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Survival Rates Following Pediatric In-Hospital Cardiac Arrests During Nights and Weekends

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Abstract

IMPORTANCE—Nearly 6000 hospitalized children in the United States receive cardiopulmonary resuscitation (CPR) annually. Little is known about whether the survival of these children is influenced by the time of the event (eg, nighttime or weekends). Differences in survival could have important implications for hospital staffing, training, and resource allocation.

OBJECTIVE—To determine whether outcomes after pediatric in-hospital cardiac arrests differ during nights and weekends compared with days/evenings and weekdays.

DESIGN, SETTING, AND PARTICIPANTS—This study included a total of 354 hospitals participating in the American Heart Association's Get With the Guidelines–Resuscitation registry

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from January 1, 2000, to December 12, 2012. Index cases (12 404 children) from all children younger than 18 years of age receiving CPR for at least 2 minutes were included. Data analysis was performed in December 2014 and June 2016. We aggregated hourly blocks of time, using previously defined time intervals of day/evening and night, as well as weekend. Multivariable logistic regression models were used to examine the effect of independent variables on survival to hospital discharge. We used a combination of a priori variables based on previous literature (including age, first documented rhythm, location of event in hospital, extracorporeal CPR, and hypotension as the cause of arrest), as well as variables that were identified in bivariate generalized estimating equation models, and maintained significance of $P \leq .15$ in the final multivariable models.

MAIN OUTCOMES AND MEASURES—The primary outcome measure was survival to hospital discharge, and secondary outcomes included return of circulation lasting more than 20 minutes and 24-hour survival.

RESULTS—Of 12 404 children (56.0% were male), 8731 (70.4%) experienced a return of circulation lasting more than 20 minutes, 7248 (58.4%) survived for 24 hours, and 4488 (36.2%) survived to hospital discharge. After adjusting for potential confounders, we found that the rate of survival to hospital discharge was lower during nights than during days/evenings (adjusted odds ratio, 0.88 [95% CI, 0.80–0.97]; $P = .007$) but was not different between weekends and weekdays (adjusted odds ratio, 0.92 [95% CI, 0.84–1.01]; $P = .09$).

CONCLUSIONS AND RELEVANCE—The rate of survival to hospital discharge was lower for pediatric CPR events occurring at night than for CPR events occurring during daytime and evening hours, even after adjusting for many potentially confounding patient-, event-, and hospital-related factors.

Nearly 6000 children in the United States receive in-hospital cardiopulmonary resuscitation (CPR) each year,¹ with a rate of 2% to 6% in pediatric intensive care settings.^{2,3} Most of these children do not survive to hospital discharge.⁴ Although survival rates following pediatric in-hospital CPR have improved over the last decade, the variability in survival rates suggests potential opportunities for improvement.^{5,6}

Recent prehospital and in-hospital cardiac arrest studies of adults, as well as a prehospital study of children, have demonstrated worse outcomes for patients who had a cardiac arrest at night rather than during the day.^{7–12} Similar in-hospital studies of children are lacking and could yield different results based on the progressive nature of respiratory failure and shock that typically precede pediatric cardiac arrest,⁴ theoretically making it a more predictable event.

The American Heart Association's Get With the Guidelines–Resuscitation (GWTG-R) registry is a large multicenter registry of in-hospital cardiac arrests with standardized data reporting methods. We used the GWTG-R database to evaluate survival rates for children who had an in-hospital cardiac arrest by time of day and day of week. We hypothesized that outcomes would be worse during nights and weekends, even when adjusted for potential confounding patient-, event-, and hospital-related factors.

Methods

The GWTG-R registry is the only national registry of inhospital cardiac arrests in North America. The primary purpose is quality improvement based on the recording of de-identified data in compliance with the Health Insurance Portability and Accountability Act. Data are collected prospectively, and participation in the registry is voluntary. The GWTG-R registry uses standardized definitions and reporting forms based on the Utstein template,^{13,14} allowing for more uniform practice in the collection and review of resuscitation data. Details of hospital certification, data collection and reporting methods, and integrity verification have previously been reported.^{7,15}

Adult and pediatric patients, employees, and visitors requiring resuscitation in a hospital facility were eligible for inclusion in the registry. The 6 domains of data that were collected relate to (1) facility data, (2) patient demographic data, (3) pre-event data, (4) event data, (5) outcome data, and (6) quality improvement data.¹⁶

Institutional review board approval was not required for participation in the continuous quality improvement activities of the registry but was obtained from the McGill University Faculty of Medicine institutional review board for this research study. Informed consent was not required because the data were deidentified.

