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Trends in Survival After In-Hospital Cardiac Arrest During Nights and Weekends

Uchenna R. Ofoma, MD, MS,[a] Suresh Basnet, MD,[b] Andrea Berger, MAS,[c] H. Lester Kirchner, PhD,[c] Saket Girotra, MD, SM,[d] for the American Heart Association Get With the Guidelines - Resuscitation Investigators

ABSTRACT

BACKGROUND Survival after in-hospital cardiac arrest (IHCA) is lower during nights and weekends (off-hours) compared with daytime during weekdays (on-hours). As overall IHCA survival has improved over time, it remains unknown whether survival differences between on-hours and off-hours have changed.

OBJECTIVES This study sought to examine temporal trends in survival differences between on-hours and off-hours IHCA.

METHODS We identified 151,071 adults at 470 U.S. hospitals in the Get with the Guidelines-Resuscitation registry during 2000 to 2014. Using multivariable logistic regression with generalized estimating equations, we examined whether survival trends in IHCA differed during on-hours (Monday to Friday 7:00 AM to 10:59 PM) versus off-hours (Monday to Friday 11:00 PM to 6:59 AM, and Saturday to Sunday, all day).

RESULTS Among 151,071 participants, 79,091 (52.4%) had an IHCA during off-hours. Risk-adjusted survival improved over time in both groups (on-hours: 16.0% in 2000, 25.2% in 2014; off-hours: 11.9% in 2000, 21.9% in 2014; p for trend <0.001 for both). However, there was no significant change in the survival difference over time between on-hours and off-hours, either on an absolute ($p = 0.75$) or a relative scale ($p = 0.059$). Acute resuscitation survival improved significantly in both groups (on-hours: 56.1% in 2000, 71% in 2014; off-hours: 46.9% in 2000, 68.2% in 2014; p for trend <0.001 for both) and the difference between on-hours and off-hours narrowed over time ($p = 0.02$ absolute scale, $p < 0.001$ relative scale). In contrast, although post-resuscitation survival also improved over time in both groups (p for trend < 0.001 for both), the absolute and relative difference persisted.

CONCLUSIONS Despite an overall improvement in survival, lower survival in IHCA during off-hours compared with on-hours persists. (J Am Coll Cardiol 2018;71:402–11) © 2018 by the American College of Cardiology Foundation.

In-hospital cardiac arrest (IHCA) affects approximately 200,000 hospitalized patients annually in the United States and this rate may be increasing (1). Survival after IHCA is integrally dependent on early recognition, prompt initiation of high-quality resuscitation response, and high-quality post-resuscitation care. A previous study of 86,478 patients with IHCA found that rates of survival and neurological outcomes were 15% to 20% lower among patients who experienced a cardiac arrest during nights or weekends (defined as between 11:00 PM and 6:59 AM on weekdays or all day on Saturday and Sunday) (2).

Although poor survival during nights and weekends (off-hours) has been documented, much less is known regarding how survival differences are changing over time in patients who arrest during this period. Yet, this information is important to identify

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From the [a]Department of Critical Care Medicine, Geisinger Health System, Danville, Pennsylvania; [b]Department of Critical Care Medicine, Winchester Medical Center, Winchester, Virginia; [c]Biomedical & Translational Informatics, Geisinger Health System, Danville, Pennsylvania; and the [d]Division of Cardiovascular Diseases, Department of Medicine, University of Iowa Hospitals and Clinics and the Iowa City Veterans Affairs Medical Center, Iowa City, Iowa. Dr. Ofoma has received support from the Geisinger Health System Foundation (SRC-S-43). Dr. Girotra is supported by a career development award (K08HL122527) from the National Heart, Lung, and Blood Institute. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

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opportunities for focusing future quality improvement efforts. Given that nearly 50% of IHCAs occur during nights or weekends, improving survival during this vulnerable period could impact a substantial number of patients.

To address this gap in knowledge, we examined whether survival differences between IHCA occurring during on-hours versus off-hours have changed over time. Understanding how outcomes are changing over time in this population has important implications for improving resuscitation care at hospitals across the United States.

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METHODS

DATA SOURCE. The Get With the Guidelines-Resuscitation (GWTG-R) is a prospective, multisite registry of IHCA events in the United States. Its design has been previously described (3). Briefly, hospitalized patients with a confirmed cardiac arrest, defined as absence of pulse, apnea, and unresponsiveness in a patient without a previous do-not-resuscitate order, are identified and enrolled by trained personnel. Multiple case-finding approaches, such as centralized collection of cardiac arrest flow sheets, review of hospital page system logs, and routine checks of code carts, pharmacy tracer drug records ensure that all cases within a hospital are captured (4,5). Data collection in the registry is based on the Utstein template of uniform reporting guidelines and standardized across participating sites (4,6). A rigorous training and certification process of the medical staff at participating hospitals along with the use of standardized software, internal data checks, and a periodic reabstractions process ensures data completeness and accuracy. The institutional review board at Geisinger Medical Center deemed this study exempt because of its use of deidentified data.

