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# Effect of Time of Day on Prehospital Care and Outcomes After Out-of-Hospital Cardiac Arrest

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**Background**—More than 300 000 out-of-hospital cardiac arrests (OHCA) occur each year in the United States. The relationship between time of day and OHCA outcomes in the prehospital setting is unknown. Any such association may have important implications for emergency medical services resource allocation.

**Methods and Results**—We performed a retrospective review of cardiac arrest data from a large, urban emergency medical services system. Included were OHCA occurring in adults from January 2008 to February 2012. Excluded were traumatic arrests and cases in which resuscitation measures were not performed. Day was defined as 8 AM to 7:59 PM; night, as 8 PM to 7:59 AM. A relative risk regression model was used to evaluate the association between time of day and prehospital return of spontaneous circulation and 30-day survival, with adjustment for clinically relevant predictors of survival. Among the 4789 included cases, 1962 (41.0%) occurred at night. Mean age was 63.8 years (SD, 17.4 years); 54.5% were male. Patients with an OHCA occurring at night did not have significantly lower rates of prehospital return of spontaneous circulation compared with patients having daytime arrests (11.6% versus 12.8%;  $P=0.20$ ). However, rates of 30-day survival were significantly lower at night (8.56% versus 10.9%;  $P=0.02$ ). After adjustment for demographics, presenting rhythm, field termination, duration of call, dispatch-to-scene interval, automated external defibrillator application, bystander cardiopulmonary resuscitation, and location, 30-day survival remained significantly higher after daytime OHCA, with a relative risk of 1.10 (95% confidence interval, 1.02–1.18).

**Conclusion**—Rates of 30-day survival were significantly higher for OHCA occurring during the day compared with at night, even after adjustment for patient, event, and prehospital care differences. (*Circulation*. 2013;127:1591-1596.)

**Key Words:** cardiopulmonary resuscitation ■ emergencies ■ emergency medicine ■ emergency service, hospital ■ heart arrest ■ out-of-hospital cardiac arrest ■ resuscitation

Out-of-hospital cardiac arrest (OHCA) is a public health problem affecting nearly 300 000 individuals each year in the United States.<sup>1</sup> Survival rates from OHCA are generally poor, with 1 large US registry study documenting an 8% rate of survival to hospital discharge.<sup>2</sup> Successful resuscitation requires implementing a chain of survival with both prehospital and hospital-based links, including activation of the emergency medical services (EMS) system, early cardiopulmonary resuscitation (CPR) with an emphasis on high-quality chest compressions, defibrillation as appropriate, advanced life support measures, and postresuscitation care in the receiving hospital.<sup>3,4</sup>

## Clinical Perspective on p 1596

The detection and treatment of OHCA at night may be less effective as a result of differences in patient characteristics, event characteristics, and therapeutic measures. Previous work has shown that in-hospital cardiac arrest survival rates

exhibit temporal variability, with both return of spontaneous circulation (ROSC) and survival to hospital discharge occurring less frequently during nighttime hours, even after adjustment for multiple potential confounders, including illness category.<sup>5</sup> Likewise, a recent analysis of witnessed OHCA in Japan demonstrated that nighttime hospital admissions are associated with worsened clinical outcomes than daytime admissions.<sup>6</sup> However, no study to date has evaluated the association between time of day and OHCA outcomes and care measures in the immediate prehospital setting. Any such association may have important implications for EMS staffing, training, and resource allocation.

In this investigation, we sought to evaluate variability in prehospital ROSC by time of day among adults with OHCA. We hypothesized that outcomes after OHCA would be worse at night, even when adjusted for potentially confounding patient, event, and therapeutic characteristics.

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## Methods

### Setting and Design

This investigation was an observational, retrospective study of OHCA patients treated by the Philadelphia Fire Department (PFD). In addition to its fire suppression responsibilities, the PFD is the exclusive public provider of emergency, prehospital care, and transportation for individuals in metropolitan Philadelphia. It responds to  $\approx 270\,000$  medical emergencies per year, serving a population of  $>1.5$  million via a universal emergency access phone number (9-1-1). The PFD operates a tiered EMS system with 36 advanced life support ambulances, each staffed by 2 paramedics or 1 paramedic and 1 firefighter–emergency medical technician, and 14 basic life support ambulances staffed with 2 firefighter–emergency medical technicians. It also uses 59 engine companies and 29 ladder companies as basic life support first responders, each staffed with at least 1 firefighter–emergency medical technician. These first responder companies are equipped with automated external defibrillators (AEDs) and oxygen, among other life support materials.