Inclusion and Exclusion Criteria

All children younger than 18 years of age who received CPR for at least 2 minutes were eligible for inclusion in this study. Only index events were included (ie, the first CPR event) for any patient receiving CPR more than once during a hospitalization. Exclusion criteria were children whose resuscitation began outside of the hospital, newborns who experienced cardiac arrest in the delivery room, cardiac arrests that involved an obstetric patient, events that were limited to a shock by an implantable cardioverter-defibrillator, or events that occurred in a patient with a do-not-attempt-resuscitation order. Sequential data from 354 participating hospitals from January 1, 2000, to December 12, 2012, were analyzed.

Outcomes

The prospectively selected primary outcome variable was survival to hospital discharge. Secondary outcome variables included return of circulation lasting more than 20 minutes and 24-hour survival. Patients who survived to the initiation of extracorporeal CPR or cardiopulmonary bypass were included as having a return of circulation.

Exposures

We aggregated hourly blocks of time, with day/evening defined as 7:00 AM to 10:59 PM and night as 11:00 PM to 6:59 AM. Weekdays were defined as 7:00 AM on Monday until 10:59 PM on Friday, and weekends were defined as 11:00 PM on Friday to 6:59 AM on Monday.⁷ Using time of day (day/evening vs night) and weekend/weekday categories, we compared primary (survival to hospital discharge) and secondary outcome variables using the χ^2 test. We applied locally weighted scatterplot smoothing regression methods to confirm the time of breaking point for sensitivity analyses.

Secondary Analysis

To compare outcomes during days vs nights, we chose to aggregate and compare 7-hour epochs from 9 AM to 4 PM vs midnight to 7 AM as time frames that would consistently be considered days and nights irrespective of hospital staffing patterns. Again, using time of day (day vs night) and weekend/weekday categories, we compared survival to hospital discharge among children. Monday to Friday were considered as weekdays, and Saturday and Sunday were considered as weekends. For the nights, Monday to Thursday were considered weekdays, while Friday to Sunday were considered weekends.

Statistical Analysis

Multivariable logistic regression models were used to examine the effect of independent variables on survival to hospital discharge, 24-hour survival, and return of circulation. Selection of a priori variables was based on previous literature and included age, first documented rhythm, location of event in hospital, extracorporeal CPR, and hypotension as the cause of arrest.¹⁷ The final multivariable model was developed by fitting bivariate generalized estimating equation (GEE) models for each potential confounder and including the variable in the subsequent stage of analysis if the statistical significance was $P \leq .10$ for the primary outcome. Notably, the GEE model accounts for clustering by site. Next, all of these selected variables were included in a multivariable GEE model for each time of day and weekday/weekend exposure. If a variable remained statistically significant at a level of $P \leq .15$ for the primary outcome, it was incorporated into the final multivariable model. We included patient's sex in the final multivariable GEE models, although it did not meet all of the criteria already described.

The final multivariable GEE model for survival to discharge included several potential confounders: age; sex; race; illness category; preexisting sepsis; hypotension as the cause of arrest; metabolic or electrolyte disturbance; location of event in hospital; electrocardiographic monitoring; presence of arterial lines; central venous access or mechanical ventilation at the time of the cardiac arrest; vasoactive infusions of dobutamine, dopamine, or epinephrine; first documented rhythm; duration of CPR; epinephrine use; extracorporeal CPR; and the use of pharmacologic interventions of atropine, sodium bicarbonate, calcium chloride, or gluconate and lidocaine.

All P values are 2 sided with a significance level set at .05. Statistical analyses were performed using SAS version 9.3 (SAS Institute Inc).

