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ORIGINAL RESEARCH ARTICLE

Impact of Bystander Automated External Defibrillator Use on Survival and Functional Outcomes in Shockable Observed Public Cardiac Arrests

BACKGROUND: Survival following out-of-hospital cardiac arrest (OHCA) with shockable rhythms can be improved with early defibrillation. Although shockable OHCA accounts for only ≈25% of overall arrests, ≈60% of public OHCAs are shockable, offering the possibility of restoring thousands of individuals to full recovery with early defibrillation by bystanders. We sought to determine the association of bystander automated external defibrillator use with survival and functional outcomes in shockable observed public OHCA.

METHODS: From 2011 to 2015, the Resuscitation Outcomes Consortium prospectively collected detailed information on all cardiac arrests at 9 regional centers. The exposures were shock administration by a bystander-applied automated external defibrillator in comparison with initial defibrillation by emergency medical services. The primary outcome measure was discharge with normal or near-normal (favorable) functional status defined as a modified Rankin Score ≤2. Survival to hospital discharge was the secondary outcome measure.

RESULTS: Among 49 555 OHCAs, 4115 (8.3%) observed public OHCAs were analyzed, of which 2500 (60.8%) were shockable. A bystander shock was applied in 18.8% of the shockable arrests. Patients shocked by a bystander were significantly more likely to survive to discharge (66.5% versus 43.0%) and be discharged with favorable functional outcome (57.1% versus 32.7%) than patients initially shocked by emergency medical services. After adjusting for known predictors of outcome, the odds ratio associated with a bystander shock was 2.62 (95% confidence interval, 2.07–3.31) for survival to hospital discharge and 2.73 (95% confidence interval, 2.17–3.44) for discharge with favorable functional outcome. The benefit of bystander shock increased progressively as emergency medical services response time became longer.

CONCLUSIONS: Bystander automated external defibrillator use before emergency medical services arrival in shockable observed public OHCA was associated with better survival and functional outcomes. Continued emphasis on public automated external defibrillator utilization programs may further improve outcomes of OHCA.

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Clinical Perspective

What Is New?

- Bystander automated external defibrillation versus emergency medical services defibrillation in shockable observed public out-of-hospital cardiac arrest is associated with an increased odds of survival with full or nearly full functional recovery.
- The benefit of bystander automated external defibrillation use increases as the arrival of emergency medical services is delayed.
- Overall bystanders shocked a remarkable 19% of shockable observed public out-of-hospital cardiac arrests from 2011 to 2015 at 9 sites across the United States and Canada.

What Are the Clinical Implications?

- Efforts to increase the availability and use of automated external defibrillators in public locations are likely the most promising immediate ways to improve survival from out-of-hospital cardiac arrest.
- The effective allocation of automated external defibrillators and training may benefit from an emphasis on locations where the response time for emergency medical response is longer.

Out-of-hospital cardiac arrest (OHCA) remains a significant cause of mortality and morbidity throughout the world,[1] and sudden cardiac death is often the first symptom of underlying cardiopulmonary pathology.[2–4] Overall survival following OHCA is low.[1,5] The presenting arrest rhythm has a strong influence on prognosis. Cardiac arrest presenting with an initial rhythm of ventricular tachycardia and ventricular fibrillation has significantly better odds of survival in comparison with nonshockable rhythms, in particular, when early cardiopulmonary resuscitation and rapid defibrillation are available.[6–8] Although the overall prevalence of shockable rhythms in OHCA has decreased over the past 30 years,[9,10] the prevalence of such rhythms in observed OHCA occurring in public rather than at home has been reported to be as high as 60%.[6,11] The high proportion of shockable rhythms in public OHCA suggests that automatic external defibrillators (AEDs) located in public locations, which can be used by bystanders to decrease the time to defibrillation, may be a particularly effective allocation of resources. Given the potential for extremely rapid defibrillation before emergency medical services (EMS) arrival, the ≈18 200 individuals (annually in the United States alone) who experience shockable observed public OHCA (SOP-OHCA) represent an ideal population in which public access defibrillation can improve survival.

Indeed, the use of public access defibrillators is consistently shown to improve survival in overall shockable OHCA.[12,13] This benefit has been attributed to the decreased time to defibrillation for bystander versus EMS shock, because survival in shockable OHCA decreases significantly with each minute of delay in defibrillation.[14–16] These studies, however, did not report the detailed functional status of the patients at discharge or determine how EMS response might influence the effectiveness of bystander AED use. Recently, 3 key studies have reported on functional outcomes following bystander AED use. Malta Hansen and colleagues[17] evaluated functional outcome from bystander versus EMS shock for a subset of counties in North Carolina where EMS response was on average >8 minutes. Kitamura and colleagues[18] analyzed functional outcomes associated with bystander AED use in Japan in a setting with longer EMS response. Kragholm et al[19] reported that bystander interventions were associated with improved 1-year neurological function among 30-day survivors of OHCA. These studies suggested that bystander AED use was associated with improved functional outcome, although the definition of improved functional outcome has varied considerably between studies.

The Resuscitation Outcomes Consortium (ROC) is a collaboration among several large sites with rigorous data collection processes on multiple components of pre- and posthospital care that presents a unique opportunity to study bystander intervention in the setting of strictly monitored and often rapid EMS response times. This multicenter, international, observational cohort study compared survival and a strictly defined favorable functional outcome between patients treated with initial bystander AED shock versus initial EMS shock among SOP-OHCAs from 2011 to 2015.

METHODS

The data and analytical methods are available to other researchers for purposes of reproducing the results or replicating the procedure. The data set is available at the National Heart, Lung and Blood Institute bioLINCC (Biologic Specimen and Data Repository Information Coordinating Center) program,[20] and the analysis software is available as an online-only Data Supplement.

Study Design and Setting

The ROC is a clinical trials network implemented to investigate strategies to improve outcomes in prehospital cardiopulmonary resuscitation and severe traumatic injury. This study is a prospectively designed analysis using the ROC Epistry data set that aims to ascertain all treated OHCAs for each ROC site. The ROC Epistry defines an OHCA as a case in which cardiopulmonary resuscitation (CPR) was performed by EMS or defibrillation was attempted by EMS or a bystander. The current investigation used data from cases treated in 6 US regions (Seattle/King County, WA; Dallas/Fort Worth, TX; Pittsburgh, PA; Milwaukee, WI; Birmingham, AL; Portland, OR) and 3 Canadian regions (Toronto, ON; Ottawa, ON; Vancouver, British Columbia).

Approval for the ROC Epistry and associated investigations was provided by the institutional review boards or research ethics boards at each ROC site. All research was conducted in accordance with US and Canadian regulations on human subjects research.

Inclusion Criteria

This study included all patients at least 18 years of age with nontraumatic SOP-OHCA on whom defibrillation was attempted by EMS or a bystander. Although not a part of the primary study population, additional analyses among patients with unobserved and private OHCA was also performed to expand on the generalizability of the findings. Patients who attained return of spontaneous circulation before EMS arrival as a result of bystander AED use were included. The study excluded (1) patients on whom CPR was not attempted as a result of do-not-resuscitate orders or clear signs of death; (2) EMS-observed cardiac arrests because bystander AED is not relevant in these cases; and (3) the modest number (n=18) for whom no EMS shock was delivered, but subsequent analysis of ECG records indicated an initial shockable rhythm.

Data Collection and Definitions

A detailed description of data collection, quality control, and definitions has been reported previously.[21] In brief, data elements from each OHCA were collected by trained study personnel according to a set of predefined and uniform data collection procedures designed to maximize the validity, reproducibility, and accuracy of data. Data collection procedures and data definitions were implemented by the study investigators according to the Utstein standards. Canadian sites are not permitted to assess the race of the patient; these individuals are treated as having an unknown race. Random and centralized audits of data collection practices were conducted throughout the study period to ensure the stability and reproducibility of data acquisition. Functional outcomes were assessed from the patient health record by trained study personnel.

The primary comparison groups and outcome measures for the current study were identified prospectively, and individuals involved in patient care were not aware of the study intent. A public location was defined as a street or highway, public building, place of recreation, industrial place, or other public property, excluding healthcare facilities (hospitals, medical clinics, and other healthcare institutions). All other locations, excluding healthcare facilities as above, were defined as private. Bystander-observed cardiac arrest was defined as an arrest that was observed by a person who was not a member of the organized EMS response. Police officers were considered bystanders. A shockable rhythm was defined as any patient in whom an AED shock was delivered, an AED rhythm analysis (when available) indicated a shockable rhythm, or the initial EMS ECG readings indicated a shockable rhythm. All other arrests were considered nonshockable. The incidence of incorrect ECG analysis by an AED is rare.[22] A previous study reported the error rate in the ECG rhythm assignment by EMS providers for a portion of this data set was 3.1%.[11] Bystander AED shock was defined as any shock delivered by a bystander-applied AED before EMS arrival as reported by the bystander to EMS personnel or when AED records were available and indicated a shock was delivered. EMS shock was defined as any cardiac arrest in which the initial shock was delivered by EMS. Individuals shocked by a bystander-applied AED who were later shocked by EMS were still considered bystander-shocked. EMS response interval was defined as the time period from receipt of the initial 911 call at the dispatch center to the arrival of the EMS vehicle at the scene.

Functional Outcome

Functional outcomes were assessed from the medical record by trained ROC personnel using the modified Rankin Score (mRS), a validated, clinician-reported measure of global disability.[23,24] The mRS uses a scoring system from 0 to 6 to quantify functional outcome (0=no symptoms; 1=no significant disability; 2=slight disability; 3=moderate disability, requiring some help but able to walk without assistance; 4=moderately severe disability, unable to walk or attend to bodily needs without assistance; 5=severe disability; 6=death). An mRS≤2 is a validated dichotomous indicator of favorable functional outcome and was selected a priori as the primary functional outcome.[23] Although we chose to identify patients with minimal disability (mRS≤2) as the cutoff for favorable outcome, because of a lack of consensus in the cardiac arrest literature for cutoff mRS, we included a sensitivity analysis using the less strict ≤3 cutoff. mRS=3 indicates an inability to look after one's own affairs without assistance.[23,24]

Statistical Analysis

Subjects' characteristics and treatment were summarized with proportions, mean and SD, or median and interquartile range as appropriate. The attempt of this study was to analyze the impact of bystander AED use while limiting the impact of confounding from patient characteristics, other bystander interventions, and prehospital treatment. Therefore, in the primary analysis, multivariable logistic regression was used to quantify the relationship between bystander AED shock and good functional outcome, adjusted for age, sex, race, bystander CPR, EMS response time, and study site.

A similar analysis was conducted for the secondary outcome measure of survival to hospital discharge. Results are expressed as odds ratios with 95% confidence intervals (CIs). We undertook a sensitivity analysis that excluded cases from the bystander AED shock group who were treated by police (n=41). In a secondary analysis, we also evaluated whether the potential outcome benefit of bystander AED shock was modified by the EMS response interval by including an interaction term between bystander AED shock and EMS response interval. All statistical analyses were performed with commercially available statistical packages (SAS, version 9.4; R, version 2.14.1).

