who attended an Abbreviated Injury Scale (AIS) coding course registered the data. The JTDB captures data on trauma patients that includes age; sex; mechanism of injury; AIS code (version 1998); ISS; vital signs on hospital arrival; date, and time series from hospital arrival to discharge; medical procedures such as interventional radiology, surgical operations, and computed tomography scanning; and complications and mortality at discharge. ISS was calculated from the top 3 AIS scores in 9 sites classified by AIS code.

We extracted the following patient data from the JTDB database: age; sex; time of day and day of week of admission; cause of trauma; type of trauma; emergency life-saving technician attendance; systolic blood pressure, heart rate, respiratory rate, and Glasgow Coma Scale score on hospital arrival; ISS; Trauma Injury Severity Score (TRISS) probability of survival (Ps) rate; and prognosis (ER outcome, hospital outcome).

2.3. Endpoint

The primary endpoint was death in the ER, and the secondary endpoint was discharge to death.

2.4. Statistical analysis

In this study, we defined daytime as 09:00 AM to 16:59 PM and nighttime as 17:00 PM to 08:59 AM, weekdays as Monday to Friday, and weekends as Saturday, Sunday, and national holidays based on a previous study.[9] Hospital, patient, and emergency medical services characteristics and outcomes were evaluated between these 4 groups using the Wilcoxon rank-sum test for continuous variables and the Chi-Squared test or Fisher exact test for categorical variables. Characteristics and outcomes were also evaluated between the 2 groups. Continuous variables are presented as the median and interquartile range (IQR).

The homogeneity of circadian and weekly distribution was assessed by Chi-Squared tests. One-way analysis of variance (ANOVA) was used to evaluate the differences in the day of the week or the time of day. Multivariable analysis of the eligible trauma patients was used to assess factors associated with the outcomes by using logistic regression models, and odds ratios (ORs) and their 95% confidence intervals (CIs) were calculated. Potential confounding factors based on biological plausibility and previous studies were included in the multivariable analysis. These potential factors were age (continuous value), sex (male, female), time of day (daytime/nighttime), day of the week (weekday/weekend and holiday), and ISS (continuous value). In the subgroup analysis, death in the ER and death at hospital discharge were evaluated by age group (children aged ≤15 years old vs adults aged ≥16 years old) or by trauma severity (TRISS ≤0.5 or >0.5). A P value of <.05 was considered significant. All statistical analyses were performed using JMP 11.0.2 (SAS Institute Inc., Cary, NC, USA).

3. Results

Hospital, patient, and emergency medical characteristics by time of day (nighttime vs daytime) or day of week (weekend/holiday versus weekdays) are shown in Table 1. Compared to the patients admitted at nighttime, those admitted during the daytime were more likely to be older and female but were less likely to have an emergency life-saving technician present and a high ISS score. Patients admitted on weekdays compared to weekend/holidays were more likely to be older and have a higher systolic blood pressure on hospital arrival. Other factors were similar between the groups although there were statistically significant differences because of the very high number of patients enrolled.

Figure 2 shows the proportion of ER deaths (Fig. 2A, by day of week; 2C, by time of day), and the proportion of hospital deaths (Fig. 2B, by day of week; 2D, by time of day) in circadian and weekly distributions. In total, 170,622 patients were admitted: 76,162 during the daytime (including 51,023 on weekdays and 25,139 on weekends/holidays), and 94,460 during nighttime (including 63,334 on weekdays and 31,126 on weekends/holidays). The frequency of death in the ER for each day of the week was uniform ($P = .7569$) whereas that of death at hospital discharge was not ($P = .0002$), with greater frequency measured on Tuesday, Thursday, and Friday. The distribution of death in the ER by time of day was not uniform ($P < .0001$); the numbers of deaths were high in the period from 4:00 AM to 5:59 AM. The distribution of death at hospital discharge by time of day was also not uniform ($P < .0001$); the numbers of deaths were high in the period from 6:00 AM to 7:59 AM.

