Original Article

Weekend effect on the mortality rate of in-hospital cardiopulmonary resuscitations from 2010 through 2019: a retrospective population-based cohort study

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Background: A smaller number of in-hospital medical staff and professionals on the weekend may lead to worsened survival outcomes in patients who have receive in-hospital cardiopulmonary resuscitation (ICPR). However, information regarding the effect of the weekend on survival outcomes after ICPR remains lacking. Therefore, we aimed to evaluate the "weekend effect" on the 6-month and 1-year mortality after ICPR.

Methods: This population-based cohort study was based on data extracted from the National Health Insurance Service database in South Korea. We enrolled 298,676 adult (≥18 years old) patients who had experienced ICPR due to in-hospital cardiac arrest (IHCA) between January 1, 2010, and December 31, 2019. The primary endpoints were 6-month and 1-year mortality after ICPR. Propensity score matching (PSM) was used to adjust clinical covariates.

Results: The survival analysis before and after PSM, 6-month mortality [pre-PSM hazard ratio (HR) =1.04, 95% confidence interval (CI): 1.03–1.04, P<0.001; post-PSM HR =1.02, 95% CI: 1.01–1.03, P<0.001], and 1 year mortality (pre-PSM HR =1.03, 95% CI: 1.03–1.04, P<0.001; post-PSM HR =1.02, 95% CI: 1.01–1.03, P<0.001) of the patients who received ICPR on weekends was higher than those on weekdays. The results of the multivariable Cox regression model for 1-year mortality among the entire cohort indicated that there were significant associations between high 1-year mortality after ICPR and the confounders (weekend *vs.* weekday: HR =1.04, 95% CI: 1.03–1.05, P<0.001).

Conclusions: The "weekend effect" on ICPR survival outcomes lasted up to 1 year in South Korea. Fast-tracking development of a rapid cardiac intervention delivery system and employing an increased number of professionals on weekends can improve the weekend ICPR mortality rates. Further investigation is required into improvements that can be made to the current ICPR system.

Keywords: Critical care; intensive care unit; outcomes; resuscitation; weekend effect

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Introduction

In-hospital cardiopulmonary resuscitation (ICPR) is associated with worsening of clinical outcomes, including a lower survival rate (1). Although in-hospital cardiopulmonary arrest (IHCA) tends to be considered an irreversibly poor condition, recently outcomes have improved in the United States. This may be due to improvements in the system of cardiopulmonary resuscitation (CPR), education, and training for higher quality CPR, which can influence the clinical outcome of CPR (2).

This could also be explained by the fact that clinical outcomes after ICPR could be associated with a smaller number of medical staff and professionals, frequent changes in medical staff, lack of monitoring, delayed defibrillation, delayed procedures, and systematic errors. It could be related to the day or time, such as weekends or nights. The "weekend effect" on ICPR implies that the patients who undergo ICPR on the weekend would be associated with worse clinical outcomes after ICPR compared to those who undergo ICPR on weekdays (3-6). We previously analyzed 1195 in-hospital CPR cases and studied CPRs by day of the week, and observed that the occurrence of intra-hospital CPRs varied by Mondays-Wednesdays and Thursdays-Sundays, and that the return of spontaneous circulation (ROSC) rate of ICPRs occurring on Sundays was low even after correction (3). In a study using data from a multicenter or regional ICPR registry, patients who received ICPR on weekends/nights were associated with lower survival to discharge (5,7-9). However, no study on the weekend effect on long-term mortality was conducted from a national scale database in the Republic of Korea, including long-term survival, such as 6-month and 1-year mortality. Because overall improvement of the ICPR system is important for critical care medicine, the weekend effect on long-term survival outcomes up to 1-year after ICPR should be examined using a large population registered in a nationwide database.

Therefore, we aimed to examine the weekend effect on 6-month and 1-year mortality after ICPR using data from the National Health Insurance Service database in the Republic of Korea in 2010–2019, and to evaluate the risk factors that worsen 1-year survival. We present the following article in accordance with the STROBE reporting checklist (available at https://apm.amegroups.com/article/view/10.21037/apm-22-266/rc) (10).

Methods

Study design, setting, and ethical statement

This retrospective population-based cohort study was approved by the institutional review board (IRB) of Seoul National University Bundang Hospital (No. X-2011-651-901), and individual consent for this retrospective analysis was waived, because the data used in this study were anonymized. Permission for data use of the National Health Insurance Service (NHIS) database was obtained after approval of the study protocol (No. NHIS-2021-1-266). The study also conformed to the provisions of the Declaration of Helsinki (as revised in 2013).

Data source: NHIS database

We used a South Korean national registration database that contains information on the diagnosis of diseases and prescription of any procedures and/or drugs. For financial support from the NHIS, which is the only public insurance system in South Korea, all diagnoses of diseases and information on prescription for any procedures and/or drugs should be registered in the NHIS database by physicians. The International Diseases and Related Health Issues 10th edition (ICD-10) codes were used for disease diagnosis (Table S1).