RESULTS

Study Population

Between 2011 and 2015, a total of 49 555 cardiac arrests were treated by EMS. Of these, 4115 took place in public and were observed, and 2589 of the

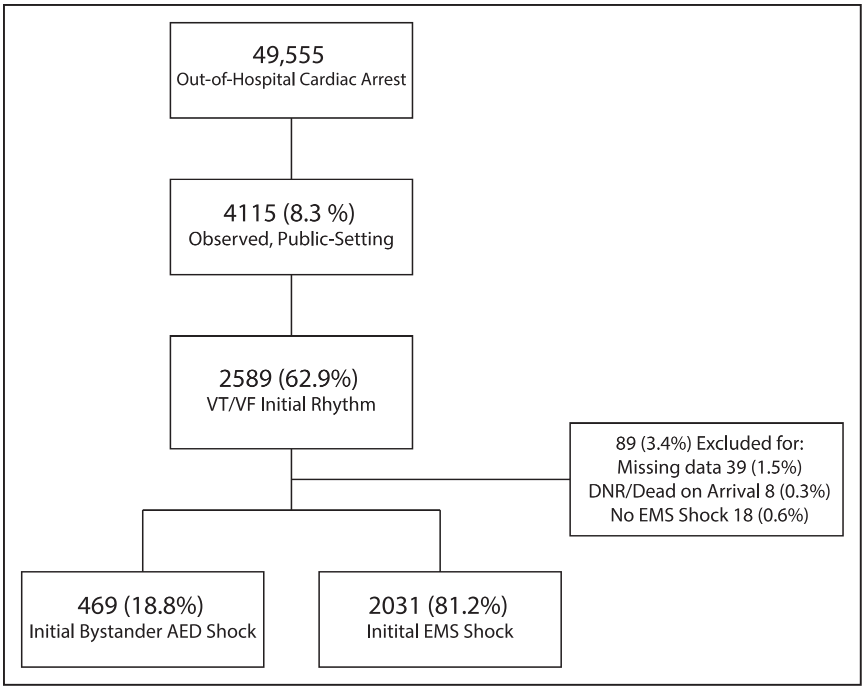

Figure 1. Patient inclusion and exclusion criteria.
Flowchart of patient inclusion and exclusion criteria. Numbers listed are the number of patients in each group. AED indicates automatic external defibrillator; DNR, do not resuscitate; EMS, emergency medical services; VF, ventricular fibrillation; and VT, ventricular tachycardia.

observed public cardiac arrests presented with an initial shockable rhythm. A total of 89 SOP-OHCAs were excluded for do-not-resuscitate orders, subjects dead on EMS arrival, missing data, or confirmed shockable rhythms that were not shocked by EMS or a bystander. Consequently, the primary study cohort of SOP-OHCAs included the 469 who were shocked by a bystander and 2031 who were initially shocked by EMS (Figure 1).

The bystander- and EMS-shocked patients in the SOP-OHCA group were similar according to the Utstein data elements with the exception of bystander CPR and administration of epinephrine (Table 1). Bystander CPR was initiated more often among bystander-shocked OHCAs, whereas epinephrine was administered more often in the EMS-shocked group. Much of the observed difference in epinephrine administration between EMS- and bystander-shocked patients is explained by the

Table 1. Characteristics of Public Cardiac Arrests

	Treated Arrests n=49 555	Private Arrests n=42 473	Public Arrests n=6973	Public Arrests, Bystander Observed n=4115	Public Observed Shockable Arrests n=2500	SOP-OHCA	
						EMS Shock n=2031	Bystander AED Shock n=469
Age, y, median (Q1, Q3)	67 (55, 80)	69 (56, 81)	61 (51, 71)	62 (53, 72)	61 (53, 72)	61 (53, 70)	62 (53, 70)
Male, %	63	61	80	80	85	84	89
Race, %							
White	25	25	27	27	28	28	26
Black	11	11	9	8	6	7	3
Other	2	2	2	2	2	2	2
Unknown	62	62	62	64	64	63	69
Bystander CPR, %							
Yes	42	40	54	66	73	67	99
No	56	58	45	33	26	32	1
Missing	2	2	1	1	1	1	0
EMS response time, min, median (Q1, Q3)	5.6 (4.3, 7.2)	5.6 (4.4, 7.2)	5.3 (4.0, 7.1)	5.3 (4.0, 7.1)	5.2 (4.0, 7.0)	5.1 (3.9, 6.8)	5.7 (4.3, 7.6)
Epinephrine, %	81	82	77	73	67	72	43
Dose, mean (SD)	3.7 (2.0)	3.7 (2.0)	3.7 (2.3)	3.7 (2.4)	3.6 (2.5)	3.5 (2.4)	3.9 (2.8)

AED indicates automatic external defibrillator; CPR, cardiopulmonary resuscitation; EMS, emergency medical services; Q1, Q3, the boundaries of the interquartile range; and SOP-OHCA, shockable observed public out-of-hospital cardiac arrest.

30.9% of bystander-shocked patients achieving return of spontaneous circulation before EMS arrival, because no patient with return of spontaneous circulation on EMS arrival received epinephrine.

Bystander-Applied Shock

Over the entire study period, bystanders initiated CPR in 73% of SOP-OHCAs (Table 1). Bystanders applied an AED and delivered a shock before the arrival of EMS personnel in 18.8% of SOP-OHCAs.

Survival and Functional Outcomes

Functionally favorable survival (mRS≤2) was greater among those patients treated with bystander AED shock than EMS shock (57.1% versus 32.7%, $P<0.001$) with most of the outcome advantage apparent when comparing the group with no disability (mRS=0 for 32.6% of AED bystander-shocked versus 14.4% of EMS-shocked, $P<0.001$) (Table 2). After multivariable adjustment, the odds ratio for discharge with favorable functional outcome (mRS≤2) associated with initial bystander shock was 2.73 (95% CI, 2.17–3.44, $P<0.001$) (Table 3). The relationships between bystander AED use and favorable outcome were similar regardless of the mRS cutoff (mRS≤3 or mRS≤2). Overall survival to hospital discharge was 66.5% among AED bystander-shocked versus 43.0% among EMS-shocked, $P<0.001$. After adjustment, the odds ratio for survival to discharge associated with initial AED bystander shock was 2.62 (95% CI, 2.07–3.31) (Table 3). No survival benefit of bystander shock in comparison with EMS shock was seen in subjects with shockable public arrest that was not observed by the bystander. In shockable arrests occurring in private locations, there was a significant survival benefit when these arrests were observed by the bystander but not in unobserved arrests (Table 3, Tables I and II in the online-only Data Supplement).

The overall survival and functional status of individuals experiencing SOP-OHCA varied with the location of arrest, and the benefit of bystander AED use versus EMS defibrillation was strongest at industrial locations and places of recreation (Table 4).

The results for favorable functional outcome and survival to discharge were similar when analyses excluded police AED shock from the bystander shock group (adjusted odds ratio, 3.02 [95% CI, 2.37–3.78] for favorable functional survival; adjusted odds ratio, 2.93 [95% CI, 2.29–3.78] for survival to discharge).

EMS Response Time and Survival Following Bystander Shock

We observed that the relative benefit of bystander AED shock was a function of EMS response interval, because the fit of the multivariable logistic model was improved with the addition of an interaction term between EMS response interval and bystander AED shock status ($P=0.013$ for interaction term). As the EMS response interval increased, survival with favorable functional outcome declined more rapidly for EMS-shocked individuals than for bystander-shocked individuals (Figure 2). For example, according to this multivariable logistic model, the adjusted odds ratio for favorable functional outcome associated with bystander AED shock in comparison with EMS initial shock was 1.86 (95% CI, 1.03–3.37) when EMS response interval was 4 minutes, 3.49 (95% CI, 1.59–7.67) when EMS response was 8 minutes, and 6.54 (95% CI, 2.15–19.91) when EMS response was 12 minutes.

DISCUSSION

In this prospective contemporary observational cohort study, we found that bystanders provided the initial shock in nearly one fifth of SOP-OHCAs among ROC sites. We observed that survival and functionally favorable outcomes were significantly higher when a bystander rather than EMS provided the initial shock. Finally, the relative and absolute survival benefit related to bystander AED shock increased as the EMS response interval became longer. These findings confirm the important role of bystander-provided defibrillation among observed public OHCAs.

In a prior investigation using the ROC Epistry spanning the years 2005 to 2007, Weisfeldt and colleagues[25] observed a lower rate of bystander AED shock for all public OHCAs in comparison with the current, more contemporary experience in public OHCA (7.8% versus 14.2%; see Table 2, all public arrests). In this previous publication, it was estimated that nearly 500 additional lives were saved each year in the United States and Canada by bystander AED use. Given the increased use of bystander AEDs reported here, we can raise this estimate to ≈1700 additional lives saved each year. Furthermore, extrapolation of our data suggests that among the 350 000 OHCAs treated in the United States each year, ≈18 200 are shockable, are observed by a bystander, and occur in public locations. According to our results, if 100% of these individuals were shocked by a bystander, ≈3459 additional lives would be saved with good neurological outcome. This is in comparison with the 2456 additional lives that the National Highway Traffic Safety Administration estimates would be saved with universal seat belt usage.[26] It is clear that continued emphasis on increasing the number of individuals shocked by a bystander is a public health imperative. The temporal increase in the rate of bystander AED use across the ROC sites raises the question of which policy and programmatic interventions may be most effective to increase