Data used in the present study were derived from an electronic database of advanced life support and basic life support patient care reports provided by the PFD to the University of Pennsylvania investigative team. Patient care reports are generated for all EMS responses. They summarize the events of the medical emergency and the treatments provided. OHCA events were extracted by the investigators from this database using a consistent approach with available data. Specifically, cases in which CPR, defibrillation, or epinephrine (1:10000 dilution) was provided as treatment were extracted because these therapies are specific for OHCA. Additional cases were extracted on the basis of EMS personnel impression of the case as a cardiac arrest or code blue, these diagnoses having been selected from a drop-down menu on generation of the patient care report.

Multiple verification steps were performed by 2 authors (S.K.W. and F.S.S.) to validate this case identification algorithm and to evaluate for missed OHCA. To assess for false positives, we randomly selected 500 cases meeting our extraction criteria for examination. Hand review of the written case narratives revealed no false positives. All patients had suffered cardiac arrests. To assess for missed cases of OHCA, we reviewed an exploratory set of cases not meeting extraction criteria in which the EMS personnel impression of the patient was unconscious/unresponsive, hypotension, or cardiac rhythm disturbance. Of the 7815 exploratory cases identified, 32 possible false negatives were found, with only 12 of these being true OHCA in progress on EMS arrival. Based on these data, the sensitivity of our original identification algorithm was 99.3% and the specificity was 100%.

The patient care reports included nearly 500 different patient- and provider-level variables, including patient sex, age, and race; event address; time interval between dispatch, arrival at patient location, and delivery to a receiving hospital or field termination; initial cardiac rhythm as shockable (ventricular fibrillation or ventricular tachycardia) versus nonshockable (pulseless electric activity or asystole); bystander CPR use (yes/no); arrest location (public or private); AED use by a bystander or first responder (yes/no); defibrillation (yes/no); epinephrine use (yes/no); and field termination status (yes/no), as well as a free-form, written case narrative.

As a result of the lack of a dedicated collection variable, bystander CPR was derived via hand extraction after review of the written case narratives by 1 investigator (A.K.A.). Our estimate is therefore conservative because it depends on mention of the bystander in the written summary of the emergency. We were not able to distinguish between public-access AED use by a bystander and AED use by a first responder (eg, PFD engine or ladder company).

This study was approved by the Institutional Review boards of the Hospital of the University of Pennsylvania, the City of Philadelphia Department of Public Health, and the Commonwealth of Pennsylvania Bureau of EMS.

### Study Sample

Our study population included all EMS-treated adult patients ( $\geq 18$  years of age) who suffered an OHCA of presumed cardiac origin between January 1, 2008, and February 20, 2012 ( $n=4789$ ). Resuscitation efforts had to be performed for a patient to be included in the study. Patients with do not resuscitate orders were excluded. Likewise,

patients found to be dead on arrival were also excluded from analysis. In this way, biases in the threshold for resuscitation efforts by time of day were minimized. Traumatic arrests, including those caused by firearm injuries and motor vehicle collisions, were excluded via an iterative key word search of the written case narratives. We also excluded patients whose name and date of birth were unknown because survival status would be impossible to determine for these individuals ( $n=152$ ). Such cases without name or birth date represented only 3.1% of the cohort, and their distribution between day and night was not significantly different ( $P=0.35$ ; data not shown).

### Measurement

Time of day was defined by the time at which the PFD was dispatched to the OHCA event. In this study, day was defined as 8 AM to 7:59 PM, and night was defined as 8 PM to 7:59 AM. These periods were selected to reflect the 12-hour shift schedule followed during the study period by EMS personnel working for the PFD.