Results

There were 12 404 index pediatric CPR events that met the inclusion criteria over the 12-year, 11-month period. Of these events, 8568 occurred during daytime or evening hours, and 3836 occurred at night. Weekday cardiac arrests (between 7 AM on Monday to 11 PM on Friday) accounted for 8586 events, and the remaining 3818 cardiac arrests occurred on weekends. The 354 hospitals contributing data during this time period had a median size of 333 beds (interquartile range, 219–499 beds), including 16 that were self-classified as “freestanding” children's hospitals.

Patients' characteristics, presented by time of day (day/evening vs night), are outlined in Table 1. Patients experiencing a CPR event at night were not different from those experiencing an event during the day with respect to age, sex, hypotensive cause of the cardiac arrest, or first documented rhythm. A higher percentage of patients had their CPR event in an intensive care setting at night compared with in the day/evening. However, fewer patients had a witnessed event at night. Patients' characteristics, presented by day of the week (weekday vs weekend), are outlined in Table 1. Patients experiencing a CPR event on weekends were not different from those experiencing an event during weekdays with respect to age, sex, hypotensive cause of the cardiac arrest, or first documented rhythm. A higher percentage of patients had their CPR event in an intensive care setting on weekends compared with on weekdays, yet fewer had a witnessed event on weekends.

Of 12 404 children, 8731 (70.4%) experienced a return of circulation lasting more than 20 minutes, 7248 (58.4%) survived for 24 hours, and 4488 (36.2%) survived to hospital discharge. The unadjusted rate of survival to hospital discharge was lower for children who had a CPR event occurring at night (1300 of 3836 [33.9%]) than for children who had a CPR event occurring during the day or evening (3188 of 8568 [37.2%]) ($P < .001$). Similarly, the unadjusted rate of survival to hospital discharge was lower on weekends (1266 of 3818 children [33.2%]) than weekdays (3222 of 8586 children [37.5%]) ($P < .001$). Survival to hospital discharge is characterized by the hour of the day in Figure 1 and by the day of the week in Figure 2, with worse outcomes on Saturday and Sunday.

After adjusting for potential confounders, we found that the rate of survival to hospital discharge remained lower at night than during the day/evening (adjusted odds ratio [OR], 0.88 [95% CI, 0.80–0.97]; $P = .007$). Although the absolute rate of survival to hospital discharge remained lower on weekends than on weekdays, this difference did not reach statistical significance (adjusted OR, 0.92 [95% CI, 0.84–1.01]; $P = .09$).

Adjusted rates of 24-hour survival were lower at night than during the day/evening (adjusted OR, 0.80 [95% CI, 0.73–0.87]; $P < .001$) and were lower during the weekends than during the weekdays (adjusted OR, 0.87 [95% CI, 0.78–0.97]; $P = .01$). Return of circulation was not significantly different at night compared with during the day/evening and was not significantly different during weekends compared with week-days (Table 2 and Table 3). Using locally weighted scatterplot smoothing regression methods, we identified 7 PM as an appropriate breaking point for sensitivity analyses.

When categorized as the 7-hour daytime epoch (9 AM to 4 PM) and the 7-hour nighttime epoch (midnight to 7 AM) in secondary analysis, 3797 CPR events occurred during the daytime epoch, and 3298 CPR events occurred during the nighttime epoch. The unadjusted rate of survival to hospital discharge was lower for children who had CPR events during the 7-hour nighttime epoch than during the 7-hour daytime epoch (33.4% [1102 of 3298] vs 39.1% [1485 of 3797]; $P < .001$). After adjusting for a priori (age, first documented rhythm, location of event in hospital, extracorporeal CPR, and hypotensive cause of arrest) and all known potential confounders, we found that the rate of survival to hospital discharge was lower during nighttime epochs than during daytime epochs (adjusted OR, 0.85 [95% CI, 0.76–0.95]; $P = .005$).