Table 2. Outcomes in the Overall and Study Population

	All Public Arrests		Public, Bystander-Observed Arrests		Public, Bystander-Observed, Shockable Arrests	
	No AED Applied n=6104	AED Applied n=869	No AED Applied n=3460	AED Applied n=655	EMS Shock n=2031	Bystander AED Shock n=469
Duration of resuscitation, min, median (Q1, Q3)	26.1 (16.7, 34.9)	24.0 (10.1, 35.0)	25.2 (14.5, 34.0)	22.2 (7.3, 34.9)	23.1 (11.4, 33.0)	15.4 (4.9, 31.2)
Prehospital ROSC, n (%)	2940 (48.2)	562 (64.7)	1929 (55.8)	480 (73.3)	1357 (66.8)	382 (81.4)
Pulses at ED arrival, n (%)	2187 (35.9)	464 (53.4)	1505 (43.5)	408 (62.3)	1117 (55.0)	338 (72.1)
Admitted to hospital, n (%)	2508 (41.4)	439 (53.7)	1707 (49.9)	381 (62.8)	1233 (61.7)	309 (73.4)
Survived to discharge, n (%)	1295 (21.2)	365 (42.0)	1004 (29.0)	343 (52.4)	874 (43.0)	312 (66.5)
mRS, n (%)						
0	435 (7.1)	172 (19.8)	339 (9.8)	167 (25.5)	293 (14.4)	153 (32.6)
1	318 (5.2)	89 (10.2)	253 (7.3)	85 (13.0)	229 (11.3)	80 (17.1)
2	210 (3.4)	42 (4.8)	160 (4.6)	39 (6.0)	142 (7.0)	35 (7.5)
3	173 (2.8)	26 (3.0)	127 (3.7)	25 (3.8)	112 (5.5)	23 (4.9)
4	99 (1.6)	26 (3.0)	80 (2.3)	18 (2.7)	66 (3.2)	14 (3.0)
5	60 (1.0)	8 (0.9)	45 (1.3)	7 (1.1)	32 (1.6)	5 (1.1)
6 (dead)	4809 (78.8)	506 (58.2)	2456 (71.0)	314 (47.9)	1157 (57.0)	159 (33.9)
mRS≤2 at discharge, n (%)	963 (15.8)	303 (34.9)	752 (21.7)	291 (44.4)	664 (32.7)	268 (57.1)
Transported to the ED, n	4958	711	3010	572	1873	431
Induced hypothermia,* n (%)	1434 (34.6)	211 (39.9)	1019 (38.3)	174 (42.0)	805 (47.2)	139 (47.0)
Diagnostic catheterization,* n (%)	442 (10.6)	91 (17.2)	336 (12.6)	82 (19.8)	301 (17.6)	71 (24.0)
PTCA,* n (%)	597 (14.4)	90 (17.0)	444 (16.7)	79 (19.1)	419 (24.6)	67 (22.6)
Admitted to hospital, n	2508	439	1707	381	1233	309
CCU/ICU, days,† median (Q1, Q3)	5.0 (3.0, 10.0)	6.0 (3.0, 10.0)	5.0 (3.0, 10.0)	6.0 (3.0, 10.0)	6.0 (3.0, 11.0)	6.0 (3.0, 9.5)
Hospitalization, days†						
Survived, median (Q1, Q3)	11.0 (7.0, 20.0)	10.0 (5.0, 19.0)	11.0 (7.0, 21.0)	10.0 (5.0, 18.0)	12.0 (7.0, 21.0)	9.5 (5.0, 17.5)
Did not survive, median (Q1, Q3)	3.0 (1.0, 6.0)	3.0 (1.0, 6.0)	3.0 (1.0, 7.0)	3.0 (1.0, 6.0)	3.0 (1.0, 7.0)	3.5 (1.0, 7.5)

AED indicates automatic external defibrillator; CCU, cardiac care unit; ED, emergency department; EMS, emergency medical services; ICU, intensive care unit; mRS, modified Rankin score; PTCA, percutaneous transluminal coronary angioplasty; ROSC, return of spontaneous circulation; and Q1, Q3, the boundaries of the interquartile range.

*Of those transported to the ED.

†Initial continuous, of those admitted to the hospital.

bystander AED use in public OHCA. There are very likely more AEDs available for public use. Analysis of Food and Drug Administration reports indicated that the number of AEDs sold in the United States increased 10-fold from 1996 to 2006, from 18 645 in 1996 to 192 400 in 2006,[27] and this trend may have continued since. In a study from the Netherlands, the increase in early AED shock was attributed to police-dispatched AEDs.[28] In North America, the role of police AED has been variable, with some but not all communities achieving earlier defibrillation and better outcomes with such a program.[29–31] Only 8.5% of the SOP-OHCAs in the current study received a bystander AED shock as a consequence of police response. A limitation to this result, however, is the fact that we are unable to determine whether the police who applied the AED were dispatched by the 911 call center versus those officers who happened to be on scene at the time of cardiac arrest. Regardless, police officers made up a limited proportion of AED applications. Furthermore, in sensitivity analysis, when police AED use was excluded, the adjusted odds ratio of favorable outcome was not reduced, indicating that nonpolice bystanders may be as effective in AED use as police. A better understanding of the temporal increase has implications for communities striving to improve their public access AED programs.

The outcome relationships in the current study are consistent with prior investigations, including those involving functional outcomes reported from Japan and North Carolina.[17,18,32,33] Median EMS response in the current study is ≈6 minutes, considerably shorter than in prior publications and similar to many US and Canadian metropolitan communities.

We did, however, observe an interaction such that the benefit of bystander shock depended on the EMS response interval. Survival with favorable functional outcome in the bystander AED shock group declined

Table 3. Association Between Bystander AED Use and Outcome in Several Populations

	Unadjusted		Adjusted	
	OR* (95% CI)	*P* Value	OR* (95% CI)	*P* Value
Public, bystander-observed, shockable arrests				
Association between mRS≤2 and bystander AED shock	2.74 (2.24–3.37)	<0.001	2.73 (2.17–3.44)	<0.001
Association between mRS≤3 and bystander AED shock	2.64 (2.15–3.25)	<0.001	2.59 (2.05–3.28)	<0.001
Association between survival and bystander AED shock for selected populations				
Public, bystander-observed, shockable arrest	2.63 (2.13–3.25)	<0.001	2.62 (2.07–3.31)	<0.001
Public unobserved shockable arrests	1.32 (0.79–2.22)	0.28	1.30 (0.74–2.32)	0.36
Private, bystander-observed, shockable arrests	2.42 (1.70–3.45)	<0.001	2.07 (1.38–3.09)	<0.001
Private unobserved shockable arrests	1.33 (0.71–2.46)	0.37	1.25 (0.66–2.38)	0.49
Public observed shockable arrests, police AED use excluded				
Association between mRS≤2 and bystander AED shock	3.05 (2.47–3.78)	<0.001	3.02 (2.37–3.78)	<0.001
Association between survival and bystander AED shock	2.89 (2.32–3.61)	<0.001	2.93 (2.29–3.78)	<0.001

Adjusted for age, sex, race, bystander CPR, EMS response time, and study site.

AED indicates automatic external defibrillator; CI, confidence interval; CPR, cardiopulmonary resuscitation; EMS, emergency medical services; mRS, modified Rankin score; and OR, odds ratio.

*Versus EMS shock without bystander AED shock.

more slowly across EMS response intervals in comparison with the group initially shocked by EMS. As a consequence, the greatest relative and absolute survival benefits of bystander AED shock occurred among cases with a longer EMS response interval. Such information may be useful as systems try to allocate placement of relatively scarce AED resources.[34] The odds of favorable neurological outcome did decrease as EMS response was delayed for those patients shocked by a bystander,

Table 4. Association Between Adjusted OR for Survival and Location of Shock Among Shockable Observed OHCAs

Association Between Survival and Bystander AED Shock	Number of Arrests	Adjusted	
		OR* (95% CI)	*P* Value
Street/highway	673	1.30 (0.56–3.03)	0.54
Public building	194	1.76 (0.85–3.65)	0.13
Place of recreation	472	2.79 (1.79–4.35)	<0.001
Industrial place	177	5.57 (2.30–13.44)	<0.001
Other public	1127	2.26 (1.56–3.28)	<0.001
Home/residence	4043	1.75 (1.10–2.79)	0.02
Residential institution	192	2.26 (0.80–6.41)	0.12
Other private	60	5.46 (1.07– 27.96)	0.04

Adjusted for age, sex, race, bystander CPR, EMS response time, and study site. Test for interaction of bystander AED application and location type has a *P* value of 0.14 after adjustment for public versus private location. AED indicates automatic external defibrillator; CI, confidence interval; CPR, cardiopulmonary resuscitation; EMS, emergency medical services; OHCA, out-of-hospital cardiac arrest; and OR, odds ratio.

*Versus EMS resuscitation without bystander AED shock.

possibly indicating that rapid transfer to definitive care does improve outcome even with early defibrillation.

It is interesting to note that when the study population was expanded to include shockable observed public arrests, there was a significant survival benefit to bystander AED shock. Although a prior study showed no significant benefit to placing AEDs in the homes of

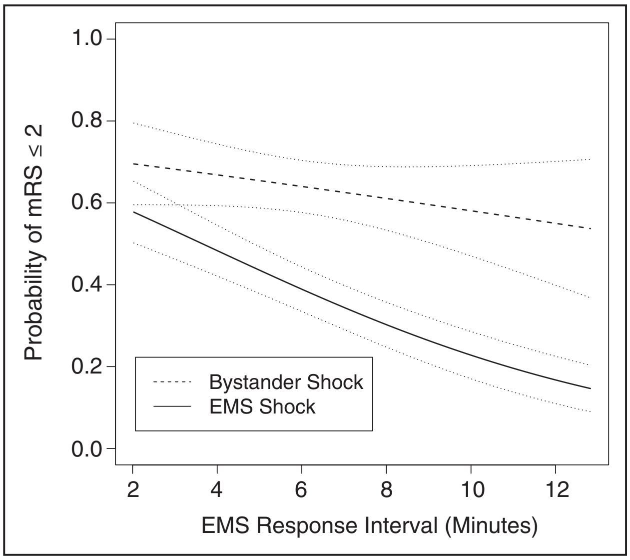

Figure 2. Logistic regression of EMS response interval and survival.

Logistic regression model of interaction between initial bystander or EMS shock and EMS response interval on functionally favorable survival. Small dotted line indicates 95% confidence interval of the probability of functionally favorable survival at any given time. Larger dashed line is bystander shock. Solid line is EMS shock. EMS indicates emergency medical services; and mRS, modified Rankin Score.

individuals at increased risk for cardiac arrest, many of these arrests were unobserved.[35] According to our results, the benefit of bystander shock was not apparent when the arrests, either private or public, were unobserved by the bystander. We propose that the benefit of bystander interventions decreases rapidly following cardiac arrest; therefore, in cases with unobserved arrest, the overall time from onset of arrest to defibrillation is longer, potentially reducing the relative time benefit of bystander shock. We chose to analyze only public arrests in the primary analysis, because this population is unique in that a substantial proportion of these arrests is shockable and observed in comparison with private arrest, in which only ≈10% of arrests are shockable and observed. It may be of interest to attempt to identify factors in private arrest that increase the likelihood of an arrest being observed, such as wearable monitoring devices, because this would be a subgroup of private arrests in which bystander AED use may be of greatest benefit.

There are several limitations to this study. First, the current study is unable to capture functional changes that emerge following hospital discharge. A prior study has demonstrated that better functional status at discharge is associated with better long-term prognosis.[36] Thus, the current findings suggest that bystander AED shock with its excess of mRS 0 and 1 (none and minimal disability) in comparison with EMS shock should correspond to favorable long-term prognosis. Furthermore, a recent publication reports that among 30-day survivors of OHCA, bystander interventions were associated with lower 1-year rates of nursing home admission and brain injury, indicating that, even after discharge, bystander inventions only further improve long-term outcomes.[19]

The study was observational. Although efforts were made in design and analysis to account for potential confounding, we cannot be certain that the survival advantage of bystander AED shock is solely attributable to this action versus other factors. For example, bystander AED shock was more likely to receive bystander CPR, so we adjusted for this covariate in the analysis. There may be unmeasured characteristics or care that could not be incorporated into the evaluation.

A strength of this study is its inclusion of multiple EMS systems from across North America. Nonetheless, the systems are involved in clinical trials, so they may be higher performing, a circumstance that could limit the generalizability. Moreover, we are not able to determine if the quality of EMS care influenced the potential survival effects of bystander AED use. The current study demonstrates that the majority of patients who receive a bystander AED shock still require EMS resuscitation and that a proportion of these patients ultimately achieves spontaneous circulation and survives intact,[37] suggesting that EMS care in these cases is likely important for prognosis. Moreover, we observed that the relative benefit of bystander AED depends on the EMS response interval, suggesting that bystander AED use may have even greater benefit in communities with slower EMS response. A recently reported meta-analysis of public access defibrillation in OHCA concluded that, for 21 accepted studies, AED application by a lay bystander resulted in 32.0% (range, 14%–78%) survival, and AED shock resulted in 53.0% (14%–78%) survival.[38] These findings are comparable to this report with 66.5% survival with bystander shock. ROC results are high but not out of range of other reports. We contend that the results presented here, therefore, are readily generalizable and serve as an example of the benefit provided by rigorously optimizing the pre- and posthospital systems as many ROC sites have done.

