Survival From In-Hospital Cardiac Arrest During Nights and Weekends

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Context Occurrence of in-hospital cardiac arrest and survival patterns have not been characterized by time of day or day of week. Patient physiology and process of care for in-hospital cardiac arrest may be different at night and on weekends because of hospital factors unrelated to patient, event, or location variables.

Objective To determine whether outcomes after in-hospital cardiac arrest differ during nights and weekends compared with days/evenings and weekdays.

Design and Setting We examined survival from cardiac arrest in hourly time segments, defining day/evening as 7:00 AM to 10:59 PM, night as 11:00 PM to 6:59 AM, and weekend as 11:00 PM on Friday to 6:59 AM on Monday, in 86 748 adult, consecutive in-hospital cardiac arrest events in the National Registry of Cardiopulmonary Resuscitation obtained from 507 medical/surgical participating hospitals from January 1, 2000, through February 1, 2007.

Main Outcome Measures The primary outcome of survival to discharge and secondary outcomes of survival of the event, 24-hour survival, and favorable neurological outcome were compared using odds ratios and multivariable logistic regression analysis. Point estimates of survival outcomes are reported as percentages with 95% confidence intervals (95% CIs).

Results A total of 58 593 cases of in-hospital cardiac arrest occurred during day/evening hours (including 43 483 on weekdays and 15 110 on weekends), and 28 155 cases occurred during night hours (including 20 365 on weekdays and 7790 on weekends). Rates of survival to discharge (14.7% [95% CI, 14.3%-15.1%] vs 19.8% [95% CI, 19.5%-20.1%], return of spontaneous circulation for longer than 20 minutes (44.7% [95% CI, 44.1%-45.3%] vs 51.1% [95% CI, 50.7%-51.5%]), survival at 24 hours (28.9% [95% CI, 28.4%-29.4%] vs 35.4% [95% CI, 35.0%-35.8%]), and favorable neurological outcomes (11.0% [95% CI, 10.6%-11.4%] vs 15.2% [95% CI, 14.9%-15.5%]) were substantially lower during the night compared with day/evening (all P values $<.001$). The first documented rhythm at night was more frequently asystole (39.6% [95% CI, 39.0%-40.2%] vs 33.5% [95% CI, 33.2%-33.9%], $P<.001$) and less frequently ventricular fibrillation (19.8% [95% CI, 19.3%-20.2%] vs 22.9% [95% CI, 22.6%-23.2%], $P<.001$). Among in-hospital cardiac arrests occurring during day/evening hours, survival was higher on weekdays (20.6% [95% CI, 20.3%-21%]) than on weekends (17.4% [95% CI, 16.8%-18%]; odds ratio, 1.15 [95% CI, 1.09-1.22]), whereas among in-hospital cardiac arrests occurring during night hours, survival to discharge was similar on weekdays (14.6% [95% CI, 14.1%-15.2%]) and on weekends (14.8% [95% CI, 14.1%-15.2%]; odds ratio, 1.02 [95% CI, 0.94-1.11]).

Conclusion Survival rates from in-hospital cardiac arrest are lower during nights and weekends, even when adjusted for potentially confounding patient, event, and hospital characteristics.

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THE INSTITUTE OF MEDICINE REports that as many as 98 000 preventable in-hospital deaths occur annually.[1] Diagnostic, treatment, preventive, and other system errors have been identified as focus areas to prevent medical injury.[2] The detection and treatment of arrests and their antecedents may be less effective at night because of patient, event, hospital, staffing, and response factors. If in-hospital cardiac arrests are more common or survival is worse on nights and weekends, this information could have important implications for hospital staffing, training, care delivery processes, and equipment decisions.

We evaluated survival rates for adults with in-hospital cardiac arrest by time of day and day of week. We hypothesized that outcome after cardiac arrest would be worse during nights and weekends, even when adjusted for potentially confounding patient, event, and hospital factors.

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METHODS

Data Collection

Sponsored by the American Heart Association (AHA), the National Registry of Cardiopulmonary Resuscitation (NRCPR) is a prospective, voluntary, multisite registry of in-hospital resuscitation events.[3] All sequential data were analyzed from 507 medical/surgical participating hospitals from January 1, 2000, through February 1, 2007.

Specially trained quality improvement personnel at each participating institution perform data abstraction for each cardiac arrest event from hospital medical records and arrest documentation forms. Comprehensive and redundant methods are used to ensure that all cardiac arrests are captured, including review of hospital and unit-based cardiac arrest medical record logs, hospital telephone/page operator logs of all cardiac arrest calls, "code blue" committee minutes, pharmacy and material management "code cart" records, pharmacy tracer drug records for resuscitation medications, and notes from routine walk-through rounds in high-risk/high-volume areas.