The unadjusted rate of survival to hospital discharge was lower during weekend daytime epochs than during weekday daytime epochs (33.1% [309 of 933 children] vs 41.1% [1176 of 2864 children]; $P < .001$). However, the rate of survival to hospital discharge was not demonstrably different on weekend nighttime epochs compared with weekday nighttime epochs (32.9% [602 of 1828 children] vs 34.0% [500 of 1470 children]; $P = .51$). After adjusting for potential confounders, we found that the difference in the rate of survival to hospital discharge approached significance between weekend daytime epochs and weekday daytime epochs (adjusted OR, 0.85 [95% CI, 0.70–1.02]; $P = .07$) but not between weekend nighttime epochs and weekday nighttime epochs (adjusted OR, 0.94 [95% CI, 0.79–1.12]; $P = .51$).

Discussion

In the large, prospective GWTG-R in-hospital cardiac arrest registry, the rate of survival to hospital discharge was lower for pediatric CPR events occurring at night than for CPR events occurring during daytime and evening hours, even after adjusting for many potentially confounding patient-, event-, and hospital-related factors. The lower survival rate among these children whose cardiac arrests occurred at nighttime are consistent with the lower survival rates among adults whose in-hospital cardiac arrests occurred at nighttime.⁷ In addition, a recent pediatric out-of-hospital investigation¹² showed a lower rate of survival to hospital discharge when the cardiac arrest occurred at nighttime despite no difference in the rate of return of spontaneous circulation at nighttime. Kitamura et al¹² postulated that the differences in survival may have been related to differences in postresuscitation care once the patients arrived in the hospital. Similar findings of lower survival at night were noted for adult out-of-hospital cardiac arrests.⁸

Lower survival rates at nighttime are an important, yet underrecognized public health concern. This is especially pertinent because suboptimal resuscitative efforts are a potentially preventable harm.¹⁸ Assuming an annual CPR rate of 6000 events per year, we found that simply improving overall survival (currently at 36.2%) to match the weekday daytime epoch survival (41.1%) would result in almost 300 additional children's lives saved per year in the United States. These findings may have important implications for hospital staffing, training, and resource allocation.

Although the results of our study are concerning, they are not entirely surprising because they align with pediatric literature demonstrating worse outcomes for critically ill children admitted to pediatric intensive care units during the evening and nighttime,¹⁹ as well as for newborns who may require resuscitation.^{20,21} Interestingly, the study by Stewart et al²¹ also demonstrated worse outcomes for newborns during the months of July and August when staffing of hospitals is typically reduced and when more senior physicians are less likely to be present.

Potential causes for the decreased survival rate after pediatric cardiac arrest at night are important to identify. Hospitals tend to have fewer senior health care professionals²² and more junior health care professionals working at night,²³ perhaps influencing the recognition and response to deteriorating patients and those experiencing cardiac arrest. In addition,

medical error is more common,²⁴ and there is reduced proficiency in performing psychomotor skills²⁵ at night. None theless, performance in other appropriately staffed and resourced time-sensitive domains, such as trauma,²⁶ has overcome the so-called weekend effect. In the GWTG-R adult study⁷ comparing survival after in-hospital cardiac during daytime/evenings vs nights, survival rates were only similar for the 2 time periods in the emergency department and trauma service—2 domains that tend to have more consistent coverage with titrated staffing patterns and the presence of attending physicians throughout the day, evening, and night.

Similarly, the rates of return of spontaneous circulation were not different between nights and weekends in the study on pediatric out-of-hospital cardiac arrests, whereas the rates of 30-day survival were.¹² Again, these data on pediatric outof-hospital cardiac arrests suggest that the “night” and “weekend” effects may have been overcome in the emergency medical services system but not in the hospital system.

Limitations

Our study has several limitations that should be considered when interpreting the results. Participation in the GWTG-R registry is voluntary, with the potential for a selection bias of participating centers that could limit extrapolation.²⁷ The data were accumulated over a long time period, from 2000 to 2012, when secular trends in resuscitation education and practice may have taken place, which might have masked some diurnal or weekday/weeknight variation. Second, the large GWTG-R data set, based on the Utstein template, allows for the adjustment for a large number of potential confounders but cannot account for unmeasured confounding variables. Third, the primary outcome variable in this study was survival to hospital discharge. Unfortunately, neurological outcome data were frequently missing for patients included in this study, thereby limiting our ability to address this important outcome without potential biases. Fourth, although the study does highlight an important public health concern, it does not identify the underlying causes for the differences in survival.