Study population

We conducted a retrospective review of all adult patients who underwent ICPR from January 1, 2010, through December 31, 2019. If a patient received more than one instance of CPR in a row, all ICPR events during the day were considered as one ICPR event. Only the first ICPR event was included in this study if the patient had experienced ICPR events more than once on different days during the study period. For example, if a patient received ICPR two times on 12 March 2010 and 16 March 2010, only the first ICPR event on 12 March 2010 was included in the study, while the ICPR event on 16 March 2010 was excluded. These exclusion criteria enable our study population to be homogeneous because physical condition of patients may be worse at a later ICPR event compared to that at an earlier ICPR event. Pediatric patients whose age were <18 years old were excluded in this study, because the

etiology and prognosis of ICPR in pediatric patients differs from those of adult patients.

Exposure variable (ICPR on weekends)

The study population was divided into two groups according to the day of the week on which the ICPR had been performed: the weekend group (ICPR on Saturdays, Sundays, or legal holidays) and the weekday group (ICPR on Monday, Tuesday, Wednesday, Thursday, and Friday).

Information collected as covariates

We extracted and collected covariates that might be related to the prognosis of ICPR. Data on age, sex, job status, residence, and household income level at ICPR were collected. Residence data, such as living in urban areas (Seoul and other metropolitan cities) or rural areas at the time of admission, were collected based on postal codes. The National Health Insurance Corporation collected information on household income levels at each year to determine patients' insurance premiums and all patients were divided into four groups using quartile ratios.

The main diagnoses of the patients who underwent ICPR were divided into four groups using the ICD-10 codes such as cardiovascular disease group (I00–I99), respiratory disease group (J00–J99), cancer group (C00–D49), and other group. Hospitalization departments at the time of CPR were classified as internal medicine (IM) and non-IM. The ICPR event was classified into one of five groups according to the duration of CPR: <15, 15–30, 30–45, 45–60, and >60 min, respectively.

Hospitals in which ICPRs were performed were classified into three categories: tertiary general hospitals, general hospitals, and other hospitals. Additionally, hospitals were divided into two distinct groups according to the number of hospital beds: <1,000 beds and ≥1,000 beds. To reflect the comorbid status of patients, the Charlson comorbidity index scores were calculated using ICD-10 codes, which were registered recently (within 1 year before ICPR) in the NHIS database as shown in Table S1.

Endpoints

The primary endpoints of this study were 6-month and 1-year mortality, which was considered as any death within 6 months or 1 year from the date of ICPR. As the date of death among the study population was extracted up to April 22, 2020, the survival time was calculated from the date of ICPR to death date or to April 22, 2020 for survivors of ICPR.

Statistical analysis

Mean values with standard deviation (SD), and number (percentages) were used to present clinicopathological characteristics of the study population, respectively. First, we used 1:1 propensity score matching (PSM) to adjust for confounding factors between the weekend and weekday groups. The nearest neighbor method without replacement was used for PSM and caliper width was set as 0.15 (11). All covariates were included in the propensity score modelling, and absolute standardized difference (ASD) ≤0.1 was used for determining sufficient covariate balance between the two group. For PSM, we used the MatchIt package of the R program (version 4.0.3; www.r-project.org). After checking for an appropriate balance between the weekend and weekday groups, we performed Cox regression analysis to examine whether the risk of 6-month and 1-year mortality differed between the two groups. In this time-to-event analysis, survival time from the date of CPR to the date of death was used as the time, and death within 6 months and 1 year were used as events. In addition, after PSM, Kaplan-Meier estimation was used to compare the median survival time after ICPR between the two groups, and the log-rank test was used to check for statistical differences in median survival time between the two groups.

Next, we performed sensitivity analyses in the entire cohort using multivariable Cox regression modeling for two reasons. First, we could confirm that our results after PSM are generalizable to the entire cohort. Second, we could examine whether the risk of 6-month and 1-year mortality differed according to the date of the weekday in detail. The 6-month and 1-year mortality risks of patients who underwent ICPR on Mondays, Tuesdays, Thursdays, Fridays, Saturdays, and Sundays were compared to those who underwent ICPR on Wednesday. The results are presented as hazard ratios (HRs) with 95% confidence intervals (CIs), and there was no issue of multicollinearity between variables according to the criterion of variance inflation factor <2.0. A log-log plot was used to confirm that the central assumption of the Cox proportional hazard model was satisfied. All the analyses in this study except for PSM were performed using SPSS software (IBM SPSS Statistics for Windows, Version 25.0, IBM Corp., Armonk, NY, USA). Statistical significance was set at two-sided $P<0.05$.