CONCLUSIONS

In this multisystem cohort study of SOP-OHCA, nearly 20% received a shock by bystander AED. An initial shock by bystander AED in comparison with an initial EMS shock was associated with a >2-fold increase in the odds of favorable functional survival after adjustment for potential confounders. Furthermore, the relative functional outcome advantage of bystander AED use increased as the EMS response interval become longer. Collectively, these findings provide support for ongoing emphasis on strategies to increase public access defibrillation.

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Impact of Bystander Automated External Defibrillator Use on Survival and Functional Outcomes in Shockable Observed Public Cardiac Arrests

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Supplemental Material

Supplemental Methods Part 1: Code for Data Processing and Tables
Supplemental Methods Part 2: Code for Plots
Supplemental Table 1: Characteristics of Arrests for Selected Additional Populations
Supplmental Table 2: Outcomes among Selected Additional Populations

Supplemental Methods Part 1: Code for Data Processing and Tables

```
**********************************;
* Data ;
**********************************;
libname E3 'data file path';
data e3;
merge E3.cases E3.newmrs;
by caseid;
if catx^=1 or epdt>'28May2015'd then delete;
*Episode year;
epyr=year(episodedt);
epmo=month(episodedt);
*Defining treating agency;
if rigag1>0 then rocag=rigag1; else if rigag2>0 then rocag=rigag2;
else if rigag3>0 then rocag=rigag3; else if rigag4>0 then rocag=rigag4;
if rocag=. then delete;
if rigid1>0 then rocrig=rigid1; else if rigid2>0 then rocrig=rigid2;
else if rigid3>0 then rocrig=rigid3; else if rigid4>0 then rocrig=rigid4;
*Outcomes;
if pdisp=0 or edispx=0 or fvshsp=1 then alive=0; else if edispx=3 or
fvshsp=0 then alive=1;
if alive=0 then mrs=6; else mrs=hdcmrs; if mrs=. then mrs=updatemrs;
if mrs in (0,1,2,3,4,5) then alive=1;
if mrs in (0,1,2,3) then mrsge3=1; else if mrs in (4,5,6) then mrsge3=0;
if mrs in (0,1,2) then mrsg3=1; else if mrs in (3,4,5,6) then mrsg3=0;
if mrs=0 then mrse0=1; else if mrs in (1,2,3,4,5,6) then mrse0=0;
/* Pulses at ED arrival */
*Calculate ROSC from CPR process;
if ynomes1=1 or ynomes2=1 or ynomes3=1 or ynomes4=1 or ynomes5=1 or
ynomes6=1 or ynomes7=1 or
ynomes8=1 or ynomes9=1 or ynomes10=1 then rosc2=1; else rosc2=0;
if prosc=1 or roscStat=1 or rosc2=1 or phrosc=1 then anyrosc=1; else
anyrosc=roscstat;
if prosc=1 then edpulse=1; else if pdisp=0 or prosc=0 then edpulse=0;
/* Admitted to hospital */
if edispx=1 then admith=1; else if pdisp=0 or edispx=0 then admith=0; else
if hosp_required=1 then admith=1;
* Age from birthyear;
age=epyr-brthye;
if age=. then age=agep;
if .<18 then delete;
*Sex;
if sexe in (0,1) then sex=sexe; else sex=sexp;
*Race and ethnicity categories;
if ethnce in (0,1) then hispeth=ethnce; else hispeth=hispp;
```

```
numrace=sum(natame,asiane,blacke,pacise,whitee);
if numrace<1 then numrace=sum(asianp,whitep,pacisp,blackp,othrcp,natamp);
if whitee=1 then newrace="Wht";
else if asiane=1 then newrace="Asn";
else if blacke=1 then newrace="Blk";
else if natame=1 then newrace="NAm";
else if pacise=1 then newrace="PI";
else if whitep=1 then newrace="Wht";
else if asianp=1 then newrace="Asn";
else if blackp=1 then newrace="Blk";
else if natamp=1 then newrace="NAm";
else if pacisp=1 then newrace="PI";
else if othrcp=1 then newrace="Oth";
if numrace>1 then newrace="Mult";
if newrace="" then newrace="Miss";
if newrace="Wht" then racecat=1;
else if newrace="Blk" then racecat=2;
else racecat=3;
*Bystander CPR;
if cpratt=1 then byscpr=1; else if cpratt=0 or resbys=0 or witems=1 then
byscpr=0; else byscpr=2;
*Duration of resuscitation;
ttfutile=(resusStopDtm-firstValidArrDtm)/60;
tttrans=(xportDtm-firstValidArrDtm)/60;
ttrosc=(roscDtm-firstValidArrDtm)/60;
tted=(edardtm-firstValidArrDtm)/60;
if pdisp=0 then do; lor=ttfutile; lortype="Futi"; end;
else if pdisp=1 and prosc=0 then do; lor=tted; lortype="ED"; end;
else if pdisp=1 and prosc=1 and plslst=0 then do; lor=ttrosc;
lortype="ROSC"; end;
else do; lor=tttrans; lortype="Tran";end;
*LOR category;
if lortype="ROSC" and (.<0 or emsCprOrder<0 or 0<10 then lorcat=1; else if
lor>=10 and lor<20 then lorcat=2;
else if lor>=20 and lor<30 then lorcat=3; else if lor>=30 then lorcat=4;
*Different time to arrival variables: emsRig1ArrMin arrivalTime
tmCallDspV1ArrMin emsFirstRigWithDtmMin;
/* Any hypothermia */
if phypt2=1 or ehthat=1 or hhthat=2 then anyhypo=1; else anyhypo=0;
/* Length of hospitalization */
if admith=1 then lhosp=hdspdt-episodedt; else if pdisp=1 then
lhosp=edspdt-episodedt; else if pdisp=0 then lhosp=0;
/* Length of ICU stay */
if icudt>. then idyccu=(icudt-hadmdt)+1;
/* Cases for E3 PAD study */
if locpub=1 and witbys=1 and ((frhyem=1 and emsshk=1) or aedshk=1) and
/*emsFirstRigWithDtmMin>. and*/ age>=18 and sex in (0,1) then paduse=1;
```

```
else paduse=0;
if paduse=1 and aedshk=1 then padaed=1; else if paduse=1 then padaed=0;
if (epyr in (2010,2011) or scrnccc=1) and mrsg3>. then pads2=paduse; else
pads2=0;
if (epyr in (2010,2011) or scrnccc=1) and /*emsFirstRigWithDtmMin>. and*/
age>=18 and sex in (0,1) and alive>. then pt1=1; else pt1=0;
if ccclegalcnsn = 1 and cccntraumca = 1 and initcompCCC = 1 then
inclCrit=1;
else if ccclegalcnsn = 0 or cccntraumca = 0 or initcompCCC = 0 then
inclCrit=0;
if cccdnr = 0 and ccctrauminj = 0 and cccresp = 0 and cccexsang = 0 and
cccprisoner = 0 and cccpregnant = 0 and cccemswitarr = 0 and
cccfstagynrc = 0 and cccadvair = 0 and cccpreextrac = 0 then exclCrit=0;
else if cccdnr = 1 or ccctrauminj = 1 or cccresp = 1 or cccexsang = 1 or
cccprisoner = 1 or cccpregnant = 1 or cccemswitarr = 1 or cccfstagynrc =
1 or cccadvair = 1 or cccpreextrac = 1 then exclCrit=1;
if inclCrit=1 and ExclCrit=0 and scrnccc=1 then in_ccc=1; else in_ccc=0;
Aopen = max(alpskitopen1,alpskitopen2,alpskitopen3,alpskitopen4);
Agive = max(alpskitgiven1,alpskitgiven2,alpskitgiven3,alpskitgiven4);
*Hospital hypothermia;
if ehthat=1 or hhthat=2 then hosphypo=1; else if (ehthat=0 and hhthat=0)
or ehnopr=1 then hosphypo=0;
*Cardiac catheterization;
if ehnopr=1 then anycath=0; else if cath24=0 then anycath=0; else if
cath24=2 then anycath=1;
if anycath=0 then do; diagcath=0; pci=0; end;
else if anycath=1 and (cathint24=0 or pci24 in (0,2)) then do;
diagcath=1; pci=0; end;
diagcath=1; pci=0; end;
else if anycath=1 and (cathint24=1 or pci24=1) then do; diagcath=0;
pci=1; end;
*Bystander shock;
if aedshk=1 then byshk=1; else byshk=0;
if aedapp=1 then byaed=1; else byaed=0;
*Shockable initial rhythm;
if frhyae=1 then vtvf=1; else if frhyem=1 then vtvf=1; else if frhyae>. or
frhyem>. then vtvf=0;
if sitecode in ("SDG") then delete;
if /*emsFirstRigWithDtmMin>. and*/ age>=18 and sex in (0,1) and alive>.
and mrs>. then useall=1; else useall=0;
*Comparison groups;
if /*emsFirstRigWithDtmMin>. and*/ age>=18 and sex in (0,1) and alive>.
/*and mrs>.*/ then usecomp=1; else usecomp=0;
*Age categories;
if 18<=age<40 then agecat=4; else if 40<=age<60 then agecat=5; else if
60<=age<75 then agecat=6;
else if 75<=age then agecat=7;
```

```
if 18<=age<40 then agecat2=1; else if 40<=age<50 then agecat2=2; else if
50<=age<60 then agecat2=3;
else if 60<=age<70 then agecat2=4; else if 70<=age<80 then agecat2=5;
else if 80<=age<90 then agecat2=6; else if age>=90 then agecat2=7;
*Time to EMS;
if emsFirstRigWithDtmMin< -15 then ttemscat="miss ";
if emsFirstRigWithDtmMin<5 then ttemscat="ref0-5";
else if 5<=emsFirstRigWithDtmMin<10 then ttemscat="5-10";
else if 10<=emsFirstRigWithDtmMin<15 then ttemscat="10-15";
else if 15<=emsFirstRigWithDtmMin<20 then ttemscat="15-20";
else if 20<=emsFirstRigWithDtmMin then ttemscat=">=20";
*Getting rid of cases with a written DNR at the start of resuscitation;
if pyhlt2=2 or cccdnr=1 then do; useall=0; pt1=0; usecomp=0; end;
format epdt date9.;
if aedshk=1 then bshock=1; else bshock=0;
*Primary subgroup;
if useall=1 and locpub=1 and witbys=1 and vtvf=1 and (byshk=1 |emsshk=1)
then mainuse=1; else mainuse=0;