The database contains precisely defined variables derived from Utstein data reporting guidelines for in-hospital cardiac arrest.[3-5] Case study methodology was used to evaluate data abstraction, entry accuracy, and operational definition compliance prior to acceptance of data transmission. Digital Innovation (Forest Hill, Maryland), the company that provides data management and software development services for the NRCPR, acts as the central data repository, assigns code numbers to each record and facility, and removes patient identifiers to ensure confidentiality and compliance with the Health Insurance Portability and Accountability Act.

Oversight for the entire process of data collection, analysis, and reporting is provided by the AHA, its National Center staff, the NRCPR Scientific Advisory Board, and the AHA Executive Database Steering Committee. The Human Subjects Protection Program at the University of Arizona College of Medicine determined that this study did not need further review by an institutional review board because the data were de-identified and already existed.

Patients aged 18 years or older who experienced a cardiac arrest requiring CPR or defibrillation were included in the analysis. Only index event pulseless events were included. An *index event* is defined as the first arrest for patients having more than 1 arrest during the same hospitalization. Exclusion criteria included all cardiac arrests in which resuscitation was initiated out of the hospital prior to arrival in the emergency department and events that involved defibrillation of ventricular fibrillation (VF) or pulseless ventricular tachycardia (pVT) solely by an implantable cardioverter-defibrillator.

The prospectively selected primary outcome measure was survival to hospital discharge. Secondary outcome measures included return of spontaneous circulation lasting more than 20 minutes, 24-hour survival, and neurological outcome. Neurological outcome was determined using cerebral performance category scales.

The neurological status before cardiac arrest and at discharge were determined by medical record review. Favorable neurological outcome was defined as a cerebral performance category score of 1 or 2 (range, 1-5) or no change from baseline cerebral performance category score.

Data Integrity

All data entry personnel are encouraged to complete formal training, including two 2-hour courses in basic and advanced data entry for the NRCPR. All data entry persons must take and pass an electronic certification examination prior to submitting any data to the central database. Monthly teleconferences and an annual users' meeting also address data integrity at the local participant level. The data set software has more than 250 built-in data checks to notify the data entry person of missing or outlying responses. "Smart skips" lead the data entry person through the data set to improve data completeness.

Statistical Analysis

All statistical analyses used commercially available statistical packages (Statistical Applications Software version 9.1; SAS Institute, Cary, North Carolina) and R version 2.6.0 (The R Project for Statistical Computing).

Treatment of Missing Data

Missing data patterns were examined for all fields by stratifying the missing category by day/evening and night. These day/evening vs night percentages did not substantially differ for any of the data fields. Events with missing data about the time, which was our primary exposure variable, were excluded from all analyses. Missing data values for all other covariates were coded as unknown or none.

Descriptive Statistics

We characterized differences between binary survival outcome groups with respect to several potential risk factors. For discrete variables, we calculated the number of observations in each level/outcome group combination and tested for significant differences between groups with χ^2 tests. For normally distributed continuous variables, we calculated outcome group means and standard deviations and used *t* tests to assess significant differences between outcome groups. Results are presented as means and 95% confidence intervals (95% CIs). For nonnormal continuous variables, we calculated medians and interquartile ranges and used the nonparametric Wilcoxon rank sum test to assess significant differences between outcome groups. All *P* values represent 2-sided hypothesis tests. The significance level for all tests was $\alpha = .05$ except when multiple comparison adjustments were deemed appropriate.

Event duration was defined as the time interval from the delivery of the first chest compression for pulseless arrest (or recognition of the need for defibrillation when initial rhythm was VT or VF) until the beginning of a sustained return of spontaneous circulation (lasting >20 minutes) or the time resuscitation efforts were terminated.

The continuous variable of event duration was collapsed to a nominal variable via lowess curve generation based on a logistic regression model incorporating smoothing splines. Hospital characteristic variables were created using hospital bed size quartiles.

For specific analyses, we aggregated hourly blocks of time. Day/evening was defined as 7:00 AM to 10:59 PM and night as 11:00 PM to 6:59 AM. Weekdays were defined from 7:00 AM on Monday through 10:59 PM on Friday, and weekends were defined as 11:00 PM on Friday through 6:59 AM on Monday. When appropriate, we compared proportions surviving by day/evening vs night according to hospital bed size quartile to account for potential hospital differences or outliers.

Multivariable Logistic Regression

To examine the association between hour of day and outcomes, we used event hour as our exposure variable. The model included prospectively designated, clinically important potential confounders or their class (sex, race, illness category, combination of preexisting condition and cause variables, interventions in place at time of event, weekend, hospital size, event location, monitored status, witnessed status, first documented rhythm, initial or subsequent VT/VF, CPR duration, delay in defibrillation, delay in CPR, delay in vasopressor use, use of epinephrine, and time from hospital admission to event). We calculated bed size quartiles to build the hospital size variable. Race and ethnicity were defined by the participating hospital and transmitted by the institution to the database. Definitions of either race or ethnicity were not provided by the investigator.