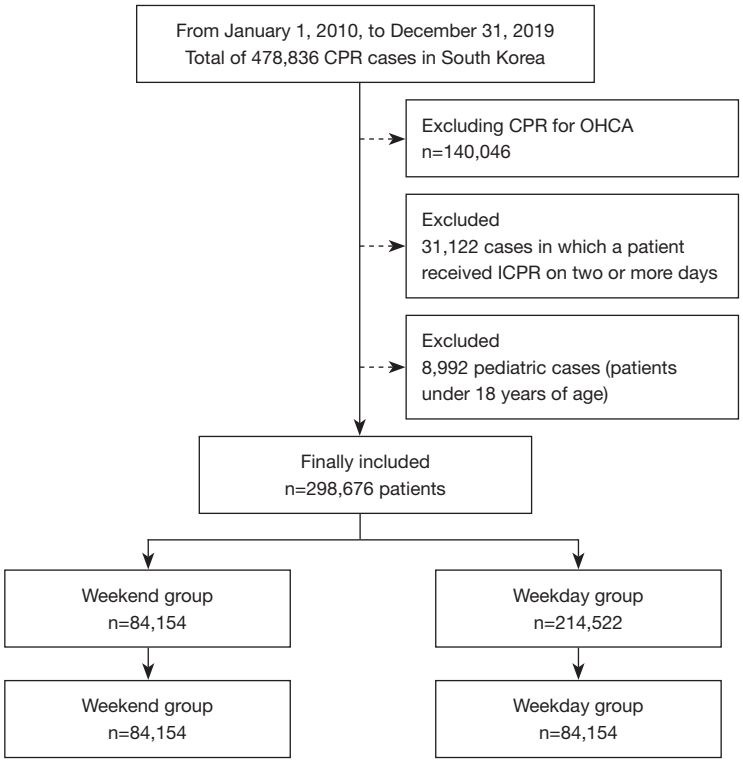

Figure 1 Flow chart depicting the patient selection process. CPR, cardiopulmonary resuscitation; OHCA, out of hospital cardiac arrest; ICPR, in-hospital cardiopulmonary resuscitation.

Results

Characteristics

There were a total of 478,836 CPR cases between January 1, 2010, and December 31, 2019, in South Korea. After excluding 140,046 cases due to out-of-hospital cardiac arrest (OHCA), 338,970 ICPR cases were initially screened. Next, 31,122 cases in which a patient received ICPR more than once on different days during the study period and 8,992 pediatric cases (patients under 18 years of age) were excluded from the final analysis. Finally, 298,676 adult patients were included in the study. Among them, 84,154 (28.2%) patients were in the weekend group, while 214,522 (71.8%) patients were in the weekday group. After PSM, 168,308 patients (84,154 patients in each group) were included in the analysis (*Figure 1*). *Table 1* shows the results of the comparison of clinicopathological characteristics between the weekend and weekday groups before and after PSM. After PSM, the two groups were appropriately balanced, as all ASDs were <0.1. There were no missing data in this study, except for those for household income level at ICPR. The missing value for household income level was considered as an "unknown group" and included in the analysis.

Comparison of 6-month and 1-year mortality rates of patients who underwent ICPR on weekends and weekdays

Table 2 shows the survival analyses before and after PSM. After PSM, the 6-month mortality rate in the weekend group was 90.1% (75,805/84,154), while that in the weekday group was 90.0% (75,771/84,154). In the Cox regression analysis, the weekend group showed a 2% increased 6-month mortality risk compared to the weekday group (HR =1.02, 95% CI: 1.01–1.03; P<0.001). After PSM, the 1-year mortality rate in the weekend group was 91.2% (76,776/84,154), while that in the weekday group was 91.2% (76,768/84,154). In the Cox regression analysis, the weekend group showed a 2% increase in the 1-year mortality risk compared to the weekday group (HR =1.02, 95% CI: 1.01–1.03; P<0.001). *Table 3* shows the median survival times after ICPR between the weekend and weekday groups. The median survival time after ICPR in the weekend group was 3 days (95% CI: 2.9–3.1), which was

Table 1 Comparison of clinicopathological characteristics between the weekend and weekday groups before and after PSM