if aedwho=2 then iscop=1; else iscop=0;
run;
data E3plots;
set E3;
where mainuse=1;
keep sitecode caseid alive emsFirstRigWithDtmMin ttrosc phdepin mrsg3
byshk agecat2 sex racecat byscpr ttemscat lor;
run;
proc export data=e3plots OUTFILE= "data for plots"
DBMS=csv REPLACE;
RUN;
proc contents data=e3; run;
*Table 1;
%macro t1(outt,subg);
proc means data=e3 noprint;
var age;
where &subg;
output out=t1age n=nage median=medianage q1=q1age q3=q3age;
run;
proc sql;
create table t1sql as select
/* Male */
sum(sex in (0,1)) as Nsex,
sum(sex=1) as Nmale,
(calculated Nmale)/(calculated Nsex) as perMale,
/* Race */
count(newrace) as Nrace,
sum(newrace="Wht") as Nwht,
(calculated Nwht)/(calculated Nrace) as perWht,
```

```
sum(newrace="Blk") as Nblk,
(calculated Nblk)/(calculated Nrace) as perblk,
sum(newrace in ("Asn","PI","Oth","Mul","NAm")) as Noth,
(calculated Noth)/(calculated Nrace) as peroth,
sum(newrace in ("Mis")) as Nunk,
(calculated Nunk)/(calculated Nrace) as perunk,
/* Bystander CPR */
count(byscpr) as Nkbcpr,
sum(byscpr=1) as Nbcpr,
(calculated Nbcpr)/(calculated Nkbcpr) as perbcpr,
sum(byscpr=0) as Nbcprno,
(calculated Nbcprno)/(calculated Nkbcpr) as perbcprno,
sum(byscpr=2) as Nbcprmi,
(calculated Nbcprmi)/(calculated Nkbcpr) as perbcprmi,
/* Epi */
count(phdepin) as Nkepi,
sum(phdepin=1) as Nepi,
(calculated Nepi)/(calculated Nkepi) as perepi
from e3
where &subg;
quit;
proc means data=e3 noprint;
var emsFirstRigWithDtmMin;
where &subg;
output out=t1tte n=ntte median=mediantte q1=q1tte q3=q3tte;
run;
proc means data=e3 noprint;
var phdepinds;
where &subg;
output out=t1epi n=nepi median=medianepi q1=q1epi q3=q3epi mean=meanepi
std=stdepi;
run;
proc sql;
create table t1site as select
count(*) as N,
/* Site */
sum(sitecode="ARC") as Narc,
(calculated Narc)/(calculated N) as Parc,
sum(sitecode="VAN") as Nbc,
sum(sitecode="VAN") as Nbc,
(calculated Nbc)/(calculated N) as Pbc,
sum(sitecode="DAL") as Ndal,
(calculated Ndal)/(calculated N) as Pdal,
sum(sitecode="MLW") as Nmlw,
(calculated Nmlw)/(calculated N) as Pmlw,
sum(sitecode="OTT") as Nott,
(calculated Nott)/(calculated N) as Pott,
```

```
sum(sitecode="PGH") as Npgh,
(calculated Npgh)/(calculated N) as Ppgh,
sum(sitecode="PTL") as Nptl,
(calculated Nptl)/(calculated N) as Pptl,
sum(sitecode="SDG") as Nsdg,
(calculated Nsdg)/(calculated N) as Psdg,
sum(sitecode="SKC") as Nskc,
(calculated Nskc)/(calculated N) as Pskc,
sum(sitecode="TOR") as Ntor,
(calculated Ntor)/(calculated N) as Ptor,
sum(locpub=1) as Npub,
sum(locpub=0) as Npri,
sum(loctyp=1) as Nst,
(calculated Nst) / (calculated N) as Pst,
sum(loctyp=2) as Npubld,
(calculated Npubld) / (calculated N) as Ppubld,
sum(loctyp=3) as Nrec,
(calculated Nrec) / (calculated N) as Prec,
sum(loctyp=4) as Nind,
(calculated Nind) / (calculated N) as Pind,
sum(loctyp=5) as Nres,
(calculated Nres) / (calculated N) as Pres,
sum(loctyp=6) as Nfarm,
(calculated Nfarm) / (calculated N) as Pfarm,
sum(loctyp=7) as Nhealth,
(calculated Nhealth) / (calculated N) as Phealth,
sum(loctyp=8) as Nresinst,
(calculated Nresinst) / (calculated N) as Presinst,
sum(loctyp=9) as Nothpub,
(calculated Nothpub) / (calculated N) as Pothpub,
sum(loctyp=10) as Nprioth,
(calculated Nprioth) / (calculated N) as Pprioth
from e3
where &subg;
quit;
data &outt;
merge t1age t1sql t1tte t1epi t1site;
run;
proc datasets;
delete t1age t1sql t1tte t1epi t1site;
run;
%mend;
%t1(outt=t1all,subg=(useall=1))
%t1(outt=t1pri,subg=(useall=1 and locpub=0))
%t1(outt=t1pub,subg=(useall=1 and locpub=1))
%t1(outt=t1pubbys,subg=(useall=1 and locpub=1 and witbys=1))
%t1(outt=t1pubbysshk,subg=(mainuse=1))
```

```
%t1(outt=t1mall,subg=(pt1=1))
%t1(outt=t1mpri,subg=(pt1=1 and locpub=0))
%t1(outt=t1mpub,subg=(pt1=1 and locpub=1))
%t1(outt=t1mpubbys,subg=(pt1=1 and locpub=1 and witbys=1))
%t1(outt=t1mpubbysshk,subg=(pt1=1 and locpub=1 and witbys=1 and vtvf=1))
%t1(outt=t1pubnaed,subg=(useall=1 and locpub=1 and aedapp^=1))
%t1(outt=t1pubaed,subg=(useall=1 and locpub=1 and aedapp=1))
%t1(outt=t1pubbysnaed,subg=(useall=1 and locpub=1 and witbys=1 and
aedapp^=1))
%t1(outt=t1pubbysaed,subg=(useall=1 and locpub=1 and witbys=1 and
aedapp=1))
%t1(outt=t1pubbysshknaed,subg=(mainuse=1 and aedshk^=1))
%t1(outt=t1pubbysshkaed,subg=(mainuse=1 and aedshk=1))
%t1(outt=t1mpubnaed,subg=(pt1=1 and locpub=1 and aedapp^=1))
%t1(outt=t1mpubaed,subg=(pt1=1 and locpub=1 and aedapp=1))
%t1(outt=t1mpubbysnaed,subg=(pt1=1 and locpub=1 and witbys=1 and
aedapp^=1))
%t1(outt=t1mpubbysaed,subg=(pt1=1 and locpub=1 and witbys=1 and aedapp=1))
%t1(outt=t1mpubbysshknaed,subg=(pt1=1 and locpub=1 and witbys=1 and vtvf=1
and aedshk^=1))
%t1(outt=t1mpubbysshkaed,subg=(pt1=1 and locpub=1 and witbys=1 and vtvf=1
and aedshk=1))
*Adding non-shockable cases;
%t1(outt=t1_ns_all,subg=(useall=1 and locpub=1 and witbys=1 and vtvf^=1))
%t1(outt=t1_ns_aed,subg=(useall=1 and locpub=1 and witbys=1 and vtvf^=1
and byaed=1))
%t1(outt=t1_ns_naed,subg=(useall=1 and locpub=1 and witbys=1 and vtvf^=1
and byaed=0))
*Other Populations of Interest;
*Private unwitnessed;
%t1(outt=t1_priunwit_all,subg=(usecomp=1 and locpub=0 and witbys=0 and
witems=0 and vtvf=1 and loctyp^=7))
%t1(outt=t1_priunwit_aed,subg=(usecomp=1 and locpub=0 and witbys=0 and
witems=0 and byshk=1 and vtvf=1 and loctyp^=7))
%t1(outt=t1_priunwit_naed,subg=(usecomp=1 and locpub=0 and witbys=0 and
witems=0 and byshk=0 and vtvf=1 and loctyp^=7))
*Private witnessed;
%t1(outt=t1_priwit_all,subg=(usecomp=1 and locpub=0 and witbys=1 and vtvf=1
and loctyp^=7))
%t1(outt=t1_priwit_aed,subg=(usecomp=1 and locpub=0 and witbys=1 and
byshk=1 and vtvf=1 and loctyp^=7))
%t1(outt=t1_priwit_naed,subg=(usecomp=1 and locpub=0 and witbys=1 and
byshk=0 and vtvf=1 and loctyp^=7))
*Pblic unwitnessed;
%t1(outt=t1_pubun_all,subg=(usecomp=1 and locpub=1 and witbys=0 and
witems=0 and vtvf=1 and loctyp^=7))
%t1(outt=t1_pubun_aed,subg=(usecomp=1 and locpub=1 and witbys=0 and
```

```
witems=0 and byshk=1 and vtvf=1 and loctyp^=7))
%t1(outt=t1_pubun_naed,subg=(usecomp=1 and locpub=1 and witbys=0 and
witems=0 and byshk=0 and vtvf=1 and loctyp^=7))
data t1;
set t1all t1pri t1pub t1pubbys t1pubbysshk t1mall t1mpri t1mpub t1mpubbys
t1mpubbysshk t1pubnaed t1pubaed
t1pubbysnaed t1pubbysaed t1pubbysshknaed t1pubbysshkaed t1mpubnaed
t1pubbysnaed t1pubbysaed t1pubbysshknaed t1pubbysshkaed t1mpubnaed
t1mpubaed
t1mpubbysnaed t1mpubbysaed t1mpubbysshknaed t1mpubbysshkaed t1_ns_all
t1_ns_aed t1_ns_naed;
run;
PROC EXPORT DATA= WORK.t1
OUTFILE= "output table 1 location"
DBMS=csv REPLACE;
RUN;
data t1oth;
set t1_priunwit_all t1_priunwit_aed t1_priunwit_naed t1_priwit_all
t1_priwit_aed t1_priwit_naed t1_pubun_all t1_pubun_aed t1_pubun_naed;
run;
PROC EXPORT DATA= WORK.t1oth
OUTFILE= "output table 1 other groups"
DBMS=csv REPLACE;
RUN;
%macro t2(outt,subg);
proc sql;
create table t2sql as select
/* ROSC */
sum(anyrosc in (0,1)) as Nkrosc,
sum(anyrosc=1) as Nrosc,
(calculated Nrosc)/(calculated Nkrosc) as perROSC,
/* Pulse at ED arrival */
sum(edpulse in (0,1)) as Nkedp,
sum(edpulse=1) as Nedp,
(calculated Nedp)/(calculated Nkedp) as perEDp,
/* Admitted to hospital */
sum(admith in (0,1)) as Nkadh,
sum(admith=1) as Nadh,
(calculated Nadh)/(calculated Nkadh) as peradh,
/* Survival to discharge */
count(alive) as Nksurv,
sum(alive=1) as Nsurv,
(calculated Nsurv)/(calculated Nksurv) as persurv,
/* MRS */
count(mrs) as Nkmrs,
sum(mrsg3=1) as Ngmrs,
(calculated Ngmrs)/(calculated Nkmrs) as pergmrs
```

```
from e3
where &subg;
quit;
proc sql;
create table t2trans as select
count(*) as Ntrans,
/* hospital hypothermia */
sum(hosphypo in (0,1)) as Nkhhypo,
sum(hosphypo=1) as Nhhypo,
(calculated Nhhypo)/(calculated Nkhhypo) as phhypo,
/* Diagnostic Cath */
sum(diagcath in (0,1)) as Nkcath,
sum(diagcath=1) as Ncath,
(calculated Ncath)/(calculated Nkcath) as pcath,
/* PCI */
sum(pci in (0,1)) as Nkpci,
sum(pci=1) as Npci,
(calculated Npci)/(calculated Nkpci) as ppci
from e3
where &subg and pdisp=1;
quit;
proc means data=e3 noprint;
var lor;
where &subg;
output out=t2lor median=LORmedian q1=LORq1 q3=LORq3;
run;
proc means data=e3 noprint;