Table 2 shows the outcomes by time of day or day of week by a multivariable logistic regression model. Deaths both in the ER and at hospital discharge were significantly lower at daytime than at nighttime (623/76,162 [0.82%] vs 954/94,460 [1.01%]; adjusted odds ratio [AOR] 0.79; 95% confidence interval [CI] 0.71–0.88 and 5765/76162 [7.57%] vs 7270/94,460 [7.70%]; AOR 0.88; 95% CI 0.85–0.92; $P < .0001$), respectively. In contrast, weekdays/weekends was not significantly related to either death in the ER (1058/114,357 [0.93%] vs 519/56,265 [0.92%]; AOR 0.95; 95% CI 0.85–1.06; $P = .32$) or death at hospital discharge (8975/114,357 [7.85%] vs 4060/56,265 [7.22%]; AOR 1.02; 95% CI 0.97–1.06; $P = .51$). Even though the death rate in hospital were different in day of week ($P = .0002$ in Fig. 2B), our multivariate regression showed that weekdays/weekends was not significantly related to death at hospital discharge.

Table 3 shows the results of the subgroup analysis. Evaluation of the deaths in the ER and at hospital discharge by age group (children versus adults) showed that in the children, daytime/nighttime and weekdays/weekends were not significantly related to the study endpoints. However, in the adults, both death in the ER and at hospital discharge were significantly lower during daytime than during nighttime (615/71,526 [0.86%] vs 942/89,172 [1.06%]; AOR 0.798, 95% CI 0.717–0.889; $P < .0001$ and 5668/71,526 [7.92%] vs 7146/89,172 [8.01%]; AOR 0.878, 95% CI 0.842–0.914: $P < .0001$, respectively). However, the weekdays/weekends was not significantly related to the endpoints. For TRISS probability of survival ≤0.5, neither daytime/nighttime nor weekdays/weekends was significantly related to the endpoints. In contrast, for TRISS probability of survival >0.5, both death in the ER and at hospital discharge were significantly lower during daytime than nighttime (114/56,834 [0.20%] vs 185/70,556 (0.26%); AOR 0.757, 95% CI 0.597–0.960; $P = .0205$ and 2216/56834 [3.90%] vs 2661/70,556 [3.77%]; AOR 0.884, 95% CI 0.832–0.939: $P < .0001$, respectively). The weekdays/weekends was not significantly related to death at hospital discharge, but when comparing weekday versus weekend/holiday, death in the ER was significantly lower on weekdays (182/85,394 (0.21%) vs 117/41,996 (0.28%); AOR 0.734, 95% CI 0.581–0.927; $P = .0105$).

Table 1

Patient characteristics by time of day or day of week.