Our prospectively selected primary outcome measure was prehospital ROSC, which was hand extracted from the written case narratives by 2 investigators (S.K.W. and A.K.A.). Our secondary outcome measure was 30-day survival as determined via the US Social Security Death Index, in conjunction with death statistics provided by the Pennsylvania Department of Health and an online obituary search using the patient's name. We defined 30-day survival as living  $\geq 30$  calendar days from the EMS cardiac arrest event date, generated at the time of dispatch. Survivors were confirmed via a public records search on LexisNexis (LexisNexis Group, Dayton, OH). We were not able to determine 30-day survival in 768 patients (16.0%) using these resources, meaning that they could be found in neither death indexes nor public records. There was no significant difference in the distribution of these patients between day and night (15.2% unknown 30-day survival status among the night cohort versus 17.2% unknown 30-day survival status among the day cohort;  $P=0.06$ ). Information pertaining to the neurological status of surviving patients was not available.

### Statistical Analysis

Data were downloaded into a statistical software package (Stata 11.2; StataCorp LP, College Station, TX) for analysis. Descriptive statistics were used to characterize the study population. We used histograms to graphically check whether continuous variables were normally distributed. Numerically, we looked at skewness and kurtosis. For normally distributed continuous variables, we calculated group means and standard deviations and applied  $t$  tests to assess significant differences between groups. Results are presented as means and 95% confidence intervals (CI). For nonnormal continuous variables such as our time interval measures, we calculated medians and interquartile ranges and used the Wilcoxon-Mann-Whitney test to assess significant differences between groups. For categorical variables, we tested for significant differences between groups using  $\chi^2$  tests.

A relative risk regression model was used to evaluate the association between time of day and our outcome measures, with adjustment for prospectively designated, clinically relevant predictors of survival. These included age, sex, race, presenting rhythm (shockable versus nonshockable), field termination status, total duration of call (dispatch to arrival at hospital or field termination), time interval from dispatch to arrival at the scene, AED application by a bystander or first responder, bystander CPR performance, and location of the arrest (public or private). Gaussian error and robust standard error estimates were used. Relative risks with 95% CIs are presented; a relative risk  $>1$  indicates an improved likelihood of ROSC or 30-day survival compared with the reference group. Adjusted associations were likewise explored between several measures of prehospital care and time of day. A value of  $P<0.05$  was considered statistically significant.

## Results

The PFD responded to 4789 OHCA cases from January 1, 2008, through February 20, 2012, that met our inclusion criteria. Among these, 2827 cases (59.0%) occurred during the day and 1962 cases (41.0%) occurred at night. Patient

demographics are shown in Table 1. The mean age of the cohort was 63.8 years (SD, 17.4 years). Men represented 54.5% of the group (n=2607). Patients suffering an OHCA at night were significantly younger (62.8 years; SD, 17.5 years) than patients experiencing an OHCA during the daytime (64.4 years; SD, 17.4 years;  $P=0.002$ ). Patient sex and race did not vary significantly by time of day. The majority of the cohort was black (52.1%) or white (35.9%). Other races represented included Asian (1.3%), Hispanic (4.9%), South Indian (0.6%), other (0.4%), and unknown (4.8%).

Arrest event characteristics stratified by time of day are displayed in Table 2. OHCA events occurring during the night were less likely to present in a shockable initial rhythm than daytime events (24.5% versus 28.3%;  $P=0.003$ ). Night OHCA cases also had significantly longer median total call times, defined as time from dispatch to arrival at the hospital or field termination (30 minutes; interquartile range, 23–38 minutes) compared with day cases (28 minutes; interquartile range, 22–36 minutes;  $P=0.01$ ). Dispatch-to-scene time intervals were also significantly different by time of day when evaluated with a nonparametric test, although the median value was the same for both groups at 6 minutes ( $P<0.001$ ). The application of an AED by a bystander or first responder was less likely to occur at night (47.0% versus 50.1%;  $P=0.04$ ). Finally, rates of bystander CPR were significantly lower at night compared with the day (7.59% versus 12.7%;  $P<0.001$ ). The rate of field termination did not differ by time of day, nor did arrest location.