Variables	Before PSM (n=298,676)		ASD	After PSM (n=168,308)		ASD
	Weekend group (n=84,154)	Weekday group (n=214,522)		Weekend group (n=84,154	Weekday group (n=84,154)	
Age (years)	69.5 (15.3)	70.0 (15.1)	0.029	69.5 (15.3)	69.6 (15.3)	0.008
Sex (male), n (%)	51,105 (60.7)	129,289 (60.3)	0.009	51.105 (60.7)	51,184 (60.8)	0.002
Have a job at ICPR, n (%)	43,511 (51.7)	109,542 (51.1)	0.013	43,511 (51.7)	43,392 (51.6)	0.003
Residence at ICPR, n (%)						
Urban area	36,356 (43.2)	92,701 (43.2)		36,356 (43.2)	40,762 (48.4)	
Rural area	47,798 (56.8)	121,821 (56.8)	<0.001	47,798 (56.8)	43,392 (51.6)	0.002
Household income level at ICPR, n (%)						
Q1 (lowest)	26,072 (31.0)	67,706 (31.6)		26,072 (31.0)	26,113 (31.0)	
Q2	12,982 (15.4)	33,244 (15.5)	0.002	12,982 (15.4)	13,126 (15.6)	0.005
Q3	16,666 (19.8)	41,962 (19.6)	0.006	16,666 (19.8)	16,519 (19.6)	0.004
Q4 (highest)	26.825 (31.9)	67,599 (19.6)	0.008	26.825 (31.9)	26,815 (31.9)	<0.001
Unknown	1,609 (1.9)	4,011 (1.9)	0.003	1,609 (1.9)	1,581 (1.9)	0.002
Main diagnosis at ICPR, n (%)						
Cardiovascular disease	34,289 (40.7)	80,870 (37.7)		34,289 (40.7)	33,877 (40.3)	
Respiratory disease	11,322 (13.5)	30,627 (14.3)	0.024	11,322 (13.5)	11,478 (13.6)	0.005
Cancer	8,410 (10.0)	25,088 (11.7)	0.057	8,410 (10.0)	8,605 (10.2)	0.008
Other	30,123 (35.8)	77,937 (36.3)	0.011	30,123 (35.8)	30,194 (35.9)	0.002
Admitting department, n (%)						
IM	45,274 (53.8)	121,505 (56.6)		45,274 (53.8)	46,005 (54.7)	
Non-IM	38,880 (46.2)	93,017 (43.4)	0.057	38,880 (46.2)	38,149 (45.3)	0.017
Duration of ICPR, n (%)						
<15 min	38,871 (46.2)	96,794 (45.1)		38,871 (46.2)	38,503 (45.8)	
15–30 min	62,080 (28.9)	62,080 (28.9)	0.003	62,080 (28.9)	24,512 (29.1)	0.002
>30–45 min	11,249 (13.4)	29,599 (13.8)	0.013	11,249 (13.4)	11,363 (13.5)	0.004
>45–60 min	5,121 (6.1)	14,106 (6.6)	0.021	5,121 (6.1)	5,275 (6.3)	0.008
>60 min	4,459 (5.3)	11,943 (5.6)	0.012	4,459 (5.3)	4,501 (5.3)	0.002
Type of hospital, n (%)						
Tertiary general hospital	32,686 (38.8)	79,604 (37.1)		32,686 (38.8)	32,493 (38.6)	
General hospital	43,352 (51.5)	109,968 (51.3)	0.005	43,352 (51.5)	43,493 (51.7)	0.003
Other hospital	8,116 (9.6)	24,950 (11.6)	0.067	8,116 (9.6)	8,168 (9.7)	0.002
Total hospital bed number, n (%)						
<1,000	71,006 (84.4)	182,178 (84.9)		71,006 (84.4)	71,079 (84.5)	
≥1,000	13,148 (15.6)	32,344 (15.1)	0.015	13,148 (15.6)	13,075 (15.5)	0.002

Table 1 (*continued*)

Table 1 (*continued*)

