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Out-of-Hospital Cardiac Arrest Survival at Nighttime
A Nationwide Cohort Study

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Abstract

IMPORTANCE Studies have demonstrated lower odds of survival from out-of-hospital cardiac arrest (OHCA) during nighttime hours, but this has not been studied in North America since 2013, and it is unclear what factors might explain this survival difference.

OBJECTIVE To identify whether OHCA survival during nighttime hours remains lower than during daytime hours using contemporary data and whether it can be explained by variable patient physiology or emergency care factors.

DESIGN, SETTING, AND PARTICIPANTS This cohort study included adults (aged ≥18 years) with OHCA in the Cardiac Arrest Registry for Enhanced Survival from 2013 to 2024.

EXPOSURE Daytime was defined as 7:00 AM to 10:59 PM, and nighttime was defined as 11:00 PM to 6:59 AM.

MAIN OUTCOME AND MEASURES Primary outcomes were sustained return of spontaneous circulation (ROSC) and neurologically favorable survival (Cerebral Performance Category score of 2 or more). A multilevel mixed-effects logistic regression model with prehospital agency as a random effect and patient or treatment characteristics as fixed effects was used. A similar analysis of postresuscitation survival was performed among patients with sustained ROSC, adjusting for the time-to-cardiopulmonary resuscitation interval and defibrillation status. A mediation analysis was performed to identify whether the prehospital response interval mediates the association.

RESULTS Of 1 151 845 patients in the registry, 874 415 were eligible and included in the analysis, and the median (IQR) age in the cohort was 64 (52-75) years with 557 515 males (63.8%) and 181 878 Black or African American patients (20.8%), 146 352 Hispanic or Latino patients (16.7%), and 447 646 White patients (51.2%). A minority of OHCA responses occurred at nighttime (241 967 [27.7%]), and the odds of sustained ROSC and neurologically favorable survival were lower at nighttime than daytime (sustained ROSC: 62 548 [25.8%] vs 193 486 [30.6%]; adjusted odds ratio [aOR], 0.85; 95% CI, 0.84-0.86; neurologically favorable survival: 16 234 [6.7%] vs 58 542 [9.3%]; aOR, 0.84; 95% CI, 0.82-0.86). Among those with sustained ROSC, the odds of postresuscitation survival at nighttime were also lower than daytime (aOR, 0.93; 95% CI, 0.90-0.95). The prehospital response interval partially mediated the nighttime survival disadvantage, with approximately 12.6% of the total effect mediated by the response interval.

CONCLUSIONS AND RELEVANCE In this cohort study of OHCA, nighttime response was associated with lower adjusted odds of sustained ROSC, neurologically favorable survival, and postresuscitation

(continued)

Key Points

Question Does out-of-hospital cardiac arrest resuscitation with nighttime prehospital response remain associated with low rates of survival using contemporary data?

Findings In this retrospective cohort study including 874 415 patients from a nationwide out-of-hospital cardiac registry from 2013 to 2024, patients with prehospital response at nighttime (11:00 PM to 6:59 AM) had 15% lower adjusted odds of neurologically favorable survival and 14% lower adjusted odds of return of spontaneous circulation.

Meaning These findings suggest that nighttime prehospital responses to patients with out-of-hospital cardiac arrest are associated with lower odds of survival than daytime responses, and further work should explore effective strategies to improve survival at night.

+ Invited Commentary

+ Supplemental content

Author affiliations and article information are listed at the end of this article.

Abstract (continued)

survival. Emergency care factors accounted for only a portion of the decreased odds of survival at nighttime.

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Introduction

Out-of-hospital cardiac arrest (OHCA) response at nighttime has been associated with worse outcomes when compared with daytime responses.[1] The most recent data on nighttime OHCA survival in North America come from a single-center study in Philadelphia (2008 to 2013), a registry-based analysis using the Cardiac Arrest Registry to Enhance Survival (CARES) (2005 to 2010), and a study from the Resuscitation Outcomes Consortium (2005 to 2007); all of which demonstrated a survival disadvantage at night.[1-3]

To our knowledge, no comprehensive studies of adult patients in the US investigating nighttime OHCA survival have been conducted since 2013, despite overall OHCA survival improving during that timeframe.[4] Thus, it is unknown if differences in daytime vs nighttime OHCA outcomes have narrowed since these studies were conducted. Notably, recent analysis from an in-hospital cardiac arrest (IHCA) registry reported a decreasing off-hours disparity in return of spontaneous circulation (ROSC) but not survival over time.[5] Further, there has been no study examining whether prehospital response time is a potential mediating factor between time of arrest and outcomes or whether the difference in day vs night outcome is localized to acute resuscitation survival or postarrest care.