var idyccu;
where &subg and admith=1;
output out=t2icud median=icudmedian q1=ICUdq1 q3=ICUdq3;
run;
proc means data=e3 noprint;
var lhosp;
where &subg and alive=1 and admith=1;
output out=t2halive median=halivemedian q1=haliveq1 q3=havlieq3;
run;
proc means data=e3 noprint;
var lhosp;
where &subg and alive=0 and admith=1;
output out=t2dead median=hdeadmedian q1=hdeadq1 q3=hdeadq3;
run;
proc sql;
create table t2mrsalive as select
/* MRS */
count(mrs) as Nkmrsalive,
sum(mrsg3=1) as Ngmrsalive,
(calculated Ngmrsalive)/(calculated Nkmrsalive) as pergmrsalive,
```

```
sum(mrs=0) as Nmrs0s,
(calculated Nmrs0s)/(calculated Nkmrsalive) as pmrs0s,
sum(mrs=1) as Nmrs1s,
(calculated Nmrs1s)/(calculated Nkmrsalive) as pmrs1s,
sum(mrs=2) as Nmrs2s,
(calculated Nmrs2s)/(calculated Nkmrsalive) as pmrs2s,
sum(mrs=3) as Nmrs3s,
(calculated Nmrs3s)/(calculated Nkmrsalive) as pmrs3s,
sum(mrs=4) as Nmrs4s,
(calculated Nmrs4s)/(calculated Nkmrsalive) as pmrs4s,
sum(mrs=5) as Nmrs5s,
sum(mrs=5) as Nmrs5s,
(calculated Nmrs5s)/(calculated Nkmrsalive) as pmrs5s,
sum(mrs=6) as Nmrs6s,
(calculated Nmrs6s)/(calculated Nkmrsalive) as pmrs6s
from e3
where &subg and alive=1;
quit;
proc sql;
create table t2mrs as select
/* MRS */
count(mrs) as Nkmrs2,
sum(mrs=0) as Nmrs0,
(calculated Nmrs0)/(calculated Nkmrs2) as pmrs0,
sum(mrs=1) as Nmrs1,
(calculated Nmrs1)/(calculated Nkmrs2) as pmrs1,
sum(mrs=2) as Nmrs2,
(calculated Nmrs2)/(calculated Nkmrs2) as pmrs2,
sum(mrs=3) as Nmrs3,
(calculated Nmrs3)/(calculated Nkmrs2) as pmrs3,
sum(mrs=4) as Nmrs4,
(calculated Nmrs4)/(calculated Nkmrs2) as pmrs4,
sum(mrs=5) as Nmrs5,
(calculated Nmrs5)/(calculated Nkmrs2) as pmrs5,
sum(mrs=6) as Nmrs6,
(calculated Nmrs6)/(calculated Nkmrs2) as pmrs6
from e3
where &subg;
quit;
data &outt;
merge t2lor t2sql t2trans t2icud t2halive t2dead t2mrsalive t2mrs;
drop _type_ _freq_;
run;
proc datasets;
delete t2lor t2sql t2trans t2icud t2halive t2dead t2mrsalive t2mrs;
run;
%mend;
```

```
%t2(outt=t2pubno,subg=(useall=1 and locpub=1 and aedapp^=1));
%t2(outt=t2puby,subg=(useall=1 and locpub=1 and aedapp=1));
%t2(outt=t2witn,subg=(useall=1 and locpub=1 and witbys=1 and aedapp^=1));
%t2(outt=t2wity,subg=(useall=1 and locpub=1 and witbys=1 and aedapp=1));
%t2(outt=t2ems,subg=(mainuse=1 and aedshk^=1));
%t2(outt=t2aed,subg=(mainuse=1 and aedshk=1));
%t2(outt=t2mpubn,subg=(pt1=1 and locpub=1 and aedapp^=1));
%t2(outt=t2mpuby,subg=(pt1=1 and locpub=1 and aedapp=1));
%t2(outt=t2mwitn,subg=(pt1=1 and locpub=1 and witbys=1 and aedapp^=1));
%t2(outt=t2mwity,subg=(pt1=1 and locpub=1 and witbys=1 and aedapp=1));
%t2(outt=t2mems,subg=(pt1=1 and locpub=1 and witbys=1 and vtvf=1 and
aedshk^=1));
%t2(outt=t2maed,subg=(pt1=1 and locpub=1 and witbys=1 and vtvf=1 and
aedshk=1));
*Non-shockable subjects;
%t2(outt=t2_ns_all,subg=(useall=1 and locpub=1 and witbys=1 and vtvf^=1))
%t2(outt=t2_ns_aed,subg=(useall=1 and locpub=1 and witbys=1 and vtvf^=1
and byaed=1))
%t2(outt=t2_ns_naed,subg=(useall=1 and locpub=1 and witbys=1 and vtvf^=1
and byaed=0))
*Other populations;
*Private unwitnessed;
%t2(outt=t2_priun_all,subg=(usecomp=1 and locpub=0 and witbys=0 and
witems=0 and vtvf=1 and loctyp^=7))
%t2(outt=t2_priun_aed,subg=(usecomp=1 and locpub=0 and witbys=0 and
witems=0 and byshk=1 and vtvf=1 and loctyp^=7))
%t2(outt=t2_prium_naed,subg=(usecomp=1 and locpub=0 and witbys=0 and
witems=0 and byshk=0 and vtvf=1 and loctyp^=7))
*Private witnessed;
%t2(outt=t2_priwit_all,subg=(usecomp=1 and locpub=0 and witbys=1 and
vtvf=1 and loctyp^=7))
%t2(outt=t2_priwit_aed,subg=(usecomp=1 and locpub=0 and witbys=1 and
byshk=1 and vtvf=1 and loctyp^=7))
%t2(outt=t2_priwit_naed,subg=(usecomp=1 and locpub=0 and witbys=1 and
byshk=0 and vtvf=1 and loctyp^=7))
*Public unwitnessed;
%t2(outt=t2_pubun_all,subg=(usecomp=1 and locpub=1 and witbys=0 and
witems=0 and vtvf=1 and loctyp^=7))
%t2(outt=t2_pubun_aed,subg=(usecomp=1 and locpub=1 and witbys=0 and
witems=0 and byshk=1 and vtvf=1 and loctyp^=7))
%t2(outt=t2_pubum_naed,subg=(usecomp=1 and locpub=1 and witbys=0 and
witems=0 and byshk=0 and vtvf=1 and loctyp^=7))
data t2;
set t2pubno t2puby t2witn t2wity t2ems t2aed t2mpubn t2mpuby t2mwitn
t2mwity t2mems t2maed t2_ns_all t2_ns_aed t2_ns_naed;
run;
data t2oth;
```

```
set t2_priun_all t2_priun_aed t2_prium_naed t2_priwit_all t2_priwit_aed
t2_priwit_naed t2_pubun_all t2_pubun_aed t2_pubum_naed;
run;
PROC EXPORT DATA= WORK.t2
OUTFILE= "output table 2 location"
DBMS=csv REPLACE;
RUN;
PROC EXPORT DATA= WORK.t2oth
OUTFILE= "table 2 in other subgroups"
DBMS=csv REPLACE;
RUN;
%macro getor(outcome,predvar,subg,outd,efname);
proc glimmix data=e3 maxopt=100 empirical;
class &outcome ;
model &outcome (event=last) = &predvar/ dist=binary s cl;
random _residual_ ;
where &subg;
ods output ParameterEstimates=t3unadj;
run;
proc glimmix data=e3 maxopt=100 empirical;
class &outcome racecat byscpr sitecode agecat2 ttemscat;
class &outcome racecat byscpr sitecode agecat2 ttemscat;
model &outcome (event=last) = &predvar agecat2 sex racecat byscpr ttemscat
sitecode / dist=binary s cl;
random _residual_ ;
where &subg;
ods output ParameterEstimates=t3adj;
run;
data &outd;
set t3unadj t3adj;
if effect=&efname;
drop ttemscat agecat2 racecat byscpr sitecode;
or=exp(estimate);
lci=exp(estimate-1.96*StdErr);
uci=exp(estimate+1.96*StdErr);
run;
proc datasets;
delete t3unadj t3adj;
run;
%mend;
%getor(outcome=mrsg3,predvar=byaed,subg=(useall=1),outd=alls,efname="byaed"
)
;
%getor(outcome=mrsg3,predvar=byaed,subg=(useall=1 and
locpub=1),outd=pubs,efname="byaed");
%getor(outcome=mrsg3,predvar=byaed,subg=(useall=1 and locpub=1 and
witbys=1),outd=wits,efname="byaed");
```

```
%getor(outcome=alive,predvar=byaed,subg=(mainuse=1),outd=shks,efname="byae
d")
;
%getor(outcome=alive,predvar=byshk,subg=(mainuse=1),outd=bshks,efname="bys
hk")
;
%getor(outcome=mrsg3,predvar=byshk,subg=(mainuse=1),outd=bshksmrs,efname
="byshk")
;
%getor(outcome=mrsg3,predvar=byshk,subg=(mainuse=1 and
aedwho^=2),outd=bshksmrsnopol,efname="byshk");
%getor(outcome=alive,predvar=byshk,subg=(mainuse=1 and
aedwho^=2),outd=bshkalivenopol,efname="byshk");
%getor(outcome=mrsge3,predvar=byshk,subg=(mainuse=1),outd=bskmrs3,efname
="byshk")
;
%getor(outcome=mrse0,predvar=byshk,subg=(mainuse=1),outd=mrse0,efname="b
yshk")
;
%getor(outcome=mrsg3,predvar=byaed,subg=(mainuse=1),outd=mrsAEDapp,efna
me="byaed")
;
%getor(outcome=alive,predvar=byaed,subg=(pt1=1),outd=pt1s,efname="byaed");
%getor(outcome=alive,predvar=byaed,subg=(pt1=1 and
locpub=1),outd=pt1pubs,efname="byaed");
%getor(outcome=alive,predvar=byaed,subg=(pt1=1 and locpub=1 and
witbys=1),outd=pt1wits,efname="byaed");
%getor(outcome=alive,predvar=byaed,subg=(pt1=1 and locpub=1 and witbys=1
and vtvf=1),outd=pt1shks,efname="byaed");
%getor(outcome=mrsg3,predvar=byaed,subg=(pt1=1),outd=pt1m,efname="byaed"
);
%getor(outcome=mrsg3,predvar=byaed,subg=(pt1=1 and
locpub=1),outd=pt1pubm,efname="byaed");
%getor(outcome=mrsg3,predvar=byaed,subg=(pt1=1 and locpub=1 and
witbys=1),outd=pt1witm,efname="byaed");
%getor(outcome=mrsg3,predvar=byaed,subg=(pt1=1 and locpub=1 and witbys=1
and vtvf=1),outd=pt1shkm,efname="byaed");
%getor(outcome=mrsg3,predvar=byshk,subg=(pt1=1 and locpub=1 and witbys=1
and vtvf=1),outd=pt1shkgm,efname="byshk");
%getor(outcome=alive,predvar=byshk,subg=(pt1=1 and locpub=1 and witbys=1
and vtvf=1),outd=pt1shkgs,efname="byshk");
*Non-shockable, aed applied;
%getor(outcome=alive,outd=t3_ns_surv,predvar=byaed,subg=(useall=1 and
locpub=1 and witbys=1 and vtvf^=1),efname="byaed"));
%getor(outcome=mrsg3,outd=t3_ns_mrs,predvar=byaed,subg=(useall=1 and
locpub=1 and witbys=1 and vtvf^=1),efname="byaed");
*Other subgroups, all survival as outcome and aed shock as variable of
```

```
interest;
%getor(outcome=alive,predvar=byshk,subg=(mainuse=1 and locpub=1 and
witbys=1 and vtvf=1 and loctyp^=7),outd=AApubwitshock,efname="byshk");
%getor(outcome=alive,predvar=byshk,subg=(usecomp=1 and locpub=1 and
witbys=1 and vtvf=1 and loctyp^=7),outd=AApubwit,efname="byshk");
%getor(outcome=alive,predvar=byshk,subg=(usecomp=1 and locpub=1 and
witbys=0 and witems=0 and vtvf=1 and