	Time of day			Day of week		
	Daytime (N=76,162)	Nights (N=94,460)	*P* value	Weekdays (N=114,357)	Weekends/holidays (N=56,265)	*P* value
Sex, n (%)						
Female	28,641 (37.61)	33,113 (35.06)	<0.0001	41,991 (36.72)	19,763 (35.12)	<.0001
Male	47,521 (62.39)	61,347 (64.94)		72,366 (63.28)	36,502 (64.88)	
Age, years, median (IQR)	64 (41–78)	55 (31–73)	<0.0001	61 (36–76)	58 (34–75)	<.0001
Time of day, n (%)						
Daytime	–	–		51,023 (44.62)	25,139 (44.68)	.8077
Nights	–	–		63,334 (55.38)	31,126 (55.32)	
Day of week, n (%)						
Weekdays	51,023 (66.99)	63,334 (67.05)	0.8077	–	–	
Weekends/holidays	25,139 (33.01)	31,126 (32.95)		–	–	
Cause of trauma, n (%)			<0.0001			<.0001
Accident	63,203 (82.98)	80,321 (85.03)		95,109 (83.17)	48,415 (86.05)	
Suicide	3383 (4.44)	6061 (6.42)		6505 (5.69)	2939 (5.22)	
Injury	573 (0.75)	2162 (2.29)		1660 (1.45)	1075 (1.91)	
Occupational injury	7013 (9.21)	2925 (3.10)		7778 (6.80)	2160 (3.84)	
Others	354 (0.46)	556 (0.59)		585 (0.51)	325 (0.58)	
Unknown	1636 (2.15)	2435 (2.58)		2720 (2.38)	1351 (2.40)	
Type of trauma, n (%)			<0.0001			.4318
Blunt	70,521 (92.59)	86,274 (91.33)		104,993 (91.81)	51,802 (92.07)	
Penetrating	2556 (3.36)	3732 (3.95)		4261 (3.73)	2027 (3.60)	
Burn	1905 (2.50)	3004 (3.18)		3318 (2.90)	1591 (2.83)	
Others	208 (0.27)	210 (0.22)		278 (0.24)	140 (0.25)	
Unknown	972 (1.28)	1240 (1.31)		1507 (1.32)	705 (1.25)	
ELT attendance, n (%)						
Yes	51,273 (67.32)	68,269 (72.27)	<0.0001	80,319 (70.24)	39,223 (69.71)	.0002
No	4274 (5.61)	3792 (4.01)		5240 (4.58)	2826 (5.02)	
Unknown	20,615 (27.07)	22,399 (23.71)		28,798 (25.18)	14,216 (25.27)	
Systolic blood pressure on hospital arrival (mmHg), median (IQR)	137 (118–158) (n=74,923)	134 (115–155) (n=92,962)	<0.0001	136 (117–157) (n=112,570)	134 (116–156) (n=55,315)	<.0001
Heart rate on hospital arrival (beats/min), median (IQR)	83 (72–97) (n=73,823)	85 (73–99) (n=91,674)	<0.0001	84 (72–98) (n=111,022)	84 (72–98) (n=54,475)	.1494
Respiratory rate on hospital arrival (breaths/min), median (IQR)	20 (17–24) (n=66,659)	20 (18–24) (n=83,301)	<0.0001	20 (18–24) (n=100,811)	20 (18–24) (n=49,149)	.6998
GCS score on hospital arrival, median (IQR)	15 (14–15) (n=70,808)	15 (13–15) (n=88,048)	<0.0001	15 (13–15) (n=106,591)	15 (14–15) (n=52,265)	.0819
ISS score, median (IQR)	10 (9–20)	11 (9–20)	<0.0001	10 (9–20)	10 (9–20)	<.0001
TRISS probability of survival, median (IQR)	0.9675 (0.9278–0.9867) (n=60,248)	0.9675 (0.9293–0.9912) (n=75,066)	<0.0001	0.9675 (0.9264–0.9887) (n=90,933)	0.9675 (0.9334–0.9897) (n=44,381)	<.0001

ELT = emergency life-saving technician, GCS = Glasgow Coma Scale, IQR = interquartile range, ISS = Injury Severity Score, TRISS = Trauma Injury Severity Score.

4. Discussion

From the analysis of a nationwide trauma registry in Japan, this study revealed that nighttime was significantly related to both death in the ER and death at hospital discharge of emergency trauma patients, but weekdays/weekends was not. To our knowledge, this is the first report to assess the association of trauma emergency outcomes with time of day or day of week in Asia, and a national-scale registry made evaluation of these outcomes possible. Our findings not only provide basic epidemiological information about trauma patients but may also help to improve the emergency medical system in the prehospital settings and in the emergency department after hospital arrival.

In this study, both death in the ER and death at hospital discharge were significantly lower at daytime than nighttime, but the weekdays/weekends was not significantly related to death either in the ER or at hospital discharge. Metcalfe and colleagues did not find effects of time of day or day of week on injured patients treated within MTCs in the UK.[14] In the United States, however, the time period from 6:00 PM to 6:00 AM had a significantly higher adjusted relative risk for in-hospital mortality than the 6 AM to 6 PM time frame (adjusted relative risk = 1.18, $P < .0001$).[12] The results of the present study were similar to those from the United States in terms of showing poor prognosis at nighttime.