Prospectively designated clinically important variables (age, Hispanic ethnicity, month of year, other cardiac arrest medication use, and induced hypothermia) were then entered into a stepwise multivariable logistic regression for the primary end point of survival to hospital discharge. The criterion for the stepwise selection of variables was $P < .25$.

Using this model, we then analyzed effect of time of day on the secondary end points of return of spontaneous circulation for longer than 20 minutes, survival to 24 hours, and survival to discharge with favorable neurological outcome (defined as a cerebral performance category score of 1 or 2 or no change from admission cerebral performance category score). We used C statistics (C=0.85) to assess the final model fit. Post hoc analysis of effect of a hospitalwide response activation on survival to discharge was performed.

Effect Modifications

We examined 7 variables for evidence of effect modification by including their interactions with time of day in logistic regression models (first documented rhythm, event location, whether the event was monitored, whether the event was witnessed, delay in defibrillation, race [specifically black vs white], and illness category). Three variables (event location, monitored status, and illness category) demonstrated statistical significance. For these analyses, we collapsed the hour of day variable into a dichotomous day (7:00 AM to 10:59 PM) vs night (11:00 PM to 6:59 AM) variable and fit a separate regression model for each of the 3 variables. Odds ratios (ORs) and their 95% CIs are displayed with forest plots. Odds ratios greater than 1 indicate a greater chance of survival when compared with the reference group.

RESULTS

There were 86 748 consecutive, inpatient, index event, pulseless cardiac arrests reported from January 1, 2000, through February 1, 2007, including 58 593 cases during day/evening hours and 28 155 cases during night hours. Patient demographics are shown in TABLE 1.

Arrest event characteristics are shown in TABLE 2. The precipitating conditions for cardiac arrest were similar in the day/evening vs night. Cardiac arrests occurring during the night were less likely to be monitored by telemetry/electrocardiography (74.3% [95% CI, 73.8%-74.8%] vs 77.0% [95% CI, 76.6%-77.3%]; $P < .001$) or witnessed (75.1% [95% CI, 74.6%-75.6%] vs 82.8% [95% CI, 82.5%-83.1%]; $P < .001$) compared with arrests during the day/evening. The proportion of arrests by first documented rhythm during the day/evening were 33.5% asystole (95% CI, 33.2%-33.9%), 36.9% pulseless electrical activity (95% CI, 36.5%-37.3%), and 22.9% pVT/VF (95% CI, 22.6%-23.2%). These proportions were significantly different during the night: 39.6% asystole (95% CI, 39.0%-40.2%), 34.6% pulseless electrical activity (95% CI, 34.0%-35.2%), and 19.8% pVT/VF (95% CI, 19.3%-20.2%) (day/evening vs night, $P < .001$). Patients who had cardiac arrest at night were also less likely to have VF/pVT occur at any subsequent time during the arrest than patients who had cardiac arrest during the day/evening (56.0% [95% CI, 55.4%-56.5%] vs 52.0% [95% CI, 51.6%-52.4%]; $P < .001$).

Patients with cardiac arrest that occurred at night had a significantly lower survival rate than patients whose arrest occurred during the day or evening (TABLE 3). FIGURE 1 depicts adjusted odds ratios for the hourly cardiac arrest primary outcome of survival to hospital discharge with reference hour 3:00 PM, which had the highest survival rate. We found effect modifications for the relationship between time of day and survival to discharge for 3 variables: event location, illness category, and monitored status ($P = .002$, $P = .03$, and $P = .01$ for event hour $\times$ effect modifier interaction terms, respectively).

Using the collapsed day/evening vs night variable, we fit 3 separate regressions to estimate the ORs for event location, illness category, and monitored status. FIGURE 2 shows the adjusted odds of survival to discharge for day/evening vs night for each event location, illness category, and monitored status. The day/evening vs night differential was strongest in the operating room/postanesthesia care unit (36.6% vs 16.7%; OR, 2.63; 95% CI, 1.76-3.93), followed by the interventional catheterization laboratory (34.4%

vs 23.9%; OR, 1.48; 95% CI, 1.07-2.06). The emergency department was the only location that did not have a significantly different survival rate during the night. Among illness categories, the largest day/evening vs night survival differential occurred for surgical noncardiac events (20.4% vs 12.0%; OR, 1.46; 95% CI, 1.26-1.68). Trauma was the only illness category for which there was no significant difference in survival rates by time of day.

FIGURE 3 shows that survival to discharge at night was similar during the week (14.6%; 95% CI, 14.1%-15.2%) and weekends (14.8%; 95% CI, 14.1%-15.2%; OR, 1.02 [95% CI, 0.94-1.11]). Survival during day/evening weekdays (20.6%; 95% CI, 20.3%-21.0%) was higher than on weekends (17.4%; 95% CI, 16.8%-18.0%; OR, 1.15 [95% CI, 1.09-1.22]).