loctyp^=7),outd=AApubun,efname="byshk");
%getor(outcome=alive,predvar=byshk,subg=(usecomp=1 and locpub=0 and
witbys=1 and vtvf=1 and loctyp^=7),outd=AApriwit,efname="byshk");
%getor(outcome=alive,predvar=byshk,subg=(usecomp=1 and locpub=0 and
witbys=0 and witems=0 and vtvf=1 and
loctyp^=7),outd=AApriun,efname="byshk");
data t3or;
set alls pubs wits shks pt1s pt1pubs pt1wits pt1shks pt1m pt1pubm pt1witm
pt1shkm pt1shkgm pt1shkgs bshks bshksmrs
bshksmrsnopol bskmrs3 mrse0 t3_ns_surv t3_ns_mrs bshkalivenopol
mrsAEDapp;
run;
PROC EXPORT DATA= WORK.t3or
OUTFILE= "odds ratios location"
DBMS=csv REPLACE;
RUN;
data t3oth;
set AApubwitshock AApubwit AApubun AApriwit AApriun;
run;
PROC EXPORT DATA= WORK.t3oth
OUTFILE= "extra odds ratios"
DBMS=csv REPLACE;
RUN;
*Flow chart numbers;
%macro getflow(outd,subg);
proc sql;
create table &outd as select
count(*) as N,
/* Bystander AED use */
sum(aedapp=1) as Naedapp,
sum(aedshk=1) as Naedshk
from e3
where &subg;
quit;
quit;
%mend;
%getflow(outd=ntx,subg=(catx=1));
%getflow(outd=nndnr,subg=(pyhlt2^=2 and cccdnr^=1));
%getflow(outd=nmrs,subg=(pyhlt2^=2 and cccdnr^=1 and (epyr in (2010,2011)
or scrnccc=1)));
```

```
%getflow(outd=npub,subg=(pyhlt2^=2 and cccdnr^=1 and (epyr in (2010,2011)
or scrnccc=1) and locpub=1));
%getflow(outd=npubwit,subg=(pyhlt2^=2 and cccdnr^=1 and (epyr in
(2010,2011) or scrnccc=1) and locpub=1 and witbys=1));
%getflow(outd=nvtvf,subg=(pyhlt2^=2 and cccdnr^=1 and (epyr in (2010,2011)
or scrnccc=1) and locpub=1 and witbys=1 and vtvf=1));
%getflow(outd=npds2,subg=(pads2=1));
data flow;
set ntx nndnr nmrs npub npubwit nvtvf npds2;
run;
PROC EXPORT DATA= WORK.flow
OUTFILE= "flowchart.csv"
DBMS=csv REPLACE;
RUN;
proc freq data=e3;
table mrs*sitecode / missing;
where useall=1 and locpub=1 and witbys=1 and vtvf=1;
run;
data mismrs;
set e3;
where mrs=. and useall=1 and locpub=1 and witbys=1 and vtvf=1;
keep caseid epdt sitecode edid has_hvs byaed byshk;
run;
proc print data=mismrs;
run;
proc sort data=mismrs;
by sitecode caseid;
run;
PROC EXPORT DATA= WORK.mismrs
OUTFILE= "missingMRS.csv"
DBMS=csv REPLACE;
RUN;
data pubwitshk;
set e3;
where useall=1 and locpub=1 and witbys=1 and vtvf=1;
if emsCprOrder<0 then noemscpr=1; else noemscpr=0;
keep mrsg3 agecat2 sex racecat byscpr ttemscat sitecode alive noemscpr;
run;
/**************************************
*Epi use and length of resuscitation
**************************************/
proc freq data=e3 noprint;
table lorcat / out=lorbshock;
where mainuse=1 and aedshk=1;
run;
proc freq data=e3 noprint;
table lorcat / out=loreshock;
```

```
where mainuse=1 and aedshk^=1;
run;
proc freq data=e3 noprint;
table lorcat / out=lorbshepi;
where mainuse=1 and aedshk=1 and phdepin=1;
run;
proc freq data=e3 noprint;
table lorcat / out=loreshepi;
where mainuse=1 and aedshk^=1 and phdepin=1;
run;
data lorns;
set lorbshock loreshock lorbshepi loreshepi;
run;
PROC EXPORT DATA= WORK.lorns
OUTFILE= "lorns.csv"
DBMS=csv REPLACE;
RUN;
*LOR type;
proc freq data=e3 noprint;
table lortype / out=lortbshock;
where mainuse=1 and aedshk=1;
run;
proc freq data=e3 noprint;
table lortype / out=lorteshock;
where mainuse=1 and aedshk^=1;
run;
proc freq data=e3 noprint;
table lortype / out=lortbshepi;
where mainuse=1 and aedshk=1 and phdepin=1;
run;
proc freq data=e3 noprint;
table lortype / out=lorteshepi;
where mainuse=1 and aedshk^=1 and phdepin=1;
run;
data lorts;
set lortbshock lorteshock lortbshepi lorteshepi;
run;
PROC EXPORT DATA= WORK.lorts
OUTFILE= "lorts.csv"
DBMS=csv REPLACE;
RUN;
proc freq data=e3 noprint;
table phdepin*lorcat / out=epibshk outpct;
where mainuse=1 and aedshk=1;
run;
proc freq data=e3 noprint;
proc freq data=e3 noprint;
```

```
table phdepin*lorcat / out=epieshk outpct;
where mainuse=1 and aedshk^=1;
run;
data epips;
set epibshk epieshk;
run;
PROC EXPORT DATA= WORK.epips
OUTFILE= "epilor.csv"
DBMS=csv REPLACE;
RUN;
/****************************************
* Other assorted numbers
****************************************/
proc freq data=e3;
table aedwho;
where mainuse=1 and byshk=1;
run;
*Bystander CPR process data;
proc freq data=e3;
table ecgagy1*cprmeas1 fraesr/ missing;
where mainuse=1 and byshk=1;
run;
*Does type of location matter?;
*In public;
proc glimmix data=e3 maxopt=100 empirical;
class mrsg3 racecat byscpr sitecode agecat2 ttemscat loctyp;
model mrsg3 (event=last) = byaed agecat2 sex racecat byscpr ttemscat
sitecode loctyp loctyp*byaed / dist=binary s cl;
random _residual_ ;
where mainuse=1;
run;
*Private;
proc glimmix data=e3 maxopt=100 empirical;
class alive racecat byscpr sitecode agecat2 ttemscat loctyp;
model alive (event=last) = byaed agecat2 sex racecat byscpr ttemscat
sitecode loctyp loctyp*byaed / dist=binary s cl;
random _residual_ ;
where usecomp=1 and locpub=0 and witbys=1;
ods output ParameterEstimates=t3adj;
run;
*Overall;
*Get the estimated OR in each category;
*Dropping health care facility;
proc glimmix data=e3 maxopt=100 empirical;
class alive racecat byscpr sitecode agecat2 ttemscat loctyp;
model alive (event=last) = agecat2 sex racecat byscpr ttemscat sitecode
loctyp loctyp*byaed / dist=binary s cl;
```

```
random _residual_ ;
where usecomp=1 and witbys=1 and loctyp not in (7);
ods output ParameterEstimates=t3byloc;
run;
PROC EXPORT DATA= WORK.t3byloc
OUTFILE= "t3byloc.csv"
DBMS=csv REPLACE;
RUN;
proc freq data=e3;
table loctyp*byaed;
where usecomp=1 and witbys=1 and loctyp not in (7);
run;
*Shockable arrest, AED shock;
proc glimmix data=e3 maxopt=100 empirical;
class alive racecat byscpr sitecode agecat2 ttemscat loctyp;
model alive (event=last) = agecat2 sex racecat byscpr ttemscat sitecode
loctyp loctyp*byshk / dist=binary s cl;
random _residual_ ;
where usecomp=1 and witbys=1 and loctyp not in (7) and vtvf=1;
ods output ParameterEstimates=t3byloc2;
run;
PROC EXPORT DATA= WORK.t3byloc2
OUTFILE= "t3byloc2.csv"
DBMS=csv REPLACE;
RUN;
proc freq data=e3;
table loctyp*byshk;
where usecomp=1 and witbys=1 and loctyp not in (7) and vtvf=1;
run;
proc glimmix data=e3 maxopt=100 empirical;
class alive racecat byscpr sitecode agecat2 ttemscat loctyp;
model alive (event=last) = agecat2 sex racecat byscpr ttemscat sitecode
byaed locpub loctyp loctyp*byaed / dist=binary s cl;
random _residual_ ;
where usecomp=1 and witbys=1;
ods output ParameterEstimates=t3byloc3;
run;
*Do police AEDs have worse outcomes?;
*Includes EMS defib group;
proc glimmix data=e3 maxopt=100 empirical;
class mrsg3 racecat byscpr sitecode agecat2 ttemscat loctyp;
model mrsg3 (event=last) = byaed agecat2 sex racecat byscpr ttemscat
sitecode iscop / dist=binary s cl;
random _residual_ ;
where mainuse=1 and locpub=1 and witbys=1 and vtvf=1;
ods output ParameterEstimates=t3adj;
run;
```

```
*Just looking at bystander AED group;
proc glimmix data=e3 maxopt=100 empirical;
class mrsg3 racecat byscpr sitecode agecat2 ttemscat loctyp;
model mrsg3 (event=last) = agecat2 sex racecat byscpr ttemscat sitecode
iscop / dist=binary s cl;
random _residual_ ;
where mainuse=1 and locpub=1 and witbys=1 and vtvf=1 and byaed=1;
ods output ParameterEstimates=t3adj;
run;
*AED applied versus shock given;
proc freq data=e3;
proc freq data=e3;
table byaed*byshk frhyae*frhyem / missing;
where vtvf=1 and usecomp=1;
run;
proc freq data=e3;
table frhyae*frhyem / missing;
where vtvf=1 and usecomp=1 and byaed=1 and byshk^=1 ;
run;
*What sites have police bystander AED use?;
proc freq data=e3;
table sitecode;
where usecomp=1 and byaed=1 and iscop=1;
run;
proc freq data=e3;
table byshk*emsshk /missing;
where useall=1 and locpub=1 and witbys=1 and vtvf=1;
run;
proc freq data=e3;
table byaed alive mrsg3;
where useall=1 and locpub=1 and witbys=1 and vtvf=1 and byshk=0 and
emsshk=0;
run;
*Test of interaction of public location with bystander AED application;
proc glimmix data=e3 maxopt=100 empirical;
class alive racecat byscpr sitecode agecat2 ttemscat byaed;
model alive (event=last) = byaed agecat2 sex racecat byscpr ttemscat
sitecode locpub locpub*byaed / dist=binary s cl;
random _residual_ ;
where useall=1 and witbys=1 and vtvf=1;
*ods output ParameterEstimates=t3adj;
run;
```