Why could the present study and other studies not find a weekend effect for trauma patients? In the study of all emergency patients admitted to hospital, higher mortality rates at weekends would reflect a lower probability of hospital admission. The reduced availability of primary care services and the higher thresholds of accident and emergency admissions at weekends suggest that fewer and sicker patients were admitted at weekends

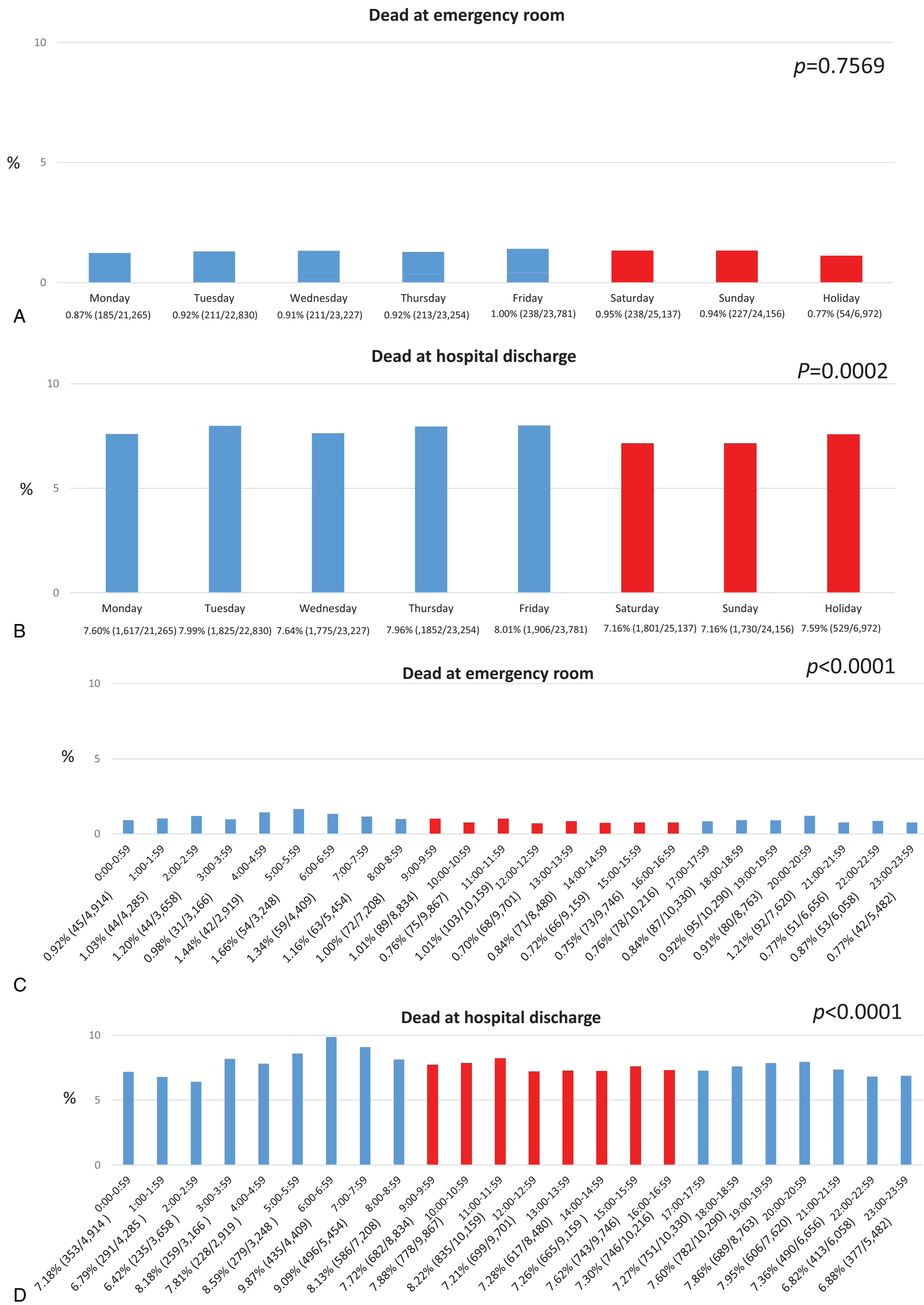

Figure 2. The number of ER deaths and hospital deaths according to the day of the week or the time of day. A, ER deaths by day of week; B, hospital deaths by day of week; C, ER deaths by time of day; D, hospital deaths by time of day.