Of the 58 593 cases of in-hospital cardiac arrest that occurred during day/evening hours, 43 483 occurred on weekdays and 15 110 occurred on weekends. Of the 28 155 cases of in-hospital cardiac arrest that occurred during night hours, 20 365 occurred on weekdays and 7790 occurred on weekends. Survival to discharge rates did not vary significantly by bed size quartiles, with values of 19.3% (95% CI, 18.5%-20.1%), 16.4% (95% CI, 15.8%-17.1%), 19.1% (95% CI, 18.5%-19.6%), and 18.2% (95% CI, 17.8%-18.5%) for quartiles 1 (low) through 4 (high), respectively.

We used process of care exceptions, defined as defibrillation delay longer than 2 minutes, CPR delay longer than 1 minute, and vasoconstrictor administration delay longer than 5 minutes, as surrogate markers of performance within hospitals. The frequency of self-reported process of care exceptions was not associated with the day/evening vs night differential in survival to discharge. Post hoc analysis of the association between presence of a hospital-wide response activation and survival to discharge demonstrated no significant change in our model ($P=.57$).

Table 1. Patient Characteristics

	No. (%)			
	Day/Evening (n = 58 593)[a]	Night (n = 28 155)[a]	Total (N = 86 748)	*P* Value
Age at event, median (25%-75%), y	69 (56-78)	69 (56-79)	69 (56-78)	.02
Male sex	33 698 (58)	16 518 (59)	50 216 (58)	.001
Race				
White	40 377 (69)	19 449 (69)	59 826 (69)	.49
African American	11 775 (20)	5686 (20)	17 461 (20)	
Other/unknown	6441 (11)	3020 (11)	9461 (11)	
Illness category				
Medical, cardiac	21 395 (37)	9924 (35)	31 319 (36)	< .001
Medical, noncardiac	24 377 (42)	12 560 (45)	36 937 (43)	
Surgical, cardiac	4267 (7)	1748 (6)	6015 (7)	
Surgical, noncardiac	6678 (11)	3082 (11)	9760 (11)	
Trauma	1646 (3)	756 (3)	2402 (3)	
Other	230 (0)	85 (0)	315 (0)	
Preexisting conditions[b]				
Acute myocardial infarction	11 177 (19)	4995 (18)	16 172 (19)	< .001
Arrhythmia	19 828 (34)	9216 (33)	29 044 (33)	< .001
Congestive heart failure (this admission)	10 651 (18)	5103 (18)	15 754 (18)	.82
Respiratory insufficiency	23 918 (41)	11 566 (41)	35 484 (41)	.51
Hypotension	16 803 (29)	7785 (28)	24 588 (28)	.001
Pneumonia	7398 (13)	3749 (13)	11 147 (13)	.005
Septicemia	8077 (14)	3924 (14)	12 001 (14)	.57
Renal insufficiency	18 307 (31)	8968 (32)	27 275 (31)	.08
Metabolic/electrolyte abnormality	10 511 (18)	5127 (18)	15 638 (18)	.35
None	2769 (5)	1204 (4)	3973 (5)	.003
Interventions in place at time of event[c]				
Vascular access	53 414 (91)	25 818 (92)	79 232 (91)	.009
Pulmonary artery catheter	2691 (5)	1135 (4)	3826 (4)	< .001
Arterial catheter	5498 (9)	2235 (8)	7733 (9)	< .001
Vasoactive infusion	15 398 (26)	7349 (26)	22 747 (26)	.58
Mechanical ventilation	17 416 (30)	7877 (28)	25 293 (29)	< .001

[a] Day/evening was defined as 7:00 AM to 10:59 PM, night as 11:00 PM to 6:59 AM.
[b] Multiple comparison adjusted significance level $\alpha = .005$.
[c] Multiple comparison adjusted significance level $\alpha = .01$.

COMMENT

In-hospital cardiac arrest is a major public health problem. During 2005 and 2006, more than 21 000 in-hospital cardiac arrests were reported to the AHA NRCPR from approximately 10% of the hospitals in the United States. The principal finding of this study was that survival to discharge following in-hospital cardiac arrest was lower during nights and weekends compared with day/evening times on weekdays, even after accounting for many potentially confounding patient, arrest event, and hospital factors.

Our findings are consistent with data from small, single-institution studies.[6-8] Peng et al[8] reported that survival was worse from midnight to 8:00 AM compared with all other times among 77 patients with in-hospital cardiac arrest. Similarly, Wright et al[6] found that survival was worse for patients with VF in the night compared with the daytime. The prospective evaluation by Dumot et al[9] of 445 in-hospital cardiac arrests demonstrated a disproportionately high incidence of unwitnessed arrests during the night (midnight to 6:00 AM) in unmonitored beds. In our study, worse outcomes occurred in monitored intensive care units as well as non–intensive care unit settings even after controlling for potentially confounding variables. The differences in day/evening vs night survival were not as large among the monitored patients as among the unmonitored patients, suggesting that monitoring per se or other potential confounders (eg, intensive care staff) may mitigate worse outcomes with nighttime cardiac arrests. Jones-Crawford et al[10] found that a significantly higher percentage of events had an initial documented rhythm of asystole during the overnight hours, and this was the only factor significantly related to patients' survival to discharge after controlling for potentially confounding variables. Asystole often occurs late into an arrest after the heart has lost the energy stores to generate VF and can be a surrogate marker for prolonged downtime.