In this study, we leveraged the large, nationwide CARES OHCA registry to investigate whether differences in day vs night OHCA survival have narrowed over time. We also aimed to identify whether these differences are mediated by prolonged emergency response intervals.

Methods

Study Design and Setting

This observational cohort study used prospectively collected data from CARES.[6,7] CARES is a registry of nontraumatic OHCA that collects data in a catchment area that includes approximately 186 million people in the US, or 56% of the population.[7] This includes any response from CARES-participating prehospital agencies for patients with attempted resuscitation of OHCA (excluding OHCA with traumatic etiology, stillborn births, and outside of the 911 response system). This cohort study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline.[8] The study was reviewed by the institutional review board of Albert Einstein College of Medicine Office of Human Research Affairs and determined to be exempt from the requirement for informed consent, given the fully deidentified nature of the database.

Selection of Participants

We included all adult patients aged 18 years or older with OHCA in the CARES registry between January 2013 and December 2024. We excluded patients who experienced OHCA in a nursing home or health care facility, or who had missing prehospital dispatch times. Patients from a nursing home or health care facility were excluded because their staffing differs from that of OHCA responses in residential and public settings.

Main Outcomes and Measurements

The primary outcomes in this study were sustained ROSC (at least 20 minutes in duration or present at the end of prehospital care) and neurologically favorable survival at discharge (defined as a Cerebral Performance Category [CPC] of 1 or 2). All variables and definitions used in this study are

detailed in the CARES data dictionary.[7] CARES trains participating agency personnel to enter data using specified definitions in a standardized data form, using information from the electronic health record. Data entry was monitored rigorously by trained CARES data coordinators.

Statistical Analysis

Data were analyzed from July to October 2025. All tests were 2-sided, and statistical significance was set at $P < .05$.

Primary Analysis

Descriptive statistics were used to evaluate demographics and arrest characteristics, both overall and stratified by daytime (prehospital dispatch time between 7:00 AM and 10:59 PM) and nighttime (prehospital dispatch time between 11:00 PM and 6:59 AM), aligned with times most vulnerable to a survival disadvantage identified in previous research.[1] Categorical variables were reported using frequencies and proportions. Continuous variables were reported using median (IQR).

For our primary analysis, we examined daytime vs nighttime exposure, and our primary outcomes were sustained ROSC and neurologically favorable survival. We used a multilevel mixed effects logistic regression model adjusting for prehospital agency as a random effect, and age, sex, race or ethnicity, witnessed status, suspected etiology, incident location, cardiopulmonary resuscitation (CPR) prior to emergency medical services (EMS) arrival (including bystander and first responder), automated external defibrillator (AED) application prior to EMS arrival (including bystander and first responder), and initial monitored rhythm as fixed effects. For those with sustained ROSC, we calculated postresuscitation neurologically favorable survival, adjusting for time-to-CPR and whether defibrillation was performed. The prehospital response interval was not included in the adjustment set because the authors concluded it was a potentially strong mediator between daytime status and survival. For all analyses, complete case analyses were used, and missingness for variables was stratified by exposure status in eTable 1 in Supplement 1.

Secondary Analysis

We then calculated risk-adjusted survival using the same logistic regression model for each calendar year to identify whether the nighttime survival disadvantage changed over time. For this analysis, we used the STATA margins postestimation command holding other covariates at their averaged values (ie, predictive margins) (STATA version 19.5e, StataCorp). We tested whether the association between nighttime and survival varied by year using an interaction term (time-of-day × year) in our mixed-effects model. An omnibus Wald test was used to formally assess whether the nighttime outcome differed across years.