than on weekdays, and higher mortality rates at weekends are, therefore, found amongst the direct admissions.[19] However, the analysis of trauma patients such as those in the present study was not thought to be inconsistent with the analysis of all emergency patients. The hospitals participating in the JTDB are major emergency medical institutions with ability equal to the Level I trauma centres in the United States and MTCs in the UK. These hospitals are equipped with trauma systems that can treat

Table 2

Outcomes by time of day or day of week.

	% (n/N)	% (n/N)	Crude OR (95% CI)	*P* value	Adjusted OR* (95% CI)	*P* value
Dead in the emergency room	Daytime	Night				
	0.82 (623/76,162)	1.01 (954/94,460)	0.808 (0.730–0.895)	<.0001	0.790 (0.710–0.879)	<.0001
	Weekday	Weekend and holiday				
	0.93 (1058/114,357)	0.92 (519/56,265)	1.003 (0.903–1.115)	.9555	0.945 (0.846–1.055)	.3170
Dead at hospital discharge	Daytime	Night				
	7.57 (5765/76,162)	7.70 (7270/94,460)	0.982 (0.947–1.018)	.3263	0.882 (0.847–0.919)	<.0001
	Weekday	Weekend and holiday				
	7.85 (8975/114,357)	7.22 (4060/56,265)	1.095 (1.054–1.138)	<.0001	1.015 (0.971–1.060)	.5143

* Adjusted for age, sex, and Injury Severity Score.
ORs were calculated for daytime vs. night and weekday vs weekend and holiday.
CI = confidence interval, OR = odds ratio.

emergency trauma patients, and medical resources are available 24 hours a day. Therefore, emergency trauma patients could be treated as usual even on weekends/holidays or at night. Considering these findings, the weekend effect could not be detected in our study in Japan or in the United States or the UK.

Human factors might be related to worsened prognosis among trauma patients at nighttime. Emergency physicians report negative impacts of night shift work, including fatigue, poor quality of sleep, mood decrement, irritability, and health challenges.[20] Of 4 cognitive abilities (speed of processing

Table 3

Outcomes by time of day or day of week according to age group or TRISS.