Future research might explore the effect of hospital staffing, better patient monitoring with earlier detection of decompensation, the presence of a rapid response team, the quality of CPR,^{28–30} post-event quantitative debriefing,^{31,32} and postarrest management (eg, targeted temperature management or hemo-dynamic support³³) on the differential survival during day/evening vs night. Although these observational findings do not identify the specific mechanisms that will eliminate disparity in night vs day survival, they may have important implications for hospital staffing, training, and resource allocation. Of note, the absolute difference in witnessed cardiac arrests was relatively smallatnightcomparedwithduringtheday/evening(1.1%),even though it was statistically significant. An alternative explanationoftheday-night difference is that there are different pathologies operating at night.Aformalcost-benefitorcost-effectiveness study would be required to assess the cost, personnel, and education that would be required to achieve daytime/nighttime and weekday/weekend parity in survival outcomes.

A final limitation of the study may have been the lack of power to demonstrate differences in outcomes on weekends. The absolute rate of survival during the weekend daytime (33%) was lower than during the weekday daytime (41%) and was quite similar to the absolute rate

of survival during the week-day nighttime (34%). Nevertheless, the adjusted OR for weekend daytime survival to hospital discharge was 0.85 (95% CI, 0.70–1.02) ($P = .07$). We speculate that the much smaller number of patients in this pediatric GWTG-R study may have masked the true difference in outcomes on weekends in contrast to the adult GWTG-R study that showed worse outcomes on weekend daytimes.⁷

Conclusions

In this large, prospective GWTG-R in-hospital cardiac arrest registry, the rate of survival to hospital discharge was lower for pediatric patients who experienced CPR events at night than for those who experienced CPR events during daytime and evening hours, even after adjusting for important potentially confounding patient-, event-, and hospital-related factors. Although the absolute rate of survival to hospital discharge was lower on weekends than weekdays, this difference did not reach statistical significance when adjusted for confounding factors. Discrepancy between daytime and nighttime outcomes represents an important patient safety concern that warrants further investigation.

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Key Points**Question**

Do survival rates after pediatric in-hospital cardiac arrests differ during nights and weekends compared with days/evenings and weekdays?

Findings

In this national registry-based cohort study of hospitalized children younger than 18 years of age receiving cardiopulmonary resuscitation (CPR), the rate of survival to hospital discharge was 36.2% (4488 of 12 404 children) overall. After adjusting for important potential confounders, we found that the rate of survival to hospital discharge was significantly lower during nights than during days/evenings, but there was no difference between weekends and weekdays.

Meaning

The rate of survival to hospital discharge was lower for pediatric CPR events occurring at night than for CPR events occurring during daytime and evening hours.

Figure 1.
Rate of Survival to Hospital Discharge by Hour of Day When Cardiopulmonary Resuscitation Occurred

Figure 2.
Rate of Survival to Hospital Discharge by Day of Week When Cardiopulmonary Resuscitation Occurred

Table 1.

Description of Study Sample, Excluding Delivery Room, Obstetric, and Other/Visitor Events