We performed a subgroup analysis using the primary model in the subcohort of patients with initially shockable, bystander-witnessed OHCA, where we estimated that patient physiology characteristics between daytime and nighttime would be most similar, to better isolate response characteristics as potential contributing factors to the disparity. We also performed a subgroup analysis using the primary model in a subcohort of OHCAs that were witnessed by a 911 responder. A forest plot was used to visualize survival outcomes by hour of the day. We performed a sensitivity analysis defining nighttime as 7:00 PM to 6:59 AM and another excluding OHCA from March 2020 to March 2021 to identify whether any process changes during the height of the COVID-19 pandemic impacted results. Results were reported with adjusted odds ratios (aOR) and 95% CI.

To identify whether the missingness of the time-to-CPR interval affected the analysis of post-resuscitation survival, we performed a sensitivity analysis using multiple imputation with chained equations to assess the impact of missingness in the time-to-CPR variable in the model of postresuscitation survival. We generated 20 imputed datasets using predictive mean matching with 10 nearest neighbors. This model includes all covariates used in the original postresuscitation survival. The mixed-effects logistic regression model was fit separately within each of the 20 imputed datasets. The results of the multiple-imputation analysis were compared with the original model to

assess the integrity of the findings. All multiple imputation procedures were conducted using STATA version 19.5 SE (StataCorp). We also performed a causal mediation analysis with the original cohort using counterfactual methods to assess whether prehospital response interval mediates the nighttime survival disadvantage. Prehospital response time was chosen as the mediator given its strong association with outcomes and high potential for system-level intervention.[9] The mediation analysis was performed using the STATA mediate command STATA version 19.5 SE (StataCorp), which uses parametric regression models. We used the same covariates as in our primary models, with adjustment for clustering at the agency level. We report the estimated total effect, the natural direct effect (not mediated by response time), and the natural indirect effect (mediated through response time), along with corresponding confidence intervals and the proportion of the total effect mediated.

Results

Characteristics of Study Participants

Of 1 151 845 patients in CARES from 2013 to 2024, 874 415 were included after applying exclusion criteria as described in **Figure 1**. The median (IQR) age of the cohort was 64 (52-75) years, with 557 515 males (63.8%) and 181 878 Black or African American patients (20.8%), 146 352 Hispanic or Latino patients (16.7%), and 447 646 White patients (51.2%).

Bystander-witnessed arrests accounted for 335 851 (38.4%) of the cohort, 718 803 (82.2%) had a suspected cardiac etiology, and 727 287 (83.2%) experienced OHCA at home. Patient and OHCA characteristics are further described in **Table 1**, stratified by time of day. Missingness for variables in this study are reported, stratified by exposure, in eTable 1 in Supplement 1.

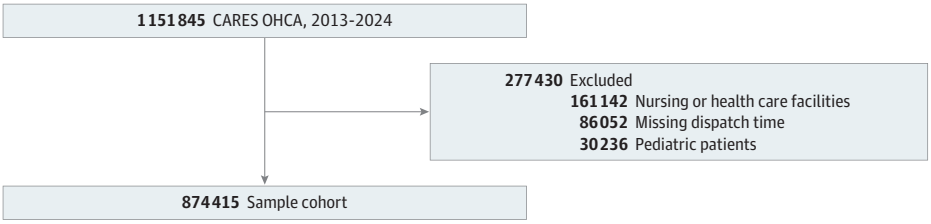
Main Results

A total of 241 967 (27.7%) OHCA responses occurred at nighttime. The odds of sustained ROSC and neurologically favorable survival were lower at nighttime than daytime (sustained ROSC: 62 548 [25.8%] vs 193 486 [30.6%]; aOR, 0.85, 95% 0.84-0.86; neurologically favorable survival: 16 234 [6.7%] vs 58 542 [9.3%]; aOR, 0.84; 95% CI, 0.82-0.86). The odds of neurologically favorable survival were significantly reduced between the hours of 8:00 PM to 8:00 AM (**Figure 2**). The risk-adjusted neurologically favorable survival remained higher during daytime hours from 2013 to 2024 (**Figure 3**). When performing interaction testing, the interaction between year and nighttime was not statistically significant ($\chi^2_{11} = 5.79$; $P = .89$), suggesting that this disadvantage has not changed over time. Sensitivity analyses demonstrated that the survival disadvantage remains when using an alternate exposure definition and when excluding COVID-era years (2020 to 2021) (eTable 2 in Supplement 1).