	% (n/N)	% (n/N)	Crude OR (95% CI)	*P* value	Adjusted OR* (95% CI)	*P* value
Children						
Dead in the emergency room	Daytime	Night				
	0.17 (8/4636)	0.23 (12/5288)	0.760 (0.310–1.861)	.5481	0.696 (0.268–1.808)	.4526
	Weekday	Weekend and holiday				
	0.19 (12/6362)	0.22 (8/3562)	0.839 (0.343–2.056)	.7019	0.852 (0.328–2.211)	.7431
Dead at hospital discharge	Daytime	Night				
	2.09 (97/4636)	2.34 (124/5288)	0.890 (0.680–1.164)	.3951	0.898 (0.665–1.213)	.4833
	Weekday	Weekend and holiday				
	2.34 (149/6362)	2.02 (72/3562)	1.162 (0.875–1.545)	.2994	1.096 (0.795–1.509)	.5745
Adults						
Dead in the emergency room	Daytime	Night				
	0.86 (615/71,526)	1.06 (942/89,172)	0.812 (0.733–0.900)	<.0001	0.798 (0.717–0.889)	<.0001
	Weekday	Weekend and holiday				
	0.97 (1,046/107,995)	0.97 (511/52,703)	0.999 (0.898–1.111)	.9844	0.949 (0.849–1.061)	.3588
Dead at hospital discharge	Daytime	Night				
	7.92 (5668/71,526)	8.01 (7146/89,172)	0.988 (0.953–1.024)	.5112	0.878 (0.842–0.914)	<.0001
	Weekday	Weekend and holiday				
	8.17 (8826/107,995)	7.57 (3988/52,703)	1.087 (1.046–1.130)	<.0001	1.013 (0.970–1.059)	.5523
TRISS probability of survival ≤0.5						
Dead in the emergency room	Daytime	Night				
	8.82 (301/3414)	10.11 (456/4510)	0.860 (0.738–1.002)	.0515	0.860 (0.737–1.004)	.0548
	Weekday	Weekend and holiday				
	9.59 (531/5539)	9.48 (226/2385)	1.013 (0.860–1.193)	.8777	1.016 (0.862–1.197)	.854
Dead at hospital discharge	Daytime	Night				
	60.02 (2049/3,414)	57.67 (2601/4,510)	1.102 (1.006–1.206)	.0357	1.087 (0.993–1.191)	.0715
	Weekday	Weekend and holiday				
	58.49 (3240/5,539)	59.12 (1410/2,385)	0.975 (0.884–1.074)	.6041	0.961 (0.872–1.060)	.4277
TRISS probability of survival >0.5						
Dead in the emergency room	Daytime	Night				
	0.20 (114/56,834)	0.26 (185/70,556)	0.765 (0.605–0.966)	.023	0.757 (0.597–0.960)	.0205
	Weekday	Weekend and holiday				
	0.21 (182/85,394)	0.28 (117/41,996)	0.765 (0.606–0.965)	.0252	0.734 (0.581–0.927)	.0105
Dead at hospital discharge	Daytime	Night				
	3.90 (2216/56,834)	3.77 (2661/70,556)	1.035 (0.977–1.096)	.2383	0.884 (0.832–0.939)	<.0001
	Weekday	Weekend and holiday				
	3.91 (3341/85,394)	3.66 (1536/41,996)	1.073 (1.008–1.141)	.0252	1.011 (0.948–1.077)	.7443

* Adjusted for age, sex, and Injury Severity Score.
ORs were calculated for daytime vs. night and weekday vs. weekend and holiday.
CI = confidence interval, OR = odds ratio, TRISS = Trauma Injury Severity Score.

information, working memory capacity, perceptual reasoning, and cognitive flexibility), the first 3 were impaired after a night shift of 14 hours compared with those after a rest night at home.[21] Working the night shift decreases the cognitive performance of intensive care unit physicians; all 4 the cognitive abilities worsened after a night shift.[22] These studies suggest that the cause of poor patient prognosis at nighttime may be the decline in cognitive ability of emergency or intensive care physicians and other medical staff working at this time.

In the sub-analyses, we found no effect on prognosis in children treated at nighttime and on weekends. To our knowledge, although no studies have assessed the association of trauma emergency outcomes with time of day or day of week in children, Ramsden, and colleagues in the UK reviewed the association of all paediatric patients' outcomes and timings of admission and concluded that weekend admission overall does not increase mortality.[23] However, Desai and colleagues reported that in paediatric neurosurgery patients, weekday after-hours and weekend emergency paediatric neurosurgical procedures were associated with significantly increased 30-day morbidity and mortality risk compared with procedures performed during regular weekday hours.[24] Further studies of paediatric trauma cases are needed to confirm our results.

Surprisingly, when considering the severity of trauma patients, in the patients with TRISS *P*s >.5, deaths both in the ER and at hospital discharge were significantly lower during the daytime than at nighttime, and day of week was significantly related to death in the ER. Trauma patients with *P*s >.5 were considered to have preventable death from trauma. In the UK, neither admission at night nor at the weekend was associated with higher odds of in-hospital death when confining analyses to the most severely injured patients (ISS >15).[14] Because the cause of higher mortality both at hospital discharge and in the ER in the patients with TRISS *P*s >.5 was unclear in the present study, further study is needed to investigate this relationship.