STUDY POPULATION. Within the GWTG-R, we identified 204,176 patients at least 18 years of age with an index pulseless IHCA between January 1, 2000, and December 31, 2014. We excluded 43,742 (21.4%) arrests that occurred outside of an intensive care unit or hospital ward (e.g., emergency room, operating room, other procedural areas), and arrests in patients with an implantable cardioverter-defibrillator because of the unique circumstances associated with resuscitation response in such situations. To ensure that the survival estimates obtained from our multivariable models were statistically reliable, we also excluded 7,109 (3.5%) arrests at 232 hospitals with <3 years of data submission or hospitals with a mean annual case volume of <5. Additionally, we also excluded 2,254 patients because of missing information related to survival and cardiac arrest timing. The final study sample comprised of 151,071 arrests at 470 participating hospitals (Figure 1).

ABBREVIATIONS AND ACRONYMS

GWTG-R = Get With The Guidelines-Resuscitation

IHCA = in-hospital cardiac arrest

STUDY VARIABLES AND OUTCOMES. Our primary exposure variable was time of cardiac arrest, which was recorded to the nearest minute. Because a previous GWTG-R study found that survival in patients who arrested during daytime and nighttime on weekends (Saturday, Sunday) was similar to patients who arrested during nighttime on weekdays (2), we categorized our exposure variable as follows: on-hours (7:00 AM to 10:59 PM Monday to Friday) or off-hours (11:00 PM to 6:59 AM Monday to Friday or anytime on weekends). The primary outcome was survival to hospital discharge. To further explore temporal trends in the primary outcome, we also examined as secondary outcomes acute resuscitation survival (defined as return of spontaneous circulation for at least 20 contiguous min at any time after the initial pulseless arrest) and post-resuscitation survival (defined as survival to hospital discharge among patients who achieved return of spontaneous circulation).

Patient-level data included demographics (age, sex, race), comorbidities and pre-existing medical conditions (current or prior myocardial infarction, current or prior heart failure, diabetes mellitus, hypotension, metabolic and electrolyte abnormalities, respiratory failure, renal insufficiency, hepatic insufficiency, metastatic or hematologic malignancy, septicemia, pneumonia, major trauma, acute stroke, baseline depression in neurological function, and cerebral performance category at time of admission), cardiac arrest characteristics (initial arrest rhythm [asystole, pulseless electrical activity, ventricular fibrillation, pulseless ventricular tachycardia], hospital location of cardiac arrest [intensive care unit, monitored ward, nonmonitored ward], whether the event was witnessed, use of hospital-wide cardiac arrest alert), and interventions in place before time of cardiac arrest (assisted or mechanical ventilation, vasoactive agent, antiarrhythmic, pulmonary artery catheter, and renal dialysis). Hospital-level variables were obtained from the American Hospital Association data and included geographic location, hospital setting (urban vs. rural), hospital ownership, bed size, and teaching status. Hospital characteristics are summarized in Online Table 1.

STATISTICAL ANALYSIS. Patient and hospital characteristics were summarized using mean ± SD or median (interquartile range) for continuous variables, and frequency counts with percentages for categorical variables. Next, we compared patient

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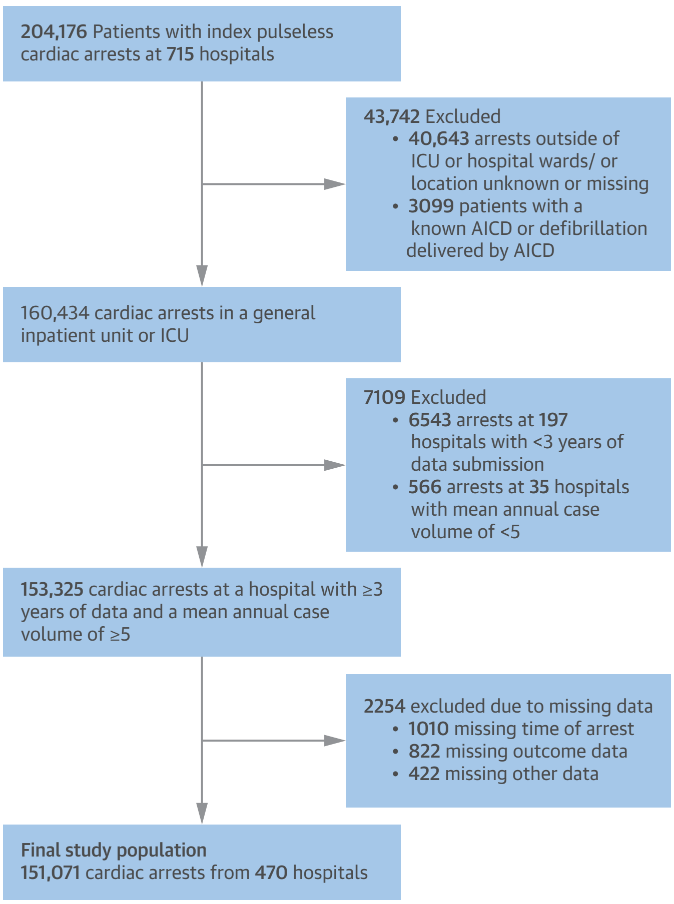
FIGURE 1 Study Flow Chart