ROSC and Survival Subgroup Analysis

When limiting to the subgroup of bystander-witnessed, initially shockable OHCA (n = 102 514), sustained ROSC and neurologically favorable survival remained lower at nighttime than daytime (sustained ROSC: 9285 [44.9%] vs 43 123 [52.7%]; aOR, 0.76; 95% CI, 0.74-0.78; neurologically favorable survival: 4755 (23.0%) vs 81 780 [30.0%]; aOR, 0.74; 95% CI, 0.71-0.77). When limiting to

Figure 1. Study Flow Diagram After Applying Exclusion Criteria



CARES indicates Cardiac Arrest Registry to Enhance Survival; OHCA, out-of-hospital cardiac arrest.

Table 1. Patient and OHCA Characteristics[a]

Characteristic	Patients, No. (%)		
	Daytime (7:00 AM to 10:59 PM) (n = 632 448)	Nighttime (11:00 PM to 6:59 AM) (n = 241 967)	Total (n = 874 415)
Demographic			
Age, median (IQR), y	64.0 (52.0-75.0)	62.0 (50.0-73.0)	64.0 (52.0-75.0)
Missing	216 (0.03)	85 (0.04)	301 (0.03)
Sex			
Male	406 529 (64.3)	150 986 (62.4)	557 515 (63.8)
Female	225 885 (35.7)	90 958 (37.6)	316 843 (36.2)
Missing	34 (0.005)	23 (0.01)	57 (0.007)
Race or ethnicity			
American Indian or Alaska Native	2480 (0.4)	1078 (0.4)	3558 (0.4)
Asian	48 817 (7.7)	19 981 (8.3)	68 798 (7.9)
Black or African-American	127 914 (20.2)	53 964 (22.3)	181 878 (20.8)
Hispanic or Latino	105 857 (16.7)	40 495 (16.7)	146 352 (16.7)
Multiracial	2550 (0.4)	1089 (0.5)	3639 (0.4)
Native Hawaiian or Pacific Islander	15 035 (2.4)	5661 (2.3)	20 696 (2.4)
White	328 482 (51.9)	119 164 (49.2)	447 646 (51.2)
Missing	1313 (0.2)	535 (0.2)	1848 (0.2)
Treatment			
Bystander CPR			
Yes	225 862 (35.7)	80 109 (33.1)	305 971 (35.0)
No	326 263 (51.6)	128 594 (53.1)	454 857 (52.0)
Not applicable (EMS-witnessed)	80 323 (12.7)	33 264 (13.7)	113 587 (13.0)
Public AED application[b]			
Yes	12 188 (1.9)	2566 (1.1)	14 754 (1.7)
No	94 565 (15.0)	21 352 (8.8)	115 917 (13.3)
Not applicable	525 695 (83.1)	218 049 (90.1)	743 744 (85.1)
Witnessed arrest status			
Unwitnessed	301 156 (47.6)	123 790 (51.2)	424 946 (48.6)
Witnessed by bystander	250 941 (39.7)	84 910 (35.1)	335 851 (38.4)
Witnessed by 911 responder[c]	80 316 (12.7)	33 262 (13.7)	113 578 (13.0)
Missing	35 (0.006)	5 (0.002)	40 (0.005)
Suspected etiology			
Cardiac	524 485 (82.9)	194 318 (80.3)	718 803 (82.2)
Respiratory	52 040 (8.2)	24 748 (10.2)	76 788 (8.8)
Drug overdose	37 845 (6.0)	16 631 (6.9)	54 476 (6.2)
Other or missing	18 078 (2.9)	6270 (2.6)	24 348 (2.8)
Incident location			
Home or residence	512 422 (81.0)	214 865 (88.8)	727 287 (83.2)
Public area	120 018 (19.0)	27 099 (11.2)	147 117 (16.8)
Missing	8 (0.001)	3 (0.001)	11 (0.001)
Initial monitored rhythm			
Nonshockable	499 955 (79.1)	203 575 (84.1)	703 530 (80.5)
Shockable	132 405 (20.9)	38 363 (15.9)	170 768 (19.5)
Missing	88 (0.01)	29 (0.01)	117 (0.01)
Response interval, median (IQR), min	6.2 (4.5-9.0)	7.0 (5.0-9.3)	6.5 (4.7-9.0)
Missing	2144 (0.3)	4321 (1.8)	6465 (0.7)
Time-to-CPR interval, median (IQR), min	5.0 (1.0-11.0)	6.0 (1.0-12.9)	5.0 (1.0-11.8)
Missing	221 647 (35.0)	90 832 (37.5)	312 479 (35.7)
Time-to-defibrillation interval, median (IQR), min	13.0 (7.8-22.0)	15.0 (9.0-25.0)	13.1 (8.0-22.8)
Not applicable	492 951 (77.9)	199 445 (82.4)	692 396 (79.2)