The results of the present study suggest that it would be important to rethink nighttime work quality to improve the prognosis of emergency trauma patients. To conduct appropriate medical allocations, it will be necessary to improve shift working hours such as by introducing full shift work instead of requiring personnel to be on duty for a full 24-hour period.

There are some limitations in this study. First, although we analyzed the JTDB database in which major critical care centres in Japan participated, there were likely some selection biases because exhaustive research was not performed. Second, our results might not be fully applicable to other areas including the United States and Europe, which have different emergency medical services and medical systems. Third, there might be unmeasured confounding factors that potentially influenced the association of trauma patient outcomes with time of day or day of week. Fourth, this registry does not include trauma patients with prehospital death, and therefore we could not compare these patients with trauma patients alive on hospital arrival. From their analysis of a large-scale data set of ambulance records in Osaka City, Japan, Katayama and colleagues reported that the factors associated with prehospital death due to traffic accidents were nighttime and elderly people and pedestrians as the types of patients,[25] and day of the week was not associated with prehospital death. Fifth, the details of nighttime behavior are unknown. There may be factors that affect outcome, such as heavy drinking as 1 example. Sixth, The criteria of this study (daytime: 9 AM - 5 PM for 8 hours, nighttime: 5 PM – 9 AM for 16 hours) which is based on the EMS and hospital medical staff daytime shift work schedule in Japan may be prone to selection bias. In the future, it will be necessary to build and analyze a trauma registry that includes data on patients suffering pre-hospital death and more details on nighttime behavior.

5. Conclusions

In the JTDB database, both death in the ER and death at hospital discharge were significantly lower during the daytime than at nighttime among emergency trauma patients in Japan, but the day of week was not associated with either endpoint.

Acknowledgments

The authors thank the emergency medical service personnel, nurses, and emergency physicians who participated in the JTDB. This article was supported by the Clinical Investigator's Research Project in Osaka University Graduate School of Medicine.

Author contributions

Conceptualization: Tomoya Hirose, Yusuke Katayama.
Data curation: Tomoya Hirose, Yusuke Katayama, Junya Sado, Tasuku Matsuyama, Kosuke Kiyohara.
Formal analysis: Tomoya Hirose, Junya Sado, Kosuke Kiyohara.
Funding acquisition: Yusuke Katayama.
Methodology: Tomoya Hirose, Takeyuki Kiguchi, Tasuku Matsuyama, Hiroki Takahashi.
Project administration: Tetsuhisa Kitamura.
Resources: Yuko Nakagawa.
Software: Tomoya Hirose.
Supervision: Yuko Nakagawa, Yasuaki Mizushima, Takeshi Shimazu.
Validation: Tomoya Hirose, Yusuke Katayama.
Writing – original draft: Tomoya Hirose.
Writing – review & editing: Tetsuhisa Kitamura, Yusuke Katayama, Junya Sado, Takeyuki Kiguchi, Tasuku Matsuyama, Kosuke Kiyohara, Yuko Nakagawa, Yasuaki Mizushima, Takeshi Shimazu.

References

[1] Bell CM, Redelmeier DA. Mortality among patients admitted to hospitals on weekends as compared with weekdays. N Engl J Med 2001;345:663–8.
[2] Schmulewitz L, Proudfoot A, Bell D. The impact of weekends on outcome for emergency patients. Clin Med (Lond) 2005;5:621–5.
[3] Pauls LA, Johnson-Paben R, McGready J, et al. The weekend effect in hospitalized patients: a meta-analysis. J Hosp Med 2017;12:760–6.
[4] Roberts SE, Thorne K, Akbari A, et al. Mortality following Stroke, the Weekend Effect and Related Factors: Record Linkage Study. PloS One 2015;10:e0131836.
[5] Isogai T, Yasunaga H, Matsui H, et al. Effect of weekend admission for acute myocardial infarction on in-hospital mortality: a retrospective cohort study. Int J Cardiol 2015;179:315–20.
[6] Orandi BJ, Selvarajah S, Orion KC, et al. Outcomes of nonelective weekend admissions for lower extremity ischemia. J Vas Surg 2014;60: 1572-1579.e1.
[7] Zapf MA, Kothari AN, Markossian T, et al. The "weekend effect" in urgent general operative procedures. Surgery 2015;158:508–14.
[8] Shih YN, Chen YT, Shih CJ, et al. Association of weekend effect with early mortality in severe sepsis patients over time. J Infect 2017;74:345–51.
[9] Kitamura T, Kiyohara K, Nitta M, et al. Survival following witnessed pediatric out-of-hospital cardiac arrests during nights and weekends. Resuscitation 2014;85:1692–8.