Average prehospital ROSC rates and 30-day survival rates partitioned by hour of the day are shown in Figure 1A and 1B. Patients with an OHCA occurring at night did not have a significantly lower rate of prehospital ROSC compared with patients who arrested during the day (11.6% versus 12.8%;  $P=0.20$ ). However, rates of 30-day survival were significantly lower at night compared with the day (8.56% versus 10.9%;  $P=0.02$ ). After adjustment for potential confounders, including age, sex, race, presenting rhythm (shockable versus nonshockable), field termination status, duration of call, dispatch-to-scene interval, AED application by a bystander or first responder, bystander CPR performance, and arrest location, 30-day survival remained significantly higher after a daytime OHCA, with a relative risk of 1.10 (95% CI, 1.03–1.18; Table 3).

Adjusted associations were likewise explored between measures of prehospital care and time of day (Figure 2). Bystander CPR was more likely to occur during the day, even after multivariate adjustment (adjusted relative risk, 1.20; 95% CI, 1.13–1.28). Shockable initial rhythms, including ventricular fibrillation and ventricular tachycardia, were also more likely to present during the day (adjusted relative risk, 1.07; 95%

CI, 1.01–1.13). Finally, the quintile of dispatch-to-scene time was significantly shorter during the day compared with the night (adjusted relative risk, 0.89; 95% CI, 0.82–0.97).

## Discussion

We found that rates of 30-day survival after OHCA were lower at night (defined as 8 PM to 7:59 AM) compared with the day (defined as 8 AM to 7:59 PM), even after adjustment for patient, arrest event, and prehospital care factors. This analysis represents the largest study to date of temporal variability in OHCA outcomes within the United States. The present work provides important insights into the prehospital patient and event characteristics that contribute to survival variability from OHCA by time of day.

Our findings are consistent with a recent analysis by Koike et al,<sup>6</sup> which found that adult OHCA patients admitted to Japanese receiving hospitals during the daytime had significantly higher rates of 1-month survival (adjusted odds ratio, 1.26; 95% CI, 1.22–1.31). The investigators also found that patients admitted for nighttime OHCA were younger on average and less likely to receive bystander CPR, consistent with our findings. This study was limited to witnessed cardiac arrests and looked only at postadmission survival outcomes. Peberdy et al<sup>5</sup> found that survival-to-discharge rates from in-hospital cardiac arrest were lower at night even after multivariate adjustment (adjusted odds ratio, 1.18; 95% CI, 1.12–1.23). The authors hypothesized that the mechanism for decreased survival at night was likely multifactorial, including physiological factors, hospital staffing, and operational differences.

Temporal variability in healthcare staff performance has been well documented in the clinical literature. Horwitz and McCall<sup>7</sup> found that evening and night shift hospital workers were at greater risk of occupational injury than their daytime counterparts. Kuhn<sup>8</sup> reviewed the effects of shift work on the disruption of circadian rhythms in emergency medicine physicians, which include increased illness and poor mood. Smith-Coggins et al<sup>9</sup> found that emergency medicine attending physicians were less effective at performing manual and cognitive tasks when working night shifts and sleeping during the day compared with working day shifts and sleeping during the night. Further research may be needed to determine whether there is a biological reason for lower OHCA survival at night or if decreased physical performance and mental performance on the part of EMS providers and receiving hospital staff are contributing factors.

Indeed, it is possible that the quality of CPR and other resuscitation care measures by EMS workers at night may be

**Table 1. Patient Characteristics**

Variable	Day OHCA, 8 AM–7:59 PM (n=2827)	Night OHCA, 8 PM–7:59 AM (n=1962)	Total (n=4789)	P Value
Age, mean (SD), y	64.4 (17.4)	62.8 (17.5)	63.8 (17.4)	0.002
Male sex, n (%)	1539 (54.6)	1068 (54.4)	2607 (54.5)	0.93
Black race, n (%)	1446 (51.2)	1050 (53.5)	2496 (52.1)	0.11

OHCA indicates out-of-hospital cardiac arrest.