Variables	Before PSM (n=298,676)		ASD	After PSM (n=168,308)		ASD
	Weekend group (n=84,154)	Weekday group (n=214,522)		Weekend group (n=84,154)	Weekday group (n=84,154)	
Annual case volume of ICPR, n (%)						
0–56	19,022 (22.6)	55,789 (26.0)		19,022 (22.6)	19,179 (22.8)	
57–194	21,763 (25.9)	54,444 (25.4)	0.011	21,763 (25.9)	21,912 (26.0)	0.004
195–276	21,449 (25.5)	51,464 (24.0)	0.034	21,449 (25.5)	21,256 (25.3)	0.005
277	21,920 (26.0)	52,825 (24.6)	0.032	21,920 (26.0)	21,807 (25.9)	0.003
Underlying disability						
Mild to moderate, n (%)	9,781 (11.6)	25,515 (11.9)	0.009	9,781 (11.6)	9,862 (11.7)	0.003
Severe, n (%)	12,426 (16.9)	37,442 (17.5)	0.014	12,426 (16.9)	14,285 (17.0)	0.001
CCI at ICPR, mean (SD)	5.9 (3.8)	6.1 (3.9)	0.056	5.9 (3.8)	5.9 (3.8)	0.012
Myocardial infarction, n (%)	15,405 (18.3)	38,752 (18.1)	0.006	15,405 (18.3)	15,282 (18.2)	0.004
Congestive heart failure, n (%)	32,643 (38.8)	84,954 (39.6)	0.017	32,643 (38.8)	32,775 (38.9)	0.003
Peripheral vascular disease, n (%)	19,488 (23.2)	51,067 (23.8)	0.015	19,488 (23.2)	19,744 (23.5)	0.007
Cerebrovascular disease, n (%)	31,871 (37.9)	80,886 (37.7)	0.003	31,871 (37.9)	34,695 (37.7)	0.004
Dementia, n (%)	18,736 (22.3)	49,021 (22.9)	0.014	18,736 (22.3)	18,700 (22.2)	0.001
Chronic pulmonary disease, n (%)	45,912 (54.6)	120,136 (56.0)	0.029	45,912 (54.6)	46,321 (55.0)	0.009
Rheumatic disease, n (%)	5,245 (6.2)	14,288 (6.7)	0.018	5,245 (6.2)	5,373 (6.4)	0.006
Peptic ulcer disease, n (%)	32,081 (38.1)	84,438 (39.4)	0.026	32,081 (38.1)	32,134 (38.2)	0.001
Mild liver disease, n (%)	40,414 (48.0)	104,525 (48.7)	0.014	40,414 (48.0)	40,615 (48.3)	0.005
Diabetes without chronic complication, n (%)	48,2588 (57.7)	125,706 (58.6)	0.017	48,2588 (57.7)	49,056 (58.3)	0.011
Diabetes with chronic complication, n (%)	19,261 (22.9)	50,629 (23.6)	0.017	19,261 (22.9)	19,521 (23.2)	0.007
Hemiplegia or paraplegia, n (%)	22,345 (26.6)	58,742 (27.4)	0.019	22,345 (26.6)	22,585 (26.8)	0.007
Renal disease, n (%)	13,981 (16.6)	37,593 (17.5)	0.025	13,981 (16.6)	25,266 (16.8)	0.006
Cancer, n (%)	22,214 (26.4)	60,919 (28.4)	0.045	22,214 (26.4)	22,474 (26.7)	0.007
Moderate or severe liver disease, n (%)	5,503 (6.5)	14,006 (6.5)	<0.001	5,503 (6.5)	5,479 (6.5)	0.001
Metastatic cancer, n (%)	6,152 (7.3)	18,307 (8.5)	0.047	6,152 (7.3)	6,281 (7.5)	0.006
AIDS/HIV, n (%)	152 (0.2)	434 (0.2)	0.005	152 (0.2)	158 (0.2)	0.002
Year of ICPR, n (%)						
2010	6,541 (7.8)	17,945 (8.4)		6,541 (7.8)	6,571 (7.8)	
2011	6,696 (8.0)	17,473 (8.1)	0.007	6,696 (8.0)	6,858 (8.1)	0.007
2012	6,855 (8.1)	17,751 (8.3)	0.005	6,855 (8.1)	6,829 (8.1)	0.001
2013	6,681 (7.9)	17,411 (8.1)	0.007	6,681 (7.9)	6,800 (8.1)	0.005
2014	6,365 (7.6)	17,331 (8.1)	0.020	6,365 (7.6)	6,498 (7.7)	0.06
2015	6,434 (7.6)	17,377 (8.1)	0.017	6,434 (7.6)	6,539 (7.8)	0.005

Table 1 (*continued*)

Table 1 (*continued*)

Variables	Before PSM (n=298,676)		ASD	After PSM (n=168,308)		ASD
	Weekend group (n=84,154)	Weekday group (n=214,522)		Weekend group (n=84,154)	Weekday group (n=84,154)	
2016	10,327 (12.3)	25,553 (11.9)	0.011	10,327 (12.3)	10,348 (12.3)	<0.001
2017	10,340 (12.3)	25,554 (11.9)	0.011	10,340 (12.3)	10,207 (12.1)	0.005
2018	12,085 (14.4)	29,524 (13.8)	0.017	12,085 (14.4)	11,950 (14.2)	0.005
2019	11,830 (14.1)	28,603 (13.3)	0.021	11,830 (14.1)	11,554 (13.7)	0.009

PSM, propensity score matching, ASD, absolute value of standardized mean difference; ICPR, in-hospital cardiopulmonary resuscitation; IM, internal medicine; CCI, Charlson comorbidity index; AIDS, Acquired immunodeficiency syndrome; HIV, human immunodeficiency virus.

Table 2 Survival analysis before and after PSM

Variables	Event	Cox regression analysis, HR (95% CI)	P value
6-month mortality before PSM			
Weekday	193,568/214,522 (90.2%)	1	
Weekend	75,805/84,154 (90.1%)	1.04 (1.03–1.04)	<0.001
1-year mortality before PSM			
Weekday	196,050/214,522 (91.4%)	1	
Weekend	76,775/84,154 (91.2%)	1.03 (1.03–1.04)	<0.001
6-month mortality after PSM			
Weekday	75,771/84,154 (90.0%)	1	
Weekend	75,805/84,154 (90.1%)	1.02 (1.01–1.03)	<0.001
1-year mortality after PSM			
Weekday	76,768/84,154 (91.2%)	1	
Weekend	76,776/84,154 (91.2%)	1.02 (1.01–1.03)	<0.001

PSM, propensity score matching; HR, hazard ratio; CI, confidence interval.

Table 3 Median survival time after ICPR in propensity score matched cohort

Group	Median survival time (95% CI)
Weekday	3 days (2.9–3.1)
Weekend	4 days (3.9–4.1)
P value	<0.001

ICPR, in-hospital cardiopulmonary resuscitation; CI, confidence interval.

significantly shorter than the median survival time of 4 days (95% CI: 3.9–4.1) in the weekday group (P<0.001).