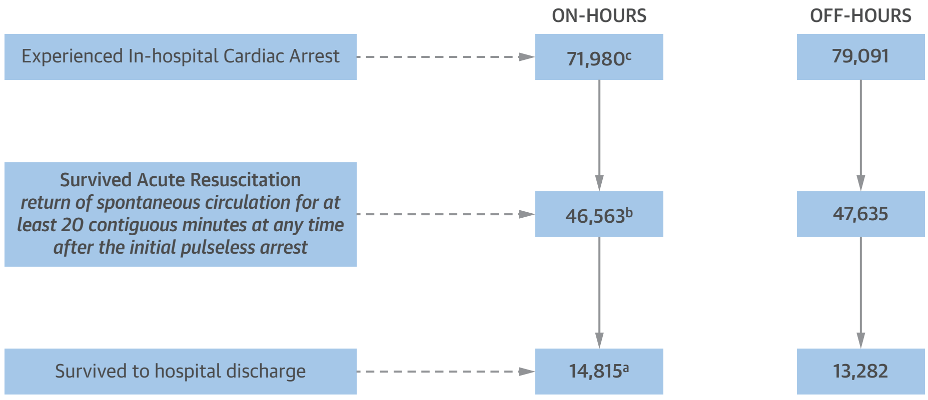
The flowchart illustrates derivation of the study cohort. AICD = automated implantable cardioverter defibrillator; ICU = intensive care unit.

demographics, comorbidities, cardiac arrest characteristics, and interventions in place at the time of cardiac arrest between on-hours and off-hours groups. Because of large sample sizes, we computed standardized difference in covariate means between on-hours and off-hours groups (7). A standardized difference of >10% suggests an imbalance of the covariate between the groups.

Next, we calculated unadjusted proportions of survival to discharge, acute resuscitation survival, and post-resuscitation survival for each calendar year and examined whether trends differed by time of cardiac arrest. To account for confounding caused by patient characteristics and clustering of patients at hospitals, we used multivariable logistic regression models with generalized estimating equations to calculate risk-adjusted survival proportions for patients with IHCA during on-hours and off-hours. The models included a categorical variable for on-hours/off-hours, a categorical variable for calendar year, and an interaction term between calendar year and time of arrest. In these models, we adjusted for specific patient demographic and clinical characteristics, cardiac arrest characteristics, and interventions in place at the time of cardiac arrest. Because survival proportions were >10%, we directly estimated rate ratios as a measure of relative risk by specifying a Poisson distribution and a robust variance estimate in our models (Zou method) (8,9). Survival in the on-hours group in the year 2000 was defined as the reference group, and the above rate ratios were multiplied by the unadjusted survival in the reference population to calculate risk-adjusted survival for patients in the on-hours and the off-hours groups during each calendar year. We evaluated whether survival trends between on-hours and off-hours differed over time, both on an absolute scale and a relative scale as follows. We computed absolute difference in risk-adjusted survival between on-hours and off-hours during each calendar year, and used linear regression to determine whether absolute risk-adjusted survival difference between the groups changed over time. Relative difference in survival trends was assessed by evaluating the significance of the interaction term between calendar-year and our exposure variable.

SENSITIVITY ANALYSES. We conducted several sensitivity analyses to evaluate the robustness of our findings. First, to ensure that our survival estimates were not dependent on the modeling strategy we used, we repeated the previously mentioned analyses using a 2-level hierarchical multivariable logistic regression model. In these models, we included hospital site as a random effect and all patient-level covariates were included as fixed effects. We used the variance components correlation structure and specified that the effect of timing of arrest (on-hours vs. off-hours) and its interaction with calendar year did not vary by hospital site. We used model coefficients for timing of arrest, calendar year, and the interaction term to compute risk-adjusted survival rates for on-hours and off-hours during each calendar year. Second, to determine whether observed survival to discharge differences between on-hours and off-hours cardiac arrests varied by location of arrest (intensive care vs. nonintensive care), we repeated our multivariable models after including a 3-way interaction term between calendar-year, time-of-arrest, and location. Third, the rationale to combine daytime events during weekends with nighttime events was based on prior work that used older

FIGURE 2 **Cardiac Arrest Survival Flow Chart**



	ON-HOURS	OFF-HOURS
Survival to hospital discharge: a/c (%)	20.6	16.8
Acute resuscitation survival: b/c (%)	64.7	60.2
Post-resuscitation survival: a/b (%)	31.8	27.9

The flowchart illustrates survival during acute resuscitation for cardiac arrest and survival to hospital discharge among the study cohort.

GWTG-R data from 2000 to 2007. Because processes of care and hospital practices may have changed over time, we re-examined survival rates according to day of the week separately for daytime and nighttime arrests. We also repeated our multivariable models for survival to discharge after classifying daytime on weekends as on-hours, instead of off-hours.