The same group found that survival from in-hospital arrest was related to age and initial rhythm.[11] We noted that age and rhythm were associated with survival to discharge outcome but were able to account for their impact and establish that they could not explain the difference in day/evening vs night survival with adjustment for these factors in our multivariable model.

In our study, survival to discharge data demonstrated important effect modification for event location, illness category, and monitored status. The emergency department and trauma services were the only locations that did not have worse survival at night compared with day/evening. Although physiological differences in these patient populations cannot be excluded as the explanation for this finding, process of care is typically different in these areas, with either attending or senior resident physicians readily available at all times. These services often have similar staffing numbers and capabilities throughout the day/evening and night, which may positively impact night survival compared with other hospital locations. Survival to discharge after cardiac arrests occurring in the day/evening was substantially higher among both monitored and unmonitored patients, but the differential survival was greater among unmonitored patients.

The difference between day/evening vs night survival was not as large on weekends. Survival at all times on weekends was similar to survival at night during the week. We cannot determine precisely which factors are responsible for the variable outcomes noted during different time periods in this observational study. Future studies should explore the possible contribution of staffing patterns, circadian biological factors in both patients and staff, a potential bias in cardiac arrest data collection or reporting by time of day or day of week, and potential differences in patients who arrest during

Table 2. Event Characteristics

	No. (%)			
	Day/Evening (n = 58 593)[a]	Night (n = 28 155)[a]	Total (N = 86 748)	*P* Value
Immediate factor related to event[b]				
Acute respiratory insufficiency	22 188 (38)	10 700 (38)	32 888 (38)	.70
Hypotension	23 718 (40)	11 011 (39)	34 729 (40)	< .001
Acute myocardial infarction or ischemia	5825 (10)	2498 (9)	8323 (10)	< .001
Metabolic/electrolyte disturbance	6494 (11)	3095 (11)	9589 (11)	.69
Acute pulmonary edema	1106 (2)	544 (2)	1650 (2)	.65
Acute pulmonary embolism	1283 (2)	457 (2)	1740 (2)	< .001
First documented pulseless rhythm				
Asystole	19 652 (34)	11 151 (40)	30 803 (36)	< .001
Pulseless electrical activity	21 608 (37)	9743 (35)	31 351 (36)	
Ventricular fibrillation	8959 (15)	3616 (13)	12 575 (14)	
Pulseless ventricular tachycardia	4464 (8)	1947 (7)	6411 (7)	
Unknown	3910 (7)	1698 (6)	5608 (6)	
Discovery status at time of event[c]				
Witnessed	48 535 (83)	21 138 (75)	69 673 (80)	< .001
Monitored via electrocardiography	45 109 (77)	20 924 (74)	66 033 (76)	< .001
Interval to first attempted defibrillation from identification of shockable rhythm, median (25%-75%), min	0 (0-0)	0 (0-0)	0 (0-0)	.66
Duration of CPR, median (25%-75%), min	17 (9-28)	18 (10-28)	17 (9-28)	< .001
Category of CPR duration, min				
0-15	24 071 (42)	10 812 (39)	34 883 (41)	< .001
16-35	23 762 (42)	12 231 (45)	35 993 (43)	
>35	9049 (16)	4379 (16)	13 428 (16)	
Interval to first vasopressor, median (25%-75%), min	2 (0-4)	2 (0-5)	2 (0-4)	.001
Pharmacologic interventions[d]				
Epinephrine	50 281 (86)	24 974 (89)	75 255 (87)	< .001
Fluid bolus	17 439 (30)	8078 (29)	25 517 (29)	.001
Atropine	40 068 (68)	20 870 (74)	60 938 (70)	< .001
Sodium bicarbonate	26 706 (46)	12 666 (45)	39 372 (45)	.10
Vasopressin	3938 (7)	1521 (5)	5459 (6)	< .001
Magnesium sulfate	4746 (8)	2176 (8)	6922 (8)	.06
Calcium chloride or gluconate	13 574 (23)	5922 (21)	19 496 (22)	< .001
Amiodarone	9410 (16)	3817 (14)	13 227 (15)	< .001
Lidocaine	8437 (14)	3477 (12)	11 914 (14)	< .001
Induced hypothermia	416 (1)	160 (1)	576 (1)	.24

Abbreviation: CPR, cardiopulmonary resuscitation.
[a] Day/evening was defined as 7:00 AM to 10:59 PM, night as 11:00 PM to 6:59 AM.
[b] Multiple comparison adjusted significance level $\alpha = .008$.
[c] Multiple comparison adjusted significance level $\alpha = .025$.
[d] Multiple comparison adjusted significance level $\alpha = .006$.

weekday days/evenings vs those who arrest on weekends.