Associated factors for 1-year mortality

Table 4 shows the results of the multivariable Cox regression model for 1-year mortality among the entire cohort as a sensitivity analysis. In model 1, the weekend group showed

Table 4 Multivariable Cox regression model for 1-year mortality among the entire cohort as a sensitivity analysis

Variables	HR (95% CI)	P value
Weekend (*vs.* weekday; model 1)	1.04 (1.03–1.05)	<0.001
Weekday in detail (model 2)		
Wednesday (n=43,113)	1	
Thursday (n=42,717)	1.00 (0.99–1.01)	0.911
Friday (n=44,212)	1.00 (0.98–1.01)	0.502
Saturday (n=36,441)	1.05 (1.04–1.07)	<0.001
Sunday (n=35,485)	1.04 (1.03–1.06)	<0.001
Monday (n=51,651)	0.99 (0.98–1.01)	0.194
Tuesday (n=45,057)	0.99 (0.98–1.01)	0.371
Other covariates in model 1		
Age, year	1.01 (1.01–1.01)	<0.001
Sex, male	1.03 (1.03–1.04)	<0.001
Have a job at ICPR	1.00 (0.99–1.00)	0.179
Residence at ICPR		
Urban area	1	
Rural area	1.02 (1.01–1.03)	<0.001
Household income level at ICPR		
Q1 (lowest)	1	
Q2	0.99 (0.98–1.00)	0.185
Q3	0.98 (0.97–0.99)	0.001
Q4	0.98 (0.97–0.99)	<0.001
Unknown	0.99 (0.97–1.00)	0.179
Main diagnosis at ICPR		
Cardiovascular disease	1	
Respiratory disease	0.91 (0.89–0.92)	<0.001
Cancer	0.82 (0.81–0.84)	<0.001
Other	0.92 (0.91–0.93)	<0.001
Admitting department		
IM	1	
Non-IM	0.70 (0.69–0.70)	<0.001
Duration of ICPR		
<15 min	1	
>15–30 min	1.63 (1.62–1.65)	<0.001
>30–45 min	1.70 (1.68–1.72)	<0.001
>45–60 min	1.67 (1.65–1.70)	<0.001
>60 min	1.65 (1.63–1.68)	<0.001
Type of hospital		
Tertiary general hospital	1	
General hospital	1.14 (1.13–1.15)	<0.001
Other hospital	1.08 (1.06–1.10)	<0.001
Total hospital bed number		
<1,000	1	
≥1,000	1.02 (1.01–1.03)	0.001
Annual case volume of ICPR		
0–56	1	
57–194	1.07 (1.06–1.09)	<0.001
195–276	1.06 (1.05–1.08)	<0.001
277	1.18 (1.16–1.19)	<0.001
Underlying disability		
Mild to moderate	1.01 (1.00–1.02)	0.048
Severe	1.00 (0.99–1.01)	0.873
Myocardial infarction	0.86 (0.85–0.86)	<0.001
Congestive heart failure	0.93 (0.92–0.94)	<0.001
Peripheral vascular disease	0.96 (0.95–0.97)	<0.001
Cerebrovascular disease	0.88 (0.87–0.89)	<0.001
Dementia	1.01 (1.00–1.02)	0.096
Chronic pulmonary disease	0.77 (0.76–0.77)	<0.001
Rheumatic disease	1.00 (0.99–1.02)	0.856
Peptic ulcer disease	0.90 (0.90–0.91)	<0.001
Mild liver disease	0.93 (0.92–0.94)	<0.001
Diabetes without chronic complication	0.89 (0.89–0.90)	<0.001
Diabetes with chronic complication	1.13 (1.12–1.15)	<0.001
Hemiplegia or paraplegia	0.86 (0.85–0.87)	<0.001
Renal disease	0.96 (0.95–0.97)	<0.001
Cancer	1.01 (1.00–1.02)	0.048
Moderate or severe liver disease	1.29 (1.27–1.31)	<0.001
Metastatic cancer	1.13 (1.11–1.14)	<0.001
AIDS/HIV	1.00 (0.92–1.09)	0.982

Table 4 (*continued*)

Table 4 (*continued*)

Variables	HR (95% CI)	P value
Year of ICPR		
2010	1	
2011	0.99 (0.97–1.01)	0.216
2012	0.99 (0.97–1.301)	0.281
2013	1.01 (0.99–1.03)	0.379
2014	1.00 (0.99–1.02)	0.700
2015	1.02 (1.00–1.04)	0.067
2016	1.32 (1.29–1.34)	<0.001
2017	1.33 (1.31–1.36)	<0.001
2018	1.31 (1.29–1.33)	<0.001
2019	1.30 (1.28–1.33)	<0.001