**Table 2. Event Characteristics**

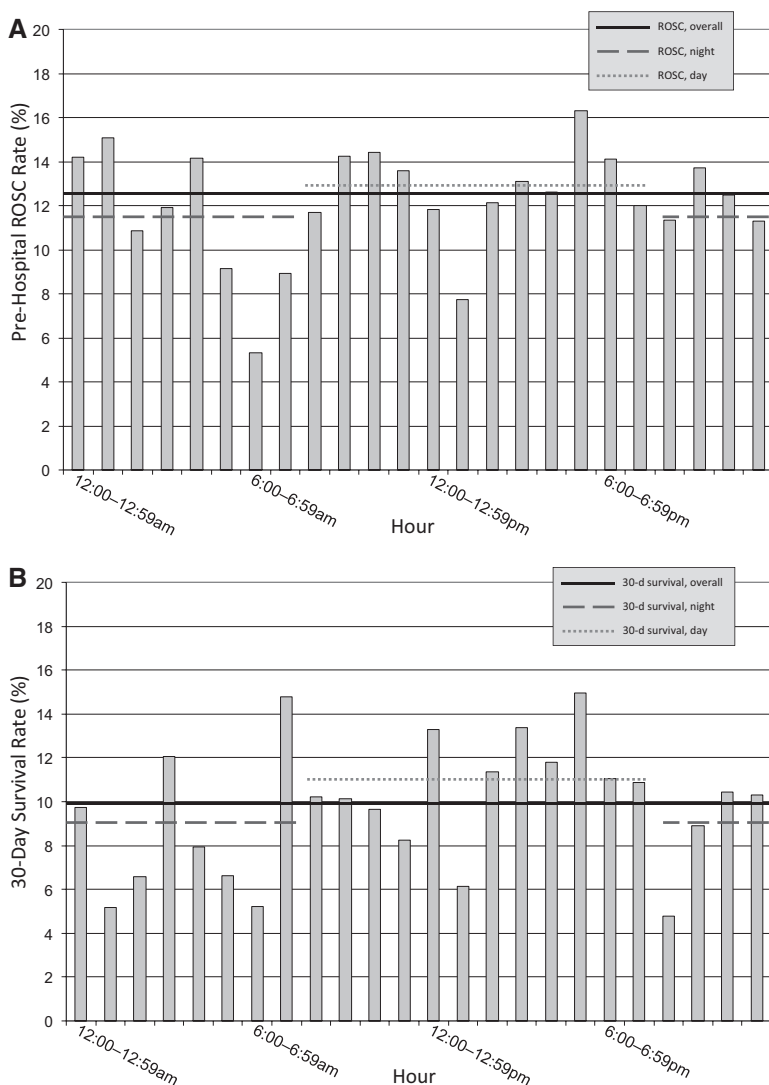
Variable	Day OHCA, 8 AM–7:59 PM (n=2827)	Night OHCA, 8 PM–7:59 AM (n=1962)	Total (n=4789)	P Value
Shockable initial rhythm, n (%)	801 (28.3)	481 (24.5)	1282 (26.8)	0.003
Resuscitation terminated in the field, n (%)	177 (6.26)	148 (7.54)	325 (6.79)	0.08
Median total call time (IQR), h:min	00:28 (00:22–00:36)	00:30 (00:23–00:38)	00:29 (00:22–00:37)	0.01
Median dispatch-to-scene time (IQR), h:min	00:06 (00:04–00:08)	00:06 (00:04–00:09)	00:06 (00:04–00:09)	<0.001
AED application, n (%)	1415 (50.1)	922 (47.0)	2337 (48.8)	0.04
Bystander CPR, n (%)	359 (12.7)	149 (7.59)	508 (10.6)	<0.001
Private arrest location, n (%)	2365 (83.7)	1644 (83.8)	4009 (83.7)	0.90
Prehospital ROSC, n (%)	362 (12.8)	227 (11.6)	589 (12.3)	0.20
30-d Survival, n (%)*	260 (10.9)	139 (8.56)	399 (9.92)	0.02

AED indicates automatic external defibrillator; CPR, cardiopulmonary resuscitation; IQR, interquartile range; OHCA, out-of-hospital cardiac arrest; and ROSC, return of spontaneous circulation.