All variables listed in the Study Variables and Outcomes section were included in the multivariable models. Overall, rate of missing data was <1% for all variables, except race and admission cerebral performance category. Missing data for race and admission cerebral performance category were treated as separate "unknown" categories in the analysis. All analyses were performed using SAS version 9.4 for Windows (SAS Institute Inc., Cary, North Carolina). All hypothesis tests were 2-sided with a significance level of 0.05.

RESULTS

Among 151,071 patients included in our study, 79,091 (52.4%) had IHCA during off-hours. Overall, 94,198 (62.4%) patients survived acute resuscitation efforts, whereas 28,097 (18.6%) subsequently survived to hospital discharge (**Figure 2**). **Table 1** shows baseline and cardiac arrest characteristics of our study population. The mean age was 66.1 years, 21.3% were black persons, and 42.2% were women. Nearly 1 in 5 patients (18.6%) had an initial rhythm of ventricular fibrillation or pulseless ventricular tachycardia. Most IHCA events (81.6%) were witnessed, and occurred either in an intensive care or a telemetry unit. Overall, standardized differences in cardiac arrest characteristics between patients who arrested during on-hours versus off-hours were small (<10%), except that a higher proportion of cardiac arrest during off-hours, compared with on-hours had an initial rhythm of asystole (36.9% vs. 32.7%), were unwitnessed (20.6% vs. 15.9%), and were associated with the activation of the hospital-wide response system (84.4% vs. 82.3%) (**Table 1**). Both groups were similar with regards to prevalence of comorbidities, location of arrest, and interventions in place at the time of arrest. Temporal trends in patient and cardiac arrest characteristics are summarized in Online Table 2.

SURVIVAL TO DISCHARGE. Overall, 18.6% survived to hospital discharge. Survival was significantly lower in patients who arrested during off-hours compared with on-hours (16.8% vs. 20.6%; $p < 0.0001$) (**Figure 2**), but increased over time in both groups (**Central Illustration**, Online Table 3). After adjustment for patient characteristics, risk-adjusted survival also increased over time in the off-hours group (11.9% in 2000 to 21.9% in 2014) and the on-hours group (16.0% in 2000 to 25.2% in 2014; p for trend <0.001 for both) (**Table 2**). However, survival difference over time persisted between the groups (absolute scale: 4.1% in

TABLE 1 Demographic, Cardiac Arrest, and Baseline Characteristics

	On-Hours (n = 71,980)	Off-Hours (n = 79,091)	Standardized Differences
Demographic characteristics			
Age, yrs	66.1 ± 15.6	66.1 ± 15.9	0.00
Sex			0.01
Female	30,607 (42.5)	33,165 (41.9)	
Male	41,373 (57.5)	45,926 (58.1)	
Race			0.01
White	49,620 (68.9)	54,635 (69.1)	
Black/African-American	15,356 (21.3)	16,749 (21.2)	
Other	2,436 (3.4)	2,744 (3.5)	
Unknown	4,568 (6.3)	4,963 (6.3)	
Cardiac arrest characteristics			
Initial arrest rhythm			0.09
Asystole	23,516 (32.7)	29,169 (36.9)	
Pulseless electrical activity	34,473 (47.9)	35,818 (45.3)	
Pulseless ventricular tachycardia	5,605 (7.8)	5,882 (7.4)	
Ventricular fibrillation	8,386 (11.7)	8,222 (10.4)	
Location of cardiac arrest			0.08
Intensive care unit	44,578 (61.9)	46,083 (58.3)	
Monitored unit	12,504 (17.4)	14,530 (18.4)	
Nonmonitored unit	14,898 (20.7)	18,478 (23.4)	
Event observation			
Witnessed	60,501 (84.1)	62,821 (79.4)	0.12
Response to event			
Use of hospital-wide cardiac arrest alert	59,245 (82.3)	66,749 (84.4)	0.06
Pre-existing medical conditions			
Current myocardial infarction	11,594 (16.1)	12,102 (15.3)	0.02
Prior myocardial infarction	11,386 (15.8)	12,041 (15.2)	0.02
Current heart failure	13,026 (18.1)	14,257 (18.0)	0.00
Prior heart failure	15,216 (21.1)	16,911 (21.4)	0.01
Hypotension	19,595 (27.2)	21,172 (26.8)	0.01
Metabolic or electrolyte abnormality	12,843 (17.8)	14,516 (18.4)	0.01
Respiratory failure	31,926 (44.4)	34,632 (43.8)	0.01
Renal insufficiency	25,847 (35.9)	28,660 (36.2)	0.01
Hepatic insufficiency	5,839 (8.1)	6,605 (8.4)	0.01
Septicemia	13,187 (18.3)	14,495 (18.3)	0.00
Pneumonia	11,155 (15.5)	12,221 (15.5)	0.00
Diabetes mellitus	22,967 (31.9)	24,830 (31.4)	0.01
Acute stroke	2,913 (4.0)	3,283 (4.2)	0.01
Baseline depression in CNS function	8,308 (11.5)	9,332 (11.8)	0.01
Admission CPC category			0.02
CPC 1	31,305 (43.5)	33,731 (42.6)	
CPC 2	14,252 (19.8)	16,062 (20.3)	
CPC 3	6,856 (9.5)	7,771 (9.8)	
CPC 4 or 5	3,529 (4.9)	4,025 (5.1)	
Unknown	16,038 (22.3)	17,502 (22.1)	
Major trauma	2,611 (3.6)	3,152 (4.0)	0.02
Metastatic/hematologic malignancy	9,204 (12.8)	10,397 (13.1)	0.01
Interventions before arrest			
Assisted or mechanical ventilation	24,337 (33.8)	25,354 (32.1)	0.04
Vasoactive agent	20,429 (28.4)	21,550 (27.2)	0.03
Intravenous antiarrhythmic therapy	3,681 (5.1)	3,844 (4.9)	0.01
Pulmonary artery catheter	8,443 (11.7)	8,247 (10.4)	0.04
Dialysis	2,808 (3.9)	2,720 (3.4)	0.02