ICPR, in-hospital cardiopulmonary resuscitation; IM, internal medicine; HR, hazard ratio; CI, confidence interval; AIDS, acquired immunodeficiency syndrome; HIV, human immunodeficiency virus.

a 4% increase in 1-year mortality risk compared to the weekday group (HR =1.04, 95% CI: 1.03–1.05; P<0.001). In model 2, compared with the patients who received ICPR on Wednesday, the 1-year mortality risk in patients who received ICPR on Saturday and Sunday was increased by 5% (HR =1.05, 95% CI: 1.04–1.07; P<0.001) and 4% (HR =1.04, 95% CI: 1.03–1.06; P<0.001) respectively. However, the 1-year mortality risk in patients who received ICPR on Thursday (P=0.911), Friday (P=0.502), Monday (P=0.194), and Tuesday (P=0.371) were not significantly different from that of patients who received ICPR on Wednesday.

Discussion

The "weekend effect" on post-ICPR 6-month and 1-year mortality was demonstrated even after adjusting for patient factors such as underlying disease, employment status, financial status, residence, hospital factors, and duration of ICPR using data (n=298,676) that were extracted from the National Health Insurance Service database in Republic of Korea in 2010–2019.

A few studies based on data from the CPR registry (n=8,000–60,000 patients) in other countries have suggested a weekend effect on survival to discharge in patients who underwent IHCA (5,7-9). However, no studies using a national database in South Korea have been conducted to investigate the weekend effect on post-ICPR mortality including long-term survival, such as 6-month and 1-year mortality. In this study, the results showed that the "weekend effect" might be maintained for 1 year after CPR even after adjusting for risk factors.

"Weekend effect" in CPR has different meanings in OHCA and IHCA. Studies on OHCA or out-of-hospital CPR at night or on weekends have been conducted, and the results have been mixed (12-15). A study conducted in Paris found that the "weekend/night effect" on outcomes of out-of-hospital CPR can be due to the fact that bystander CPR was less frequently performed and automatic external defibrillator (AED) application was delayed even if there were more bystanders on weekends or nights than during the day (13). This result differs from the results of studies in other countries. This may be related to the educational level and participation tendency of local residents on bystander CPR or usage of AEDs, security, and population distribution at night and on weekends (13,14).

On the other hand, weekend IHCA is usually predicted to have a lower survival rate due to a decrease in the number of medical staff, change of medical staff, shortage of a limited accessibility to specialists, and decrease in monitoring personnel (16). As the most common cause of pediatric cardiopulmonary arrest is respiratory problems, the clinical outcome of ICPR at a time when personnel skilled in managing the airway and intubation is not available may be worse than that of ICPR performed during the day (6,17-19). This also applies to adult CPR. The latest American Heart Association guidelines recommend minimizing interruption to chest compression, but it is difficult to intubate without interruption of CPR (20,21). Kim *et al.* found that they could improve the success rate of intubation and shorten the time to successful intubation with training. A total of 243 endotracheal intubation experiences (1,973 days of training) were necessary to achieve a 90% success rate at <30 s (20,21). However, rescuers highly skilled in airway management and monitoring and maintaining the quality of CPR may not be available on weekends and nights, particularly in smaller hospitals. In this study, the type of hospital, general hospitals, or others (*vs.* tertiary general hospital), total hospital bed number, and annual case volume of ICPR were associated with 1-year mortality after ICPR. This may be due not only to better hospital systems, including CPR systems, but also to the availability of highly skilled staff 24 h a day.

The study by Thorén *et al.* demonstrated an association

between electrocardiogram (EKG) monitoring and reduction in mortality in IHCA (22), suggesting that the lack of monitors, such as those used for EKG monitoring, may increase the mortality at night because early detection of a shockable rhythm and rapid defibrillation or cardiac catheterization is important in the ROSC and survival in adults (23). According to an analysis of 6,789 cases from 369 hospitals participating in the National Registry of Cardiopulmonary Resuscitation, delayed defibrillation was significantly associated with a lower survival rate in cases of in-hospital cardiac arrest (5). This is closely related to problems such as the availability of monitoring equipment, monitoring personnel, and professionals (5).

Furthermore, according to an analysis of 118,387 consecutive, adult, index IHCA cases in the National Registry of Cardiopulmonary Resuscitation database conducted by Ornato *et al.*, the errors in the in-hospital CPR system were more frequent during weekends (30.7% *vs.* 31.6%, error group *vs.* no error group, P=0.003), and this was significantly associated with in-hospital mortality (24).