\*The 30-day survival was available for 4021 patients.

an important, unmeasured contributing factor to the observed variability in OHCA survival by time of day. Studies have demonstrated that the quality of multiple parameters of CPR provided by healthcare staff can be inconsistent.<sup>10,11</sup> The use of innovative approaches, including debriefing sessions<sup>12</sup> and

rolling refreshers,<sup>13</sup> has been shown to enhance subsequent CPR performance quality and outcomes when imparted to healthcare workers who treat cardiac arrest. Translation of such strategies to the prehospital setting may be an important topic of future investigation.



**Figure 1. A**, Rates of prehospital return of spontaneous circulation (ROSC) by hour of day. Prehospital ROSC was 12.3% overall (solid line), 11.6% at night (dashed line), and 12.8% during the day (dotted line). The difference between night and day was not statistically significant ( $P=0.20$ ). **B**, Rates of 30-day survival by hour of day. The 30-day survival was 9.92% overall (solid line), 8.56% at night (dashed line), and 10.9% during the day (dotted line). The difference between night and day was statistically significant ( $P=0.02$ ).

**Table 3. OHCA Outcomes by Day Compared With Night**

	Day OHCA, 8 AM–7:59 PM	Night OHCA, 8 PM–7:59 AM	Total	Unadjusted Relative Risk (95% CI) for Day vs Night	Adjusted Relative Risk (95% CI) for Day vs Night†
Total, n	2827	1962	4789	4789	4789
Prehospital ROSC, n (%)	362 (12.8)	227 (11.6)	589 (12.3)	1.05 (0.98–1.12)*	1.04 (0.97–1.12)‡
Total, n	2397	1624	4021	4021	4021
30-d Survival, n (%)	260 (10.9)	139 (8.56)	399 (9.92)	1.10 (1.02–1.19)§	1.10 (1.02–1.18)§

CI indicates confidence interval; OHCA, out-of-hospital cardiac arrest; and ROSC, return of spontaneous circulation.

\* $P=0.19$  for day vs night.

†Relative risk regression adjusted for age (quintile), sex, race, presenting rhythm (shockable versus nonshockable), field termination status, total call time and call-to-scene time (quintiles), automatic external defibrillator application by a bystander or first responder, bystander CPR performance, and arrest location.

‡ $P=0.23$  for day vs night.

§ $P\leq 0.02$  for day vs night.

We found significant variation in EMS response time by time of day. The interval from dispatch to scene was significantly longer at night, as was the interval from dispatch to hospital arrival or field termination. Although we controlled for these variables in our adjusted analysis, it remains possible that the decreased rate of survival observed at night is partially a factor of delayed response times, given the time-sensitive nature of cardiac arrest and the reduced likelihood of lifesaving bystander resuscitation measures during the nighttime hours. Whether delayed response times at night are due to staffing, performance, or transportation factors is an important area of further study.

It is also important to consider other issues of survival variability from OHCA in light of our findings. Sasson et al<sup>14</sup> found differences in bystander CPR provision by neighborhood in Atlanta based on income level in a recent analysis. Likewise, Lerner et al<sup>15</sup> identified clusters of OHCA incidence and low bystander CPR in Rochester, NY. It is possible that certain geographic regions in Philadelphia are more sensitive to day and night differences in survival than others. Such neighborhoods might benefit from the placement of additional public-access AEDs or trained first responders. Geographic analysis of survival patterns in Philadelphia is an important future research goal.

Finally, it is notable that we found no significant difference in immediate prehospital ROSC by time of day, but we did find a significant difference in 30-day mortality, even after

adjustment for prehospital confounders. This finding may suggest that the reason for the observed difference lies in the hospital care provided to the patients during the day versus the night, as suggested by Koike et al.<sup>6</sup> It is possible that some hospitals offer less comprehensive treatment during the nighttime, potentially affecting patient outcome. Corroborating citywide prehospital records with hospital charts from many different facilities is often not feasible; however, future studies may wish to consider the possibility to control for this factor.