Our finding that fewer persons experiencing a cardiac arrest were monitored or witnessed and that asystole was a more common presenting rhythm at night offers more support of the hypothesis that operational process of care issues may play a role in the lower survival during this time. Because the circadian variations in outcomes were demonstrable even after adjusting for witnessed and monitored status and first documented rhythms, other factors apparently contribute to this phenomenon.

It is well documented that medical errors are higher at night.[12,13] Horwitz and McCall[14] found that hospital employees on the evening and night shifts are at increased risk of injury compared with the day shift. Physicians have been shown to perform psychomotor tasks less proficiently at night and are more likely to commit errors than during the day.[15-18] Hospital staffing patterns are different at night when there are fewer admissions, discharges, and diagnostic and therapeutic procedures compared with other times. Most hospitals decrease their inpatient unit nurse-patient ratio at night.[19] There are fewer supervisors at night, and newer, less experienced workers are sometimes required to work at night. Many caregivers during the night must deal with the negative effects of shift work on sleep, performance, and general health.[20] Lower nurse-patient ratios have been associated with an increased risk of shock and cardiac arrest.[5] There are fewer numbers of health care professionals at night available to respond to a resuscitation event.

Physician staffing also differs at night in most inpatient areas because attending and resident physicians cross-cover each others' patients at night. They may be less familiar with others' patients and may be less available to individual patients because of increased volume of cross coverage. More patient visitors are in the hospital during the day/evening, and they may alert hospital staff to impending problems. Herlitz et al[21] have shown that decreased health care worker preparedness for in-hospital cardiac arrests is associated with worse outcomes. We suspect that these factors might affect resuscitation outcomes adversely at night.

The differences between day/evening and night survival to hospital discharge were consistently demonstrable among hospitals even when partitioned by size. These data suggest that the observed worse survival outcomes following cardiac arrests occurring at night and on weekends is a robust, gen-

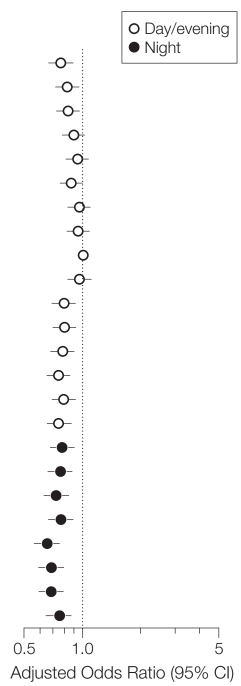
Table 3. Cardiac Arrest Outcomes by Day/Evening vs Night[a]

	No. (%) [95% Confidence Interval]			Odds Ratio (95% Confidence Interval)	
	Day/Evening (n = 58 593)[b]	Night (n = 28 155)[b]	Total (N = 86 748)	Unadjusted Odds Ratio (Day/Evening vs Night) (N = 86 748)	Adjusted Odds Ratio[c] (Day/Evening vs Night) (N = 86 748)
Survived to discharge	11 604 (19.8) [19.5-20.1]	4139 (14.7) [14.3-15.1]	15 743 (18.1) [17.9-18.4]	1.43 (1.38-1.49)	1.18 (1.12-1.23)
Return of spontaneous circulation longer than 20 min	29 920 (51.1) [50.7-51.5]	12 581 (44.7) [44.1-45.3]	42 501 (49) [48.7-49.3]	1.29 (1.26-1.33)	1.15 (1.12-1.19)
Survival at 24 h	20 236 (35.4) [35.0-35.8]	7931 (28.9) [28.4-29.4]	28 167 (32.5) [32.2-32.8]	1.35 (1.31-1.39)	1.19 (1.15-1.23)
Favorable neurological outcome[d]	8918 (15.2) [14.9-15.5]	3097 (11) [10.6-11.4]	12 015 (13.9) [13.6-14.1]	1.45 (1.39-1.52)	1.17 (1.11-1.23)

[a] $P < .001$ for day/evening vs night for all 4 outcomes.
[b] Day/evening was defined as 7:00 AM to 10:59 PM, night as 11:00 PM to 6:59 AM.
[c] Regression adjusted for sex, age, race, illness category, discovery status at time of event, witnessed event, first documented pulseless rhythm, duration of cardiopulmonary resuscitation, preexisting conditions, immediate factors related to event, delay in defibrillation, delay in cardiopulmonary resuscitation, delay in vasopressor use, weekend, hospital bed size, time from admission to event, interventions in place at time of event, and pharmacologic interventions.
[d] Either a cerebral performance category score of 1 or 2 (range, 1-5) or no change from baseline cerebral performance category score.