Abbreviations: AED, automated external defibrillator; CARES, Cardiac Arrest Registry to Enhance Survival; CPR, cardiopulmonary resuscitation; EMS, emergency medical services; OHCA, out-of-hospital cardiac arrest.

[a] Median and IQR for continuous variables and counts and proportions (%) for categorical variables.

[b] Public AED Application uses the CARES definition with a denominator excluding patients who had an OHCA at home.

[c] 911 responder includes personnel activated by emergency call to respond to the OHCA, including police officers, firefighters, emergency medical technician, paramedics, etc.

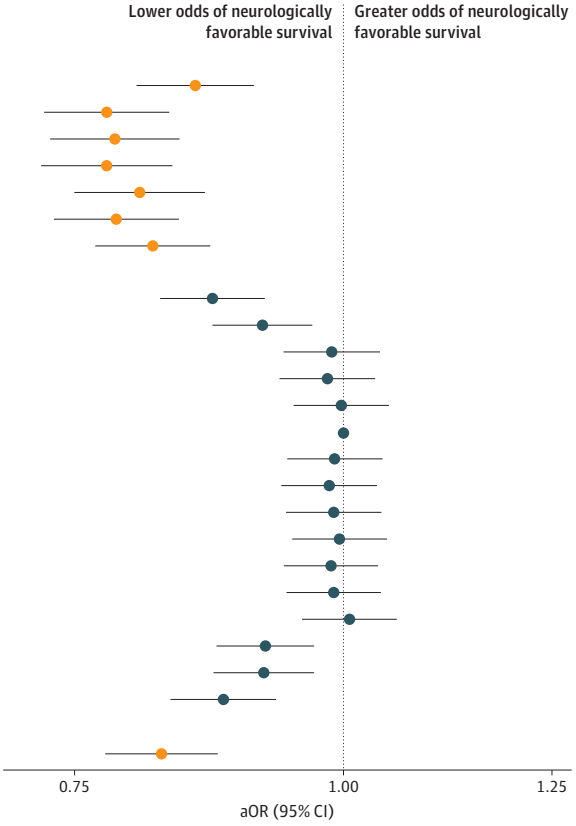
the subgroup of 911 responder-witnessed OHCA (113 578 [13.0%]), sustained ROSC and neurologically favorable survival also remained lower at nighttime than daytime (unadjusted sustained ROSC: 37.8% vs 40.5%, aOR, 0.90; 95% CI, 0.87-0.92; unadjusted neurologically favorable survival: 13.8% vs 15.0%, aOR, 0.94; 95% CI, 0.91-0.98).

Postresuscitation Survival Subgroup Analysis

When limiting to a subgroup of 180 156 patients with sustained ROSC and required covariates, 10 550 of 43 128 of patients at nighttime (24.5%) and 39 927 of 137 208 (29.1%) at daytime experienced neurologically favorable survival. Neurologically favorable postresuscitation survival

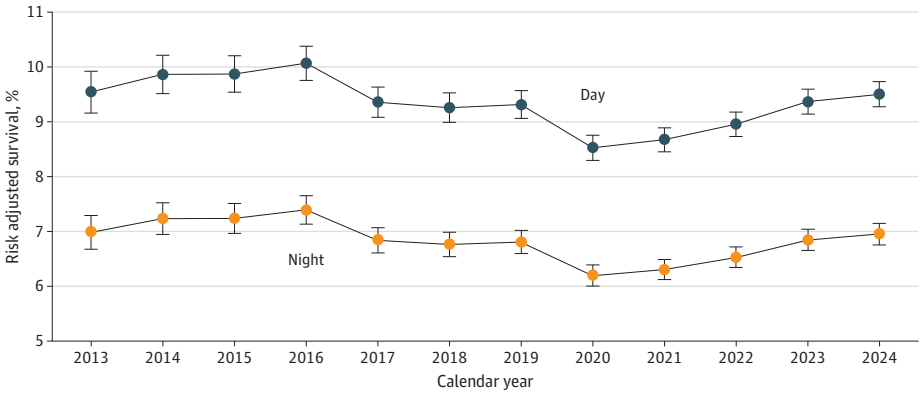
Figure 2. Forest Plot of Multilevel Multivariable Mixed-Effects Logistic Regression Model