### Limitations

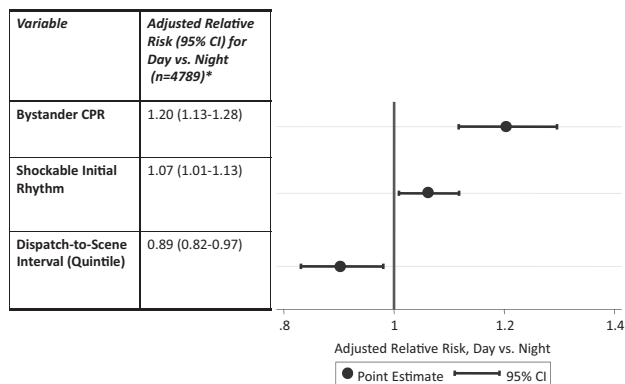
Our study has several limitations. The analysis was specific to Philadelphia and may not be generalizable to other cities with different EMS systems and patient populations. Nonetheless, Philadelphia represents a large and diverse metropolitan area with a fire department–based EMS system, common in many American cities. The PFD is large, accounting for more than one third of all EMS runs in the state of Pennsylvania and covering a heterogeneous but geographically unified population. In fact, the advantage of limiting our study to Philadelphia is that the city is served by 1 EMS system; thus, there are no confounders attributable to differences in EMS agencies.

An additional limitation to this study is that our prehospital database was not linked to inpatient records from the 27 adult receiving hospitals in Philadelphia. Thus, specific details about hospital course, postresuscitation care, and survival to discharge were not available. However, by using the US Social Security Death Index in conjunction with Pennsylvania State Vital Statistics, LexisNexis, and an online obituary search, we obtained 30-day survival status for most of the patients. Thirty-day survival is a robust clinical outcome, and its use is consistent with other published OHCA studies.<sup>16–18</sup>

No data were obtained for 30-day survival in 768 patients (16.0% of the cohort). However, there was no significant difference in the distribution of these patients between day and night, making the chance of bias in our analysis unlikely (15.2% unknown 30-day survival status among the night cohort versus 17.2% in the day cohort;  $P=0.06$ ).

### Conclusions

We observed that rates of 30-day survival were significantly lower for cases of OHCA occurring at night compared with the day, even after adjustment for patient, event, and care differences. We also found significant differences in the rates of bystander CPR, AED use, and response time intervals by



\* Relative risk regression adjusted for all other variables in the model plus age (quintile), total call time (quintile), and AED application by a bystander or first responder

**Figure 2.** Adjusted relative risk of bystander cardiopulmonary resuscitation (CPR; (yes/no), initial rhythm (shockable vs nonshockable), and longer dispatch-to-scene interval (by quintile), day vs night. AED indicates automatic external defibrillator; and CI, confidence interval.

time of day. Several factors likely contribute to the observed survival variability by time of day, including biological differences in the patients themselves, variation in the quality of CPR parameters, staffing and operational factors, and response time. These data suggest the need to further study nighttime EMS resuscitation quality and system processes to improve patient safety and survival after OHCA.

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### CLINICAL PERSPECTIVE

Out-of-hospital cardiac arrest is a public health problem affecting nearly 300 000 individuals each year in the United States, with rates of survival at <10% in most cities. Successful resuscitation requires implementing a chain of survival, including both prehospital and hospital-based care measures. The association between time of day and out-of-hospital cardiac arrest outcomes in the prehospital setting was previously poorly understood; any such association has important implications for emergency medical services planning and resource allocation. We performed a retrospective review of cardiac arrest data from a large, urban emergency medical services system and found that rates of 30-day survival were significantly higher for cases of out-of-hospital cardiac arrest occurring during the day compared with at night, even after adjustment for patient, event, and prehospital care differences. We also found significant differences in the rates of bystander cardiopulmonary resuscitation, automated external defibrillator use, and response time intervals by time of day. This analysis represents the largest study to date of temporal variability in out-of-hospital cardiac arrest outcomes in the United States. Reasons for decreased survival at night may include biological differences in patients, decreased physical and mental performance on the part of emergency medical services providers and receiving hospital staff, or differences in the quality of cardiopulmonary resuscitation and other resuscitation care measures at night. These data provide compelling evidence for the need to further study nighttime emergency medical services resuscitation quality and system processes to improve patient safety and survival after out-of-hospital cardiac arrest.