Values are mean ± SD or n (%).
CNS = central nervous system; CPC = cerebral performance category.

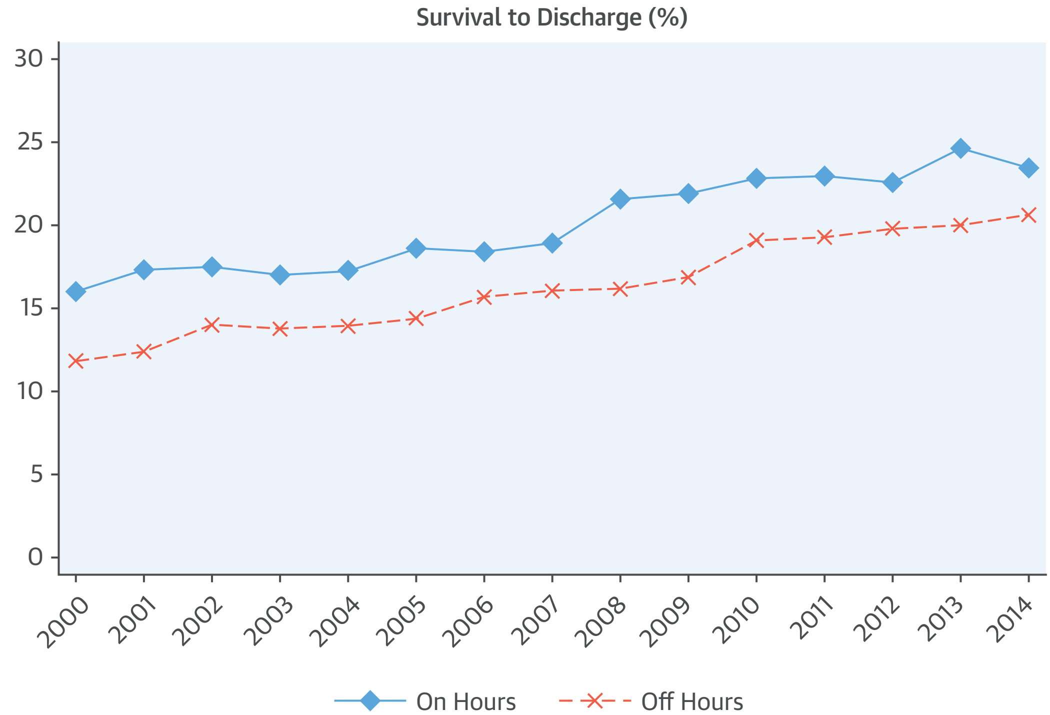
2000, 3.3% in 2014; p for trend = 0.75; relative scale: p for interaction = 0.0592) (Table 2).

ACUTE RESUSCITATION SURVIVAL. Although acute resuscitation survival was lower in patients with IHCA during off-hours compared with on-hours (60.2% vs. 64.7%; p < 0.0001) (Figure 2), survival increased over time in both groups (Figure 3A), which persisted even after adjustment for patient characteristics. Risk-adjusted acute resuscitation survival increased from 56.1% in 2000 to 71% in 2014 in the on-hours group and from 46.9% in 2000 to 68.2% in 2014 in the off-hours group (p for trend <0.001 for both) (Table 2). The previously mentioned improvement was greater in the off-hours group such that survival differences between the 2 groups decreased over time both on an absolute scale (p = 0.02) and a relative scale (p for interaction = 0.0005).

POST-RESUSCITATION SURVIVAL. Unadjusted post-resuscitation survival was lower in patients who arrested during off-hours compared with on-hours (27.9% vs. 31.8%; p < 0.0001) (Figure 2) and increased over time (Figure 3B). After risk-adjustment, although post-resuscitation survival increased in both groups (on-hours: 26.5% in 2000; 36.0% in 2014; off-hours: 24.5% in 2000, 33.5% in 2014; p for trend <0.001 for both), differences between on- and off-hours arrests did not change over time (Table 2).