Hour	aOR (95% CI)
Night	
12:00AM to 12:59AM	0.85 (0.80-0.91)
1:00AM to 1:59AM	0.78 (0.73-0.83)
2:00AM to 2:59AM	0.78 (0.73-0.84)
3:00AM to 3:59AM	0.78 (0.72-0.83)
4:00AM to 4:59AM	0.80 (0.75-0.86)
5:00AM to 5:59AM	0.78 (0.73-0.84)
6:00AM to 6:59AM	0.82 (0.77-0.87)
Day	
7:00AM to 7:59AM	0.87 (0.82-0.92)
8:00AM to 8:59AM	0.92 (0.87-0.97)
9:00AM to 9:59AM	0.99 (0.94-1.04)
10:00AM to 10:59AM	0.98 (0.93-1.03)
11:00AM to 11:59AM	1.00 (0.95-1.05)
12:00PM to 12:59PM	1 [Reference]
1:00PM to 1:59PM	0.99 (0.94-1.04)
2:00PM to 2:59PM	0.98 (0.94-1.04)
3:00PM to 3:59PM	0.99 (0.94-1.04)
4:00PM to 4:59PM	1.00 (0.95-1.05)
5:00PM to 5:59PM	0.99 (0.94-1.04)
6:00PM to 6:59PM	0.99 (0.94-1.04)
7:00PM to 7:59PM	1.01 (0.96-1.06)
8:00PM to 8:59PM	0.92 (0.87-0.97)
9:00PM to 9:59PM	0.92 (0.87-0.97)
10:00PM to 10:59PM	0.88 (0.83-0.93)
Night	
11:00PM to 11:59PM	0.82 (0.78-0.87)



A forest plot shows the results of a multilevel multivariable mixed effects logistic regression model with hour of day as an ordinal exposure with noon (12:00 PM) as the referent. Point estimates and 95% CIs are plotted with neurologically favorable survival as the outcome. aOR indicates adjusted odds ratio; orange dots indicate daytime out-of-hospital cardiac arressts (OHCA) responses; blue dots, nighttime OHCA responses.

Figure 3. Line Chart of Risk-Adjusted Neurologically Favorable Survival Difference for Days vs Nights by Year



Error bars indicate 95% CIs.

was lower at nighttime than daytime when adjusting for time-to-CPR interval, defibrillation during resuscitation, age, sex, race or ethnicity, etiology, location, initial monitored rhythm, bystander CPR status, AED application status, witnessed status, and accounting for clustering by agency (**Table 2**). The sensitivity analysis using multiple imputation for the time-to-CPR interval produced results consistent with the complete-case analysis. Using multiple imputations, nighttime remained associated with lower odds of post-resuscitation survival (aOR, 0.94; 95% CI, 0.92-0.96).

Mediation Analysis

We identified that the prehospital response interval partially mediated the nighttime survival disadvantage, with a total effect (ie, the overall observed effect of nighttime response on worsened survival) of −0.0103 (95% CI, −0.0118 to −0.0088). This effect was composed of a direct effect (ie, the effect of nighttime response on survival that does not act through the response interval) of −0.0090 (95% CI, −0.0104 to −0.0075) and an indirect effect (ie, the effect of nighttime response on survival acting through the response interval) of −0.0013 (95% CI, −0.0016 to −0.0010). Expressed as a percentage of total effect, approximately 12.6% was mediated by the response interval.

Discussion

We found that the adjusted odds of sustained ROSC and neurologically favorable survival were lower for nighttime OHCA than for daytime OHCA, even after adjusting for patient and event characteristics and pre-EMS arrival factors. Worse survival during nighttime was also observed when limiting to a bystander-witnessed, initially shockable subgroup, in a 911 responder-witnessed subgroup, and in sensitivity analyses, which accounted for alternative definitions of nighttime and the COVID-19 pandemic. The neurologically favorable survival disadvantage during nighttime was only partially mediated by response interval, suggesting that other factors also contribute to this disadvantage, which did not change over time. The adjusted odds of post-ROSC survival were also lower at nighttime than at daytime when controlling for the previous factors and the time to chest compressions and first defibrillation.