In our study, cardiovascular disease, such as myocardial infarction, was the main diagnosis in cases of cardiopulmonary arrest, and CPR was associated with a lower 1-year mortality. Patients with myocardial infarction admitted to the hospital on weekdays may be associated with lower in-hospital mortality. A study by Kostis *et al.*, who enrolled 241,164 cases from 1987 to 2002 in New Jersey, showed that patients with myocardial infarction hospitalized on weekends had increased mortality; lower use of invasive cardiac procedures was also observed in these patients (25). A lower rate of invasive cardiac intervention might cause higher mortality in patients with myocardial infarction admitted to the hospital on weekends (25). In a recent study on the weekend effect of myocardial infarction based on data from 2000 to 2016, there were no differences in the in-hospital mortality of acute myocardial infarction according to admission on weekdays *vs.* weekends in the United States (26). This implies that the weekend effect is not permanent and fixed, and might be improved by fast-tracking development of a system for rapid cardiac procedures and increasing professional staff for this on weekends. In our study, the year in which ICPR occurred was adjusted for; however, the weekend effect was maintained.

This study has some limitations. First, we could not access data for ROSC after ICPR because there is no ICD-10 code for this in the NHIS database. Second, it was not possible to extract important information such as the habits of the patients and their body mass index, other than the data registered in the National Health Insurance database. Third, missing data could not be obtained because attending physicians at individual hospitals did not enter the codes. Fourth, the patients' disease severity at ICPR was not included in the analysis, which might affect the results of this study. For example, Acute Physiology and Chronic Health Evaluation II scores at ICPR were not included in this study as this information was unavailable in the NHIS database. Finally, although the data in this study include all ICPR cases across the country, these data were collected only from South Korea. It may be difficult to generalize the results of the study to different medical systems and cultures.

Conclusions

The consistent weekend effect before and after adjustment for confounders in this study may be due to the complex reasons listed above: the decrease in monitoring due to shortage and change of medical staff and professionals, delay in defibrillation and cardiac procedures, delay in diagnosis and treatment of major cardiopulmonary problems, quality of CPR, and decrease in the success rate of airway intubation. The fact that the "weekend effect" was consistently demonstrated even after adjusting for the type, size, and ICPR case volume of the hospitals may suggest that overall improvement of the system of ICPR is needed. The fact that the weekend effect on mortality after ICPR lasts as long as a year also suggests that efforts are needed to address the weekend effect.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting Checklist. Available at https://apm.amegroups.com/article/view/10.21037/apm-22-266/rc

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://apm.amegroups.com/article/view/10.21037/apm-22-266/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related

to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This retrospective population-based cohort study was approved by the institutional review board (IRB) of Seoul National University Bundang Hospital (No. X-2011-651-901) and individual consent for this retrospective analysis was waived.

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Supplementary

Table S1 The ICD-10 codes used by comorbidity to compute the Charlson comorbidity index

Myocardial infarction: I21.x, I22.x, I25.2
Congestive heart failure: I09.9, I11.0, I13.0, I13.2, I25.5, I42.0, I42.5–I42.9, I43.x, I50.x, P29.0
Peripheral vascular disease: I70.x, I71.x, I73.1, I73.8, I73.9, I77.1, I79.0, I79.2, K55.1, K55.8, K55.9, Z95.8, Z95.9
Cerebrovascular disease: G45.x, G46.x, H34.0, I60.x–I69.x
Dementia: F00.x–F03.x, F05.1, G30.x, G31.1
Chronic pulmonary disease: I27.8, I27.9, J40.x–J47.x, J60.x–J67.x, J68.4, J70.1, J70.3
Rheumatic disease: M05.x, M06.x, M31.5, M32.x–M34.x, M35.1, M35.3, M36.0
Peptic ulcer disease: K25.x–K28.x
Mild liver disease: B18.x, K70.0–K70.3, K70.9, K71.3–K71.5, K71.7, K73.x, K74.x, K76.0, K76.2–K76.4, K76.8, K76.9, Z94.4
Diabetes without chronic complication: E10.0, E10.1, E10.6, E10.8, E10.9, E11.0, E11.1, E11.6, E11.8, E11.9, E12.0, E12.1, E12.6, E12.8, E12.9, E13.0, E13.1, E13.6, E13.8, E13.9, E14.0, E14.1, E14.6, E14.8, E14.9
Diabetes with chronic complication: E10.2–E10.5, E10.7, E11.2–E11.5, E11.7, E12.2–E12.5, E12.7, E13.2–E13.5, E13.7, E14.2–E14.5, E14.7
Hemiplegia or paraplegia: G04.1, G11.4, G80.1, G80.2, G81.x, G82.x, G83.0–G83.4, G83.9
Renal disease: I12.0, I13.1, N03.2–N03.7, N05.2–N05.7, N18.x, N19.x, N25.0, Z49.0–Z49.2, Z94.0, Z99.2
Any malignancy, including lymphoma and leukaemia, except malignant neoplasm of skin: C00.x–C26.x, C30.x–C34.x, C37.x–C41.x, C43.x, C45.x–C58.x, C60.x–C76.x, C81.x–C85.x, C88.x, C90.x–C97.x
Moderate or severe liver disease: I85.0, I85.9, I86.4, I98.2, K70.4, K71.1, K72.1, K72.9, K76.5, K76.6, K76.7
Metastatic solid tumour: C77.x–C80.x
AIDS/HIV: B20.x–B22.x, B24.x

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