SENSITIVITY ANALYSES. Results from a 2-level hierarchical model were generally consistent with those from the generalized estimating equation model as summarized in Online Table 4. Moreover, temporal trends in survival to discharge between on-hours and off-hours did not vary by location of arrest (intensive care unit vs. nonintensive care unit, p for interaction = 0.36). Finally, in analyses examining survival according to day of the week separately for IHCA events during daytime and nighttime, we found that mean survival during daytime on weekends (18.4%) was lower than daytime on weekdays (20.6%), but higher than nighttime survival (16.0%) (Online Figure 1). In sensitivity analyses in which we categorized daytime during weekends as on-hours instead of off-hours, our overall findings were similar. Risk-adjusted survival increased over time in both groups (on-hours: 15.0% in 2000 to 25.7% in 2014; off-hours: 11.4% in 2000 to 19.7% in 2014; p for trend <0.001 for both) (Online Table 5). However, differences in survival that were now larger between on-hours and off-hours, still persisted with no significant change on either an absolute scale (p for trend = 0.06) or a relative scale (p for interaction = 0.48).

CENTRAL ILLUSTRATION Trends in Survival to Discharge Stratified by Timing of In-Hospital Cardiac Arrest



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The graph shows unadjusted survival to discharge by calendar year in patients who arrested during on-hours **(blue)** and off-hours **(orange)**.

DISCUSSION

In a study of >150,000 patients with IHCA over a 15-year period, we found that survival outcomes have improved over time, both during on-hours and off-hours. However, patients who arrest during off-hours continue to experience lower survival compared with patients who arrest during on-hours. The above difference in survival has persisted despite a narrowing of the difference in acute resuscitation survival between the 2 groups.

Lower survival during nights and weekends has been documented previously for several medical conditions including cardiac arrest (2,10,11). In a previous study of the GWTG-R registry, Peberdy et al. (2) found that overall survival was an absolute 5.1% lower for arrests during nights and weekends compared with daytime. In that study, lower survival during nights and weekends was accompanied by lower survival during acute resuscitation, and lower survival to discharge in the subset of patients who achieved return of spontaneous circulation (i.e., post-resuscitation survival). Similar findings have also been reported in other studies, including a recent study of children with IHCA (12–15). We extend the work of previous investigators by showing that even though IHCA survival has improved in recent years (16), the timing of the event continues to have a major impact on patient outcomes. Patients who arrest during off-hours continue to experience lower survival compared with patients who arrest during on-hours, even after adjusting for a range of potential confounders. These findings are critically important because off-hours presentation accounted for more than 50% of IHCA events in our study, suggesting a period of high vulnerability for hospitalized patients. Thus, our findings highlight an important area to focus quality improvement efforts to ensure that improved survival trends for IHCA are sustained over time.

TABLE 2 Trends in Risk-Adjusted Survival Outcomes by Calendar-Year

Outcome	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	p Value
	Risk-Adjusted Proportions															
Survival to discharge																
On-hours	16.0	18.4	18.4	18.1	18.6	19.8	19.9	20.5	23.2	23.3	25.3	25.0	24.3	26.0	25.2	<0.001*
Off-hours	11.9	13.8	14.9	14.7	15.2	15.4	16.9	17.9	18.2	18.1	21.7	21.1	21.5	21.5	21.9	<0.001*
Absolute	4.1	4.5	3.6	3.4	3.4	4.5	3.0	2.6	5.0	5.3	3.6	3.8	2.8	4.5	3.3	0.75†
Relative	1.35	1.33	1.24	1.23	1.22	1.29	1.18	1.15	1.28	1.29	1.17	1.18	1.13	1.21	1.15	0 .059‡
Acute resuscitation survival																
On-hours	56.1	55.3	56.1	56.5	57.5	60.2	60.9	63.4	68.3	68.2	68.6	69.6	68.4	70.0	71.0	<0.001*
Off-hours	46.9	51.1	51.9	51.3	53.1	54.0	57.4	60.3	61.5	62.1	66.4	67.4	65.7	67.2	68.2	<0.001*
Absolute	9.2	4.2	4.2	5.2	4.4	6.2	3.5	3.0	6.7	6.1	2.2	2.3	2.7	2.8	2.9	0.02†
Relative	1.20	1.08	1.08	1.10	1.08	1.11	1.06	1.05	1.11	1.10	1.03	1.03	1.04	1.04	1.04	<0.001‡
Post-resuscitation survival																
On-hours	26.5	31.9	31.6	32.3	32.5	33.1	33.0	32.7	34.6	34.8	37.9	36.8	36.5	38.0	36.0	<0.001*
Off-hours	24.5	26.1	28.5	28.7	29.0	29.3	30.6	31.0	30.4	30.4	34.3	32.8	34.3	33.3	33.5	<0.001*
Absolute	2.0	5.8	3.2	3.5	3.5	3.8	2.4	1.7	4.2	4.4	3.6	4.0	2.2	4.7	2.5	0.88†
Relative	1.08	1.22	1.11	1.12	1.12	1.13	1.08	1.06	1.14	1.15	1.10	1.12	1.06	1.14	1.07	0.50‡