Variable	All Patients, No. (%)	Patients, No. (%)		P Value	Patients, No. (%)		P Value
		Day/Evening	Night		Weekday	Weekend	
Total	12 404	8568	3836		8586	3818	
Age, median (IQR), y	0.3 (0.0–2.4)	0.3 (0.0–2.4)	0.2 (0.0–2.4)	.05	0.3 (0.0–2.2)	0.3 (0.0–3.0)	.21
Sex							.48
Male	6932 (56.0)	4804 (56.2)	2128(55.6)	.55	4783 (55.8)	2149(56.5)	
Female	5448 (44.0)	3748(43.8)	1700 (44.4)		3791 (44.2)	1657 (43.5)	
Race							
White	6482(52.6)	4499 (52.9)	1983 (52.1)	.75	4527 (53.1)	1955 (51.6)	.02
African American	3110(25.2)	2137(25.1)	973(25.5)		2164(25.4)	946(25.0)	
Asian/Pacific Islander	265 (2.2)	177(2.1)	88(2.3)		163 (1.9)	102(2.7)	
Other/unknown/not documented	2461 (20.0)	1696(19.9)	765 (20.1)		1677 (19.7)	784 (20.7)	
Event location (3-level)							
ICU	9724 (78.4)	6565 (76.6)	3159(82.4)	<.001	6627 (77.2)	3097 (81.1)	<.001
ED	821 (6.6)	580 (6.8)	241 (6.3)		521(6.1)	300(7.9)	
General, inpatient	444 (3.6)	302 (3.5)	142 (3.7)		324(3.8)	120(3.1)	
Other	1413(11.4)	1120(13.1)	293 (7.6)		1112 (13.0)	301(7.9)	
Illness category							
Medical-cardiac	1786(14.4)	1246(14.6)	540(14.1)	<.001	1255 (14.6)	531(13.9)	<.001
Medical-noncardiac	4290 (34.6)	2924(34.1)	1366(35.6)		2936(34.2)	1354(35.5)	
Surgical-cardiac	2177(17.6)	1575 (18.4)	602 (15.7)		1615 (18.8)	562 (14.7)	
Surgical-noncardiac	943 (7.6)	704 (8.2)	239(6.2)		690 (8.0)	253 (6.6)	
Newborn	2482 (20.0)	1637 (19.1)	845 (22.0)		1678(19.6)	804(21.1)	
Trauma	720(5.8)	477 (5.6)	243 (6.3)		406(4.7)	314 {8.2)	
Immediate factor related to event							
Acute respiratory insufficiency	5639(50.4)	3840 (49.6)	1799(52.3)	.008	3838(49.6)	1801(52.1)	.02
Hypotension	5531 (49.4)	3826 (49.4)	1705 (49.6)		3787 (49.0)	1744(50.5)	
First documented pulseless rhythm							
Asystole	2671 (35.4)	1807 (34.7)	864(37.0)	.40	1806 (34.6)	865(37.3)	.04
PEA	2837 (37.6)	1984(38.1)	853 (36.5)		1966(37.7)	871 (37.5)	
PVT	368 (4.9)	251 (4.8)	117 (5.0)		270(5.2)	98 (4.2)	
VF	458(6.1)	319(6.1)	139(6.0)		336(6.4)	122(5.3)	
Unknown/not documented	1204(16.0)	841 (16.2)	363 (15.5)		839(16.1)	365 (15.7)	
Discovery status at time of event							
Witnessed arrest	11749(94.8)	8144(95.1)	3605 (94.0)	.02	8158(95.1)	3591(94.1)	.02
Monitored via electrocardiography	11617 (93.7)	8015 (93.6)	3602 (93.9)	.41	8037 (93.6)	3580(93.8)	.79
CPR, No. of patients	11759	8122	3637		8128	3631	
Duration of CPR, median (IQR), min	12.0(5.0–28.0)	12.0(4.0–27.0)	13.0(5.0–30.0)	<.001	12.0(4.0–28.0)	12.0(5.0–28.0)	.54

Abbreviations: CPR, cardiopulmonary resuscitation; ED, emergency department; ICU, intensive care unit; IQR, interquartile range; PEA, pulseless electrical activity; PVT, pulseless ventricular tachycardia; VF, ventricular fibrillation.

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Table 2.

Survival Outcomes at Night vs Day/Evening

Outcome	AdjustedOR(95%CI)	P Value
Survival to hospital discharge	0.88 (0.80–0.97)	.007
Survival to 24 h	0.80(0.73–0.87)	<.001
Return of circulation	0.89(0.79–1.01)	.06

Abbreviation: OR, odds ratio.

Table 3.

Survival Outcomes on Weekends vs Weekdays

Outcome	AdjustedOR(95%CI)	P Value
Survival to hospital discharge	0.92 (0.84–1.01)	.09
Survival to 24 h	0.87 (0.78–0.97)	.01
Return of circulation	1.00(0.89–1.12)	.97

Abbreviation: OR, odds ratio.