Figure 1. Survival to Discharge Rate by Hour of Day When Event Occurred

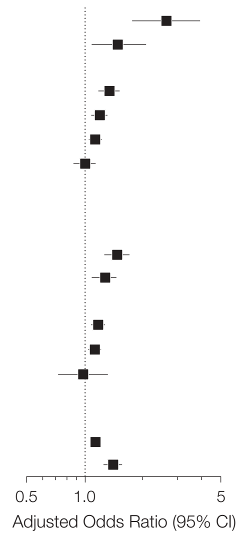
Hour	Unadjusted Survival to Discharge, No./Total No. (%)	Adjusted Odds Ratio (95% CI)
7:00 AM	570/3503 (16.3)	0.77 (0.67-0.89)
8:00 AM	721/3655 (19.7)	0.83 (0.72-0.95)
9:00 AM	761/3786 (20.1)	0.84 (0.73-0.96)
10:00 AM	801/3935 (20.4)	0.90 (0.78-1.02)
11:00 AM	831/3820 (21.8)	0.93 (0.82-1.06)
12:00 PM	781/3832 (20.4)	0.87 (0.76-0.99)
1:00 PM	851/3747 (22.7)	0.96 (0.84-1.09)
2:00 PM	828/3775 (21.9)	0.94 (0.83-1.08)
3:00 PM	830/3730 (22.3)	1 [Reference]
4:00 PM	780/3524 (22.1)	0.96 (0.84-1.10)
5:00 PM	704/3536 (19.9)	0.80 (0.70-0.91)
6:00 PM	659/3462 (19.0)	0.80 (0.70-0.92)
7:00 PM	675/3637 (18.6)	0.78 (0.68-0.90)
8:00 PM	633/3579 (17.7)	0.75 (0.65-0.86)
9:00 PM	603/3556 (17.0)	0.80 (0.69-0.92)
10:00 PM	576/3516 (16.4)	0.75 (0.66-0.87)
11:00 PM	587/3486 (16.8)	0.78 (0.68-0.90)
12:00 AM	543/3569 (15.2)	0.76 (0.66-0.88)
1:00 AM	514/3465 (14.8)	0.73 (0.63-0.84)
2:00 AM	515/3372 (15.3)	0.76 (0.66-0.88)
3:00 AM	494/3591 (13.8)	0.65 (0.57-0.76)
4:00 AM	472/3524 (13.4)	0.69 (0.59-0.80)
5:00 AM	518/3732 (13.9)	0.68 (0.59-0.79)
6:00 AM	496/3416 (14.5)	0.75 (0.65-0.87)



CI indicates confidence interval.

Figure 2. Survival Rate by Event Location, Illness Category, and Monitored Status

Variable	Unadjusted Survival to Discharge, No./Total No. (%) Day	Night	Adjusted Odds Ratio (95% CI)
Event location			
Operating room/postanesthesia care unit	682/1862 (36.6)	41/245 (16.7)	2.63 (1.76-3.93)
Interventional catheterization laboratory	1171/3401 (34.4)	78/327 (23.9)	1.48 (1.07-2.06)
Inpatient			
Not monitored	1147/8397 (13.7)	483/5209 (9.3)	1.33 (1.17-1.51)
Monitored	2207/10 067 (21.9)	1084/6161 (17.6)	1.18 (1.07-1.30)
Intensive care unit	4438/26 749 (16.6)	1797/13 301 (13.5)	1.13 (1.05-1.21)
Emergency department	1621/6919 (23.4)	600/2594 (23.1)	0.99 (0.87-1.13)
Illness category			
Surgical			
Noncardiac	1362/6678 (20.4)	369/3082 (12.0)	1.46 (1.26-1.68)
Cardiac	1540/4267 (36.1)	477/1748 (27.3)	1.25 (1.08-1.45)
Medical			
Noncardiac	3098/24 377 (12.7)	1218/12 560 (9.7)	1.15 (1.07-1.25)
Cardiac	5328/21 395 (24.9)	1963/9924 (19.8)	1.12 (1.04-1.20)
Trauma	185/1646 (11.2)	94/756 (12.4)	0.97 (0.72-1.30)
Monitored status			
Monitored	9700/46 756 (20.8)	3517/21 787 (16.1)	1.13 (1.07-1.19)
Not monitored	1904/11 837 (16.1)	622/6368 (9.8)	1.39 (1.25-1.56)