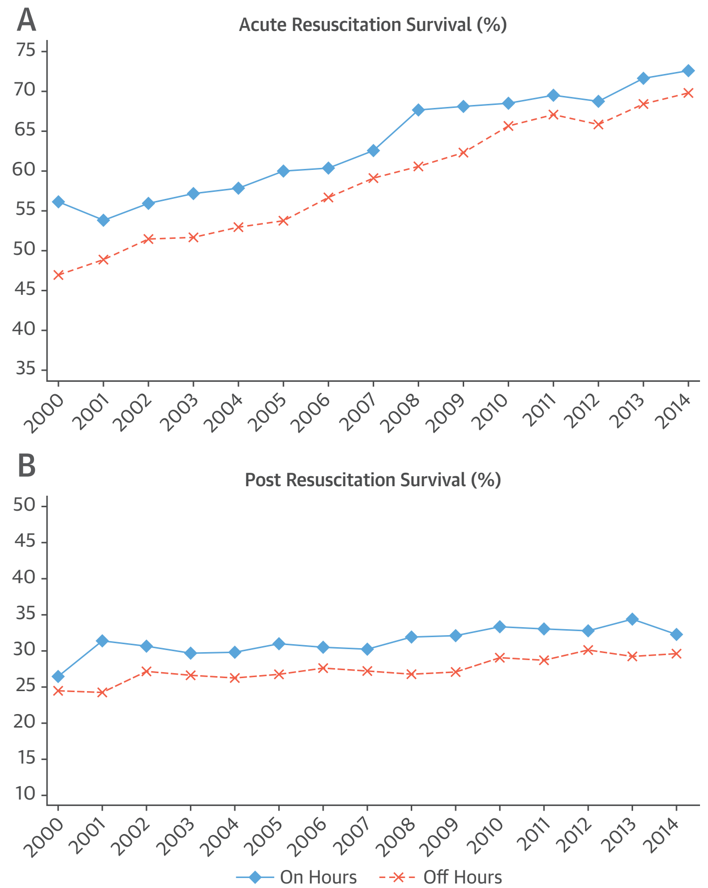
Values are %. Risk-adjusted survival was obtained using a multivariable generalized estimating equation model that adjusted for patient-level data: demographics (age, sex, race), comorbidities and pre-existing medical conditions (current or prior myocardial infarction, current or prior heart failure, diabetes mellitus, hypotension, metabolic and electrolyte abnormalities, respiratory failure, renal insufficiency, hepatic insufficiency, metastatic or hematologic malignancy, septicemia, pneumonia, major trauma, acute stroke, baseline depression in neurological function and cerebral performance category at time of admission), cardiac arrest characteristics (initial arrest rhythm [asystole, pulseless electrical activity, ventricular fibrillation, pulseless ventricular tachycardia], hospital location of cardiac arrest [intensive care unit, monitored ward, nonmonitored ward], whether the event was witnessed, use of hospital-wide cardiac arrest alert), and interventions in place before time of cardiac arrest (assisted or mechanical ventilation, vasoactive agent, antiarrhythmic, pulmonary artery catheter, and renal dialysis). The models also adjusted for cardiac arrest event year and on-hours/off-hours category of the arrest time. *p value for trend. †p value for homogeneity of the survival difference over time against the alternative of a linear trend. Null hypothesis: absolute survival difference between on-hours and off-hours remains constant over time. Alternative hypothesis: survival difference between on-hours and off-hours changes linearly over time (increases or decreases). Method used: linear regression with absolute difference as the outcome and calendar year as the independent variable. ‡p value for homogeneity of the relative survival over time against an alternative of any difference. Null hypothesis: homogeneity of relative survival over time (i.e., slopes are identical). Alternative hypothesis: relative change in survival over time differs between on-hours and off-hours group (i.e., slopes are not identical). Method used: multivariable generalized estimating equations model with Poisson distribution and interaction term between event year and on/off hours variable (p value is from interaction term).

Poor survival during nights and weekends is likely caused by a multitude of factors. Changes in hospital staffing patterns during nights and weekends are common, both numerically and in terms of expertise of available physicians (17–20). Moreover, physicians who work during nights and weekends also provide coverage to patients they may be less familiar with. Likewise, nurse-to-patient ratios are also lower during off-hours because of fewer admissions and discharges. Finally, the impact of shift work particularly during nighttime has been shown to impact psychomotor skills and performance of skilled activities, such as cardiopulmonary resuscitation (21–24). These factors likely affect the ability of hospital staff to recognize deteriorating patients, prevent IHCA, or quickly initiate resuscitation, all of which may impact survival. Our finding that a higher proportion of IHCA during off-hours were unwitnessed and were associated with an initial rhythm of asystole or pulseless electrical activity are consistent with these hypotheses. Also, ventricular fibrillation and pulseless ventricular tachycardia have better cardiopulmonary resuscitation outcomes (5,25,26) than asystole and pulseless electrical activity cardiac arrests and are more prevalent during the day (14,27–29). However, a prior study that adequately accounted for this diurnal variation in initial cardiac arrest rhythm, suggests that it does not explain the survival differences based on timing of IHCA (2). It is possible therefore that worse outcome at night may represent delayed recognition of IHCA, with patients degenerating to asystole or pulseless electrical activity, a hypothesis that requires further study.