These findings corroborate previous work describing a nighttime survival disadvantage among adults experiencing OHCA in the US within a more contemporary cohort.[1-3] Additionally, our study adds to the large body of literature indicating variable survival for OHCA based on the time-of-day

Table 2. Multilevel Mixed-Effect Logistic Regression Models

Outcome[a]	aOR (95% CI)	*P* value
Sustained ROSC		
Nighttime	0.86 (0.85-0.87)	<.001
Daytime	1 [Reference]	NA
Neurologically favorable survival at nighttime		
Nighttime	0.85 (0.84-0.88)	<.001
Daytime	1 [Reference]	NA
Sustained ROSC among bystander-witnessed, initially shockable subgroup		
Nighttime	0.79 (0.76-0.81)	<.001
Daytime	1 [Reference]	NA
Neurologically favorable survival among bystander-witnessed, initially shockable subgroup		
Nighttime	0.77 (0.74-0.80)	<.001
Daytime	1 [Reference]	NA
Postresuscitation survival		
Nighttime	0.93 (0.90-0.95)	<.001
Daytime	1 [Reference]	NA

Abbreviations: aOR, adjusted odds ratio; NA, not applicable; ROSC, return of spontaneous circulation.

[a] Daytime was defined as 7:00 AM to 10:59 PM, and nighttime was defined as 11:00 PM to 6:59 AM.

and day-of-the-week among both adults and children.[10-13] Two meta-analyses[12,14] of observational studies investigating the association between OHCA time of day and survival demonstrated pooled adjusted odds ratios of 20% to 25% disadvantage at nighttime with high heterogeneity. The highest nighttime survival disadvantages in the meta-analyses was reported by Karlsson et al[15] and Matsumura et al[16] with aOR of 2.08 and 1.66 for daytime survival, respectively, which had similar exposure definitions to our study. Importantly, neither was adjusted for clustering by prehospital agency and both were conducted outside the US. Variable exposure definitions, and adjustment sets may explain variable effect sizes, but the persistent nighttime survival disadvantage remains clear across studies.

In contrast to our work, a study of IHCA using the Get with the Guidelines-Resuscitation registry reported that the acute resuscitation survival (ie, sustained ROSC) between on hours (ie, weekdays during the daytime) and off hours (ie, weeknights or weekends) narrowed over time from 2000 to 2014.[5] There are several differences between the IHCA study[5] and our OHCA study. First, IHCA presents with different etiologies, survival rates, and response characteristics than OHCA[17] Second, the years included in the the Get With The Guidelines-Resuscitation analysis (2000 to 2014) may have had larger strides in quality improvement and cardiac arrest care than in our study, using a more contemporary cohort.[5] Regardless of the reason behind this discrepancy, it appears that the nighttime survival disadvantage has not narrowed over time in OHCA.

There are likely unmeasured factors that influence the association between nighttime OHCA response and reduced odds of survival, and 1 particular factor is the quality of bystander recognition and chest compressions prior to prehospital clinician arrival. The CARES registry defines the arrest witness status by whether a bystander saw or heard the cardiac arrest, for example, a family member who hears a noise and awakes to find an unresponsive person witnessed the arrest. It seems possible that even for witnessed arrests, the bystander recognition, action speed, and chest compression could be worse at nighttime. Furthermore, some of the definitions used in this study (eg, estimated time of arrest) may be more difficult for bystanders to provide accurately due to fatigue at nighttime.

We performed 2 analyses to determine whether patient physiology or prehospital response characteristics contributed to the nighttime survival disadvantage. First, we limited the analysis to a subgroup of patients with similar physiology (bystander-witnessed, initially shockable OHCA). Second, we performed a mediation analysis to quantify the association of prehospital response interval on the nighttime survival disadvantage. Since the survival disadvantage was not only present but also larger within the bystander-witnessed, initially shockable subgroup, this suggests that patient physiology alone does not explain the survival gap. Similarly, we showed that prehospital response interval is a partial mediator, adding further evidence that modifiable differences in response may be present. The magnitude of the mediating role of prehospital response time was quite small, only 12.6% of the total outcome. It is unclear what response factors may play a role, and further work should investigate whether AED access, time-to-epinephrine, time-to-defibrillation, CPR quality, and other CPR process metrics mediate the disadvantage. If these modifiable system-level factors do mediate this disadvantage, then the nighttime survivable disadvantage might be exploited by high-performing prehospital quality improvement leaders and clinicians performing resuscitations.