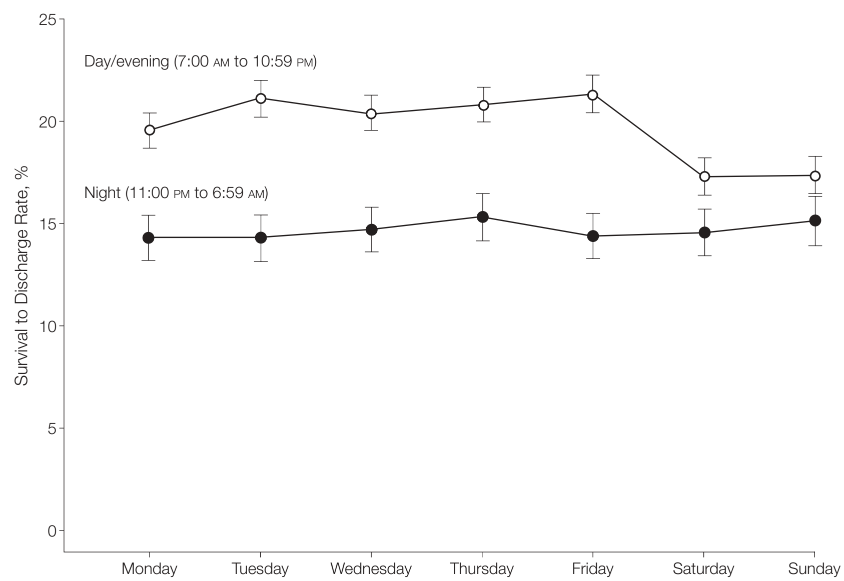


Adjusted odds ratio for survival to hospital discharge and 95% confidence intervals (CIs) for each event location, illness category, and monitored status evaluating the a priori prospectively designated, clinically important potential confounders and the prospectively designated variables identified in the "Methods" section.

eralizable observation and persists even after controlling for the confounding measured patient, arrest event, and hospital characteristic factors usually associated with cardiac arrest outcome.

Further investigation is needed to determine whether there is a physiological basis for poorer survival from in-hospital cardiac arrests occurring during nights and weekends. Given the current cultural emphasis on prevention of medical error and the fact that our results demonstrated poorer survival at night while accounting for numerous other variables, it is reasonable to focus on the potential for decreased physical and psychological performance on the part of the health care worker, different staffing patterns, and less patient surveillance during nights and weekends as possible contributing factors in poorer survival at night. These factors may influence the type and quality of care delivered to patients having cardiac arrest at night. These factors, coupled with a low-frequency and high-acuity resuscitation response, should encourage hospitals to focus on and improve hospitalwide system processes that can potentially impact the safety and outcomes of patients experiencing in-hospital cardiac arrest. Some of these factors may be modifiable. Night staff proficiency in cardiac resuscitation could be enhanced by additional training, such

Figure 3. Survival to Discharge Rate and Total Arrests by Time Category and Day of Week



Total arrests, No.	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Day/evening	8973	8827	8636	8529	8518	7657	7453
Night	4141	4002	4144	4100	3978	3888	3902

Error bars indicate 95% confidence intervals.

as "mock codes" and cardiac resuscitation simulation training. Chronobiologic scheduling, naps, or use of medications such as modafinil may also improve nighttime staff performance.[22,23]

Our study could not definitively determine the absolute prevalence or timing of every cardiac arrest occurring in the hospital because the NRCPR database does not capture the number of individuals in the hospital per hour and cannot guarantee that every cardiac arrest is reported to the registry. This large convenience sample from registry hospitals may not be representative of all US hospitals, yet the NRCPR hospitals consist of approximately 10% of all US hospitals and 15% of those with more than 500 beds. Hospitals in the NRCPR may have more of a focus on resuscitation because participation is voluntary, and we do not know the effect of this on our results. As with all large multicenter registries, the data are self-reported and have potential limitations related to integrity. We arbitrarily chose the 2 time periods of day/evening vs night to facilitate analysis and presentation of these time-related issues. This is a simplification of the complex scheduling that occurs at many hospitals. Nonetheless, the substantial differences of processes and outcomes by time of day and day of week, as defined in this study, likely represent real phenomena that cannot be explained by the patient, event, and hospital characteristics that usually account for outcome differences.

CONCLUSION

In this multicenter registry of in-hospital cardiac arrest, survival rates were substantially lower during nights and weekends, even when adjusted for potentially confounding patient, event, and hospital characteristics. The mechanism for the decreased survival during the night is likely multifactorial, potentially including biological differences in patients as well as health care staff and hospital staffing and operational factors. These data suggest the need to focus on night and weekend hospital-wide resuscitation system processes of care that can potentially improve patient safety and survival following cardiac arrest.

Author Contributions: Dr Peberdy had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
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Acquisition of data: Peberdy, Larkin, Carey, Nadkarni.
Analysis and interpretation of data: Peberdy, Ornato, Larkin, Braithwaite, Kashner, Carey, Meaney, Cen, Nadkarni, Praestgaard, Berg.
Drafting of the manuscript: Peberdy, Ornato, Larkin, Braithwaite, Meaney, Nadkarni, Praestgaard, Berg.
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Statistical analysis: Peberdy, Ornato, Larkin, Kashner, Carey, Meaney, Cen, Nadkarni, Praestgaard.
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Study supervision: Peberdy, Ornato.
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