In contrast to most acute medical conditions, a differential effect of night or weekend presentation on patient survival is no longer seen in patients with acute trauma (30,31). In a study that included 32 accredited Level I trauma centers in Pennsylvania, survival outcomes did not differ between patients who presented during on-hours compared with off-hours (30). On the contrary, odds of death were slightly lower in trauma patients who presented on nights and weekends (odds ratio: 0.89; 95% confidence interval: 0.81 to 0.97). It is likely that careful allocation of resources and process redesign at accredited Level I trauma centers, such as 24-h availability of an in-house trauma surgeon, prompt availability of other surgical specialists and intensivists, partnership with emergency medical services, and referring hospitals to achieve co-ordination ensures that care delivered to trauma victims is consistent regardless of the time of day or day of the week. These findings highlight the possibility of using a systems-based approach in the development of care delivery models to eliminate survival differences according to time of day in patients with IHCA, and other time-sensitive medical conditions (32).

We also found that acute resuscitation survival improved over time such that survival difference between on-hours and off-hours IHCA patients narrowed. Although we lacked granular data to examine the specific processes that may be driving these trends, it is possible that these trends were mediated by improvement in recognition of cardiac arrest, response times, and quality of resuscitation response, as emphasized in clinical practices guidelines from the American Heart Association (26,33). However, the modest improvement in acute resuscitation survival differences noted previously did not translate into a reduction in differences in overall survival between on-hours and off-hours IHCA patients. In contrast, temporal trends in post-resuscitation survival differences between groups remained largely unchanged during our study period. Factors related to operational processes of early post-arrest diagnostic and therapeutic care (e.g., echocardiography, coronary angiography, mechanical circulatory support), multidisciplinary teams necessary to coordinate and provide such care, and quality of intensive care and nursing, which may influence post-resuscitation survival, are also likely to vary during nights and weekends (34). Given the large burden of IHCA during nights and weekends, efforts are needed to ensure that quality of resuscitation care does not depend on IHCA timing.

FIGURE 3 **Trends in Acute Resuscitation Survival and Post-Resuscitation Survival Stratified by Timing of In-Hospital Cardiac Arrest**



The graph shows unadjusted **(A)** acute resuscitation survival and **(B)** post-resuscitation survival in patients who arrested during on-hours **(blue)** and off-hours **(orange)**.

STUDY LIMITATIONS. First, patients who arrest during off-hours may be sicker compared with patients who arrest during on-hours, in unmeasured ways. With the exception of a higher prevalence of unwitnessed arrest, and arrests caused by a nonshockable rhythm, differences between groups with regards to major comorbidities and arrest characteristics were negligible in our study. Although we adjusted for a range of patient characteristics using multivariable models, the potential for residual confounding remains. Second, although our decision to combine daytime arrests on weekends with nighttime arrests enables the interpretation of our findings in the context of prior studies, it is pertinent to note that survival from IHCA during daytime on weekends although lower than daytime on weekdays, remains higher than survival at night (Online Figure 1). In sensitivity analysis, reclassifying daytime on weekends as on-hours compared with off-hours did not impact temporal trends in survival differences during on-hours and off-hours. Third, data regarding important mediator variables, such as physician and nurse staffing patterns and how they changed over time, were not available to understand the reasons for persistently lower rates of survival during nights and weekends. Fourth, our study lacked information on post-cardiac arrest care processes that may have helped to understand the mechanism of persistent differences in post-resuscitation survival between on-hours and off-hours IHCA. Finally, our study only included hospitals participating in the GWTG-R registry and therefore our findings may not be generalizable to all U.S. hospitals.

CONCLUSIONS

We found that despite a significant improvement in IHCA survival over time, survival differences between IHCA during on-hours compared to off-hours persist. Given the large burden of IHCA during off-hours, there is an urgent need to focus quality improvement during this vulnerable period.

ADDRESS FOR CORRESPONDENCE: Dr. Uchenna R. Ofoma, Department of Critical Care Medicine, Geisinger Health System, 100 North Academy Avenue, Danville, Pennsylvania 17822. E-mail: uofoma@geisinger.edu.

PERSPECTIVES

COMPETENCY IN SYSTEMS-BASED PRACTICE: Although survival from in-hospital cardiac arrest has improved in recent years, patients who arrest during off-hours (nights and weekends) experience lower survival rates than those who arrest during daytime hours on weekdays.

TRANSLATIONAL OUTLOOK: Because more than one-half of all in-hospital cardiac arrests occur during off-hours, a systems-based approach focused on eliminating disparities in survival in relation to time of event could improve outcomes.

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KEY WORDS cardiac arrest, cardiopulmonary resuscitation, outcome, patient safety, return of spontaneous circulation

APPENDIX For a list of task force members as well as supplemental tables and a figure, please see the online version of this article.