Postresuscitation survival, the proportion of patients with sustained ROSC who subsequently survive to hospital discharge, is not commonly studied in OHCA. We found that the nighttime survival disadvantage for postresuscitation neurologically favorable survival had a smaller effect size than for sustained ROSC or neurologically favorable survival, even after controlling for time-to-CPR and defibrillation status. This reduction in the survival gap may reflect the increased impact of external factors on this measure. For example, when limiting to patients with ROSC, the quality of postarrest critical care (eg, availability of extracorporeal life support, temperature control, early mobility) likely played a larger role in survival to discharge than achieving ROSC. Hospital staffing and access to advanced therapies may be reduced during the early hours of the morning, which could contribute to this survival disadvantage. Postresuscitation survival in our study appears similar to survival

described in studies of IHCA, with approximately 25% of patients who achieved ROSC in our study surviving to discharge with a CPC of 1 or 2 compared with approximately 30% of IHCAs with ROSC surviving to discharge regardless of neurological status.[5] Initial prehospital resuscitation quality that is unmeasured in our available data likely plays some role in postresuscitation survival after OHCA, but it is possible that the persistent difference in this group reflects a gap in postresuscitation quality in the hospital setting. Future studies should explore postresuscitation survival after OHCA.

Limitations

This study has limitations. As agencies opt into CARES, a quality improvement registry, it is possible that there may be differences between agencies that do and do not participate in CARES. Any analysis of a registry like CARES over time is impacted by agencies joining and exiting the registry, thus detecting differences over the years may be distorted by changes in registry participation. However, this was mitigated by our use of a mixed-effects model to account for agency clustering. The use of postresuscitation survival as an outcome, which conditions upon sustained ROSC, is potentially prone to collider bias. Sustained ROSC is clearly influenced by nighttime hours and potentially affected by an unmeasured factor, which influences survival, introducing the possibility of spurious associations. We attempted to mitigate this limitation by focusing our primary analysis on all-comers, which allowed our exploratory analysis conditioning upon those with ROSC to be interpreted within this larger context. Additionally, our mediation analysis is limited to the potential mediator of prehospital response interval, and other mediators (eg, time-to-defibrillation interval, time-to-epinephrine interval, number of responders on scene) may also play a role. Selection bias is another limitation because only OHCA cases with prehospital resuscitation efforts are included in the registry. This potentially underestimates the nighttime survival disadvantage if a higher proportion of nighttime OHCA exhibit obvious signs of death and receive no resuscitation. This means that a large portion of OHCA cases that have no resuscitation attempted by prehospital clinicians are excluded entirely from this dataset and suggests that the nighttime survival disparity could be worse than suggested in our findings if patients with obvious signs of death on EMS arrival are included. Furthermore, missingness in select variables (eg, dispatch time) had missingness that could not be addressed in the statistical methods of this study. Finally, both residual confounding and confounding from unmeasured factors (due to an inability to capture more details in the CARES registry) may influence the observed association between nighttime hours and decreased survival in this study.

Conclusions

In this cohort study of adults who experienced OHCA, nighttime response was associated with lower adjusted odds of neurologically favorable survival compared with daytime OHCA, even when limiting to bystander-witnessed OHCA with an initially shockable rhythm. This nighttime survival disadvantage has persisted without improvement for more than a decade. Similarly, the adjusted odds of neurologically favorable survival to discharge for those with sustained ROSC were lower at nighttime, and this disadvantage did not narrow over time. The prehospital response interval only acted as a partial mediator between nighttime and survival.

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SUPPLEMENT 1.

eTable 1. Missingness of Variables Used in Different Models

eTable 2. Results of Multilevel Mixed Effect Logistic Regression Models Used for Sensitivity Analyses

SUPPLEMENT 2.

Data Sharing Statement