[10] Koike S, Tanabe S, Ogawa T, et al. Effect of time and day of admission on 1-month survival and neurologically favourable 1-month survival in out-of-hospital cardiopulmonary arrest patients. Resuscitation 2011;82:863–8.
[11] Barbosa Lde S, dos Reis Júnior GS, Chaves RZ, et al. Night admission is an independent risk factor for mortality in trauma patients - a systemic error approach. Rev Col Bras Cir 2015;42:209–14.
[12] Egol KA, Tolisano AM, Spratt KF, et al. Mortality rates following trauma: The difference is night and day. J Emerg Trauma Shock 2011; 4:178–83.
[13] Steenkamp C, Kong VY, Clarke DL, et al. The effect of systematic factors on the outcome of trauma laparotomy at a major trauma centre in South Africa. Ann R Coll Surg Engl 2017;99:540–4.
[14] Metcalfe D, Perry DC, Bouamra O, et al. Is there a 'weekend effect' in major trauma? Emerg Med J 2016;33:836–42.
[15] Rumalla K, Reddy AY, Mittal MK. Traumatic subdural hematoma: Is there a weekend effect? Clin Neurol Neurosurg 2017;154:67–73.
[16] Laupland KB, Ball CG, Kirkpatrick AW. Hospital mortality among major trauma victims admitted on weekends and evenings: a cohort study. J Trauma Manag Outcomes 2009;3:8.
[17] Ono Y, Ishida T, Iwasaki Y, et al. The off-hour effect on trauma patients requiring subspecialty intervention at a community hospital in Japan: a retrospective cohort study. Scand J Trauma Resusc Emerg Med 2015; 23:20.
[18] Yokota J. [Japan Trauma Data Bank (JTDB) managed by Japan Trauma Care and Research (JTCR)] [in Japanese]. Nihon Rinsho 2016;74: 329–36.
[19] Meacock R, Anselmi L, Kristensen SR, et al. Higher mortality rates amongst emergency patients admitted to hospital at weekends reflect a lower probability of admission. J Health Serv Res Policy 2017;22: 12–9.
[20] Smith-Coggins R, Broderick KB, Marco CA. Night shifts in emergency medicine: the american board of emergency medicine longitudinal study of emergency physicians. J Emerg Med 2014;47:372–8.
[21] Persico N, Maltese F, Ferrigno C, et al. Influence of shift duration on cognitive performance of emergency physicians: a prospective cross-sectional study. Ann Emerg Med 2018;72:171–80.
[22] Maltese F, Adda M, Bablon A, et al. Night shift decreases cognitive performance of ICU physicians. Intensive Care Med 2016;42:393–400.
[23] Ramsden L, McColgan MP, Rossor T, et al. Paediatric outcomes and timing of admission. Arch Dis Child 2018;103:611–7.
[24] Desai V, Gonda D, Ryan SL, et al. The effect of weekend and after-hours surgery on morbidity and mortality rates in pediatric neurosurgery patients. J Neurosurg Pediatr 2015;16:726–31.
[25] Katayama Y, Kitamura T, Kiyohara K, et al. Factors associated with prehospital death among traffic accident patients in Osaka City, Japan: A population-based study. Traffic Inj Prev 2018;19:49–53.