Supplemental Methods Part 2: Code for Plots

```
library(splines)
################################
# Load data
################################
baed1 <- read.table("pubwitshk2011-15.csv" , sep = ",",header=T)
names(baed1)
baed1$sitecode <- factor(baed1$sitecode,levels=rev(levels(baed1$sitecode)))
#####################################
# Epinephrine and resuscitation length
#####################################
use1 <- !is.na(baed1$lor) & baed1$lor>-1.2 &!is.na(baed1$phdepin) &
baed1$lor<33.5
#Overall plot
ttrsc <- min(baed1$lor[use1]) + 0.001*1:999*(max(baed1$lor[use1])-
min(baed1$lor[use1]))
fit <- glm(phdepin~ns(lor,df=4),family=binomial,data=baed1,subset=use1)
pred.fit <-
predict(fit,newdata=data.frame(lor=ttrsc),type="response",se.fit=T)
plot(ttrsc,pred.fit$fit,xlab="Length of Resuscitation",ylab="Probability of
Receiving Epinephrine",
type="l",ylim=c(0,1))
lines(ttrsc,pred.fit$fit,col=1,lwd=1.5)
lines(ttrsc,pred.fit$fit-1.96*pred.fit$se.fit,col=1,lty=2)
lines(ttrsc,pred.fit$fit+1.96*pred.fit$se.fit,col=1,lty=2)
#Broken down by EMS, bystander shock
#Unadjusted
fit2 <-
glm(phdepin~ns(lor,df=3)+byshk+ns(lor,df=3)*byshk,family=binomial,data=baed1,
subset=use1
)
pred.fit2 <- predict(fit2,type="response",se.fit=T)
pred.fitEMS <-
predict(fit2,newdata=data.frame(lor=ttrsc,byshk=0),type="response",se.fit=T
)
pred.fitBYS <-
predict(fit2,newdata=data.frame(lor=ttrsc,byshk=1),type="response",se.fit=T
)
plot(ttrsc,pred.fitEMS$fit,xlab="Length of Resuscitation",ylab="Probability
of Receiving Epinephrine",
type="l",ylim=c(0,1),lwd=1.5)
lines(ttrsc,pred.fitBYS$fit,type="l",lty=2,lwd=1.5,col=4)
lines(ttrsc,pred.fitEMS$fit-1.96*pred.fitEMS$se.fit,col=1,lty=3)
lines(ttrsc,pred.fitEMS$fit+1.96*pred.fitEMS$se.fit,col=1,lty=3)
lines(ttrsc,pred.fitBYS$fit-1.96*pred.fitBYS$se.fit,col=4,lty=3)
lines(ttrsc,pred.fitBYS$fit+1.96*pred.fitBYS$se.fit,col=4,lty=3)
```

```
#Broken down by EMS, bystander shock
#Adjusted
fit3 <-
glm(phdepin~ns(lor,df=3)+byshk+ns(lor,df=3)*byshk+sitecode+as.factor(sex)+as.f
actor(racecat
)
+as.factor(agecat2)+as.factor(byscpr)+as.factor(ttemscat),
family=binomial,data=baed1,subset=use1)
pred.fit3 <- predict(fit2,type="response",se.fit=T)
pred.fit3EMS <-
predict(fit3,newdata=data.frame(lor=ttrsc,byshk=0,sitecode="VAN",sex=1,racecat=
3,agecat2=4,byscpr=1
,
ttemscat="5-10"),type="response",se.fit=T)
pred.fit3BYS <-
predict(fit3,newdata=data.frame(lor=ttrsc,byshk=1,sitecode="VAN",sex=1,racecat=
3,agecat2=4,byscpr=1
,
ttemscat="5-10"),type="response",se.fit=T)
#pdf("TimePlots.pdf")
plot(ttrsc,pred.fit3EMS$fit,xlab="Length of
Resuscitation",ylab="Probability of Receiving Epinephrine",
type="l",ylim=c(0,1),lwd=1.5)
lines(ttrsc,pred.fit3BYS$fit,type="l",lty=2,lwd=1.5,col=4)
lines(ttrsc,pred.fit3EMS$fit-1.96*pred.fit3EMS$se.fit,col=1,lty=3)
lines(ttrsc,pred.fit3EMS$fit+1.96*pred.fit3EMS$se.fit,col=1,lty=3)
lines(ttrsc,pred.fit3BYS$fit-1.96*pred.fit3BYS$se.fit,col=4,lty=3)
lines(ttrsc,pred.fit3BYS$fit+1.96*pred.fit3BYS$se.fit,col=4,lty=3)
legend(legend=c("Bystander Shock","EMS
Shock"),col=c(4,1),lty=c(2,1),x=0,y=1)
#Check negative time to ROSC -- pulses at EMS arrival?
#Do I need to adjust for other confounders? Almost certainly
#####################################
# EMS response time and survival
# Logistic regression
# Spline for time
#####################################
use2 <- !is.na(baed1$emsFirstRigWithDtmMin) & !is.na(baed1$alive) &
baed1$emsFirstRigWithDtmMin>2 & baed1$emsFirstRigWithDtmMin<13
ttems <- min(baed1$emsFirstRigWithDtmMin[use2])+
0.001*1:999*(max(baed1$emsFirstRigWithDtmMin[use2])-
min(baed1$emsFirstRigWithDtmMin[use2]))
fit4 <-
glm(alive~ns(emsFirstRigWithDtmMin,df=3)+byshk+ns(emsFirstRigWithDtmMin,d
f=3)*bysh
k
+sitecode+as.factor(sex)+as.factor(racecat)
```

```
+as.factor(agecat2)+as.factor(byscpr),
family=binomial,data=baed1,subset=use2)
pred.fit4EMS <- predict(fit4,newdata=data.frame(emsFirstRigWithDtmMin=ttems
,byshk=0,sitecode="VAN",sex=1,racecat=3,agecat2=4,byscpr=1),type="response",se.
fit=T
)
pred.fit4BYS <- predict(fit4,newdata=data.frame(emsFirstRigWithDtmMin=ttems
,byshk=1,sitecode="VAN",sex=1,racecat=3,agecat2=4,byscpr=1),type="response",se.
fit=T
)
plot(ttems,pred.fit4EMS$fit,xlab="Time to EMS",ylab="Probability of
Survival",
type="l",ylim=c(0,1),lwd=1.5)
lines(ttems,pred.fit4BYS$fit,type="l",lty=2,lwd=1.5,col=4)
lines(ttems,pred.fit4EMS$fit-1.96*pred.fit4EMS$se.fit,col=1,lty=3)
lines(ttems,pred.fit4EMS$fit+1.96*pred.fit4EMS$se.fit,col=1,lty=3)
lines(ttems,pred.fit4BYS$fit-1.96*pred.fit4BYS$se.fit,col=4,lty=3)
lines(ttems,pred.fit4BYS$fit+1.96*pred.fit4BYS$se.fit,col=4,lty=3)
legend(legend=c("Bystander Shock","EMS
Shock"),col=c(4,1),lty=c(2,1),x=2,y=0.2)
anova(fit4,test="LRT")
#Unadj
fit5 <-
glm(alive~ns(emsFirstRigWithDtmMin,df=2)+byshk+ns(emsFirstRigWithDtmMin,d
f=2)*bysh
k
,family=binomial,data=baed1,subset=use2)
pred.fit5EMS <-
predict(fit5,newdata=data.frame(emsFirstRigWithDtmMin=ttems,byshk=0),type="r
esponse",se.fit=T
)
pred.fit5BYS <-
predict(fit5,newdata=data.frame(emsFirstRigWithDtmMin=ttems,byshk=1),type="r
esponse",se.fit=T
)
plot(ttems,pred.fit5EMS$fit,xlab="Time to EMS",ylab="Probability of
Survival",
type="l",ylim=c(0,1),lwd=1.5)
lines(ttems,pred.fit5BYS$fit,type="l",lty=2,lwd=1.5,col=4)
lines(ttems,pred.fit5EMS$fit-1.96*pred.fit4EMS$se.fit,col=1,lty=3)
lines(ttems,pred.fit5EMS$fit+1.96*pred.fit4EMS$se.fit,col=1,lty=3)
lines(ttems,pred.fit5BYS$fit-1.96*pred.fit4BYS$se.fit,col=4,lty=3)
lines(ttems,pred.fit5BYS$fit+1.96*pred.fit4BYS$se.fit,col=4,lty=3)
legend(legend=c("Bystander Shock","EMS
Shock"),col=c(4,1),lty=c(2,1),x=0,y=1)
#dev.off()
#####################################################
```

```
# Logistic regression
# Linear trend for time
####################################################
use.missonly <- !is.na(baed1$emsFirstRigWithDtmMin) & !is.na(baed1$mrsg3)
fit6 <-
glm(mrsg3~emsFirstRigWithDtmMin+byshk+emsFirstRigWithDtmMin*byshk
+sitecode+as.factor(sex)+as.factor(racecat)
+as.factor(agecat2)+as.factor(byscpr),
family=binomial(link = "logit"),data=baed1,subset=use2)
pred.fit6EMS <- predict(fit6,newdata=data.frame(emsFirstRigWithDtmMin=ttems
,byshk=0,sitecode="TOR",sex=1,racecat=3,agecat2=4,byscpr=1),type="response",se.
fit=T
)
pred.fit6BYS <- predict(fit6,newdata=data.frame(emsFirstRigWithDtmMin=ttems
,byshk=1,sitecode="TOR",sex=1,racecat=3,agecat2=4,byscpr=1),type="response",se.
fit=T
)
#anova(fit6, test="LR") # Sequential test!
#pdf("TimePlotsLinear.pdf")
#setEPS()
#postscript("TimePlotsLinear.eps")
plot(ttems,pred.fit6EMS$fit,xlab="Time to EMS",ylab=expression
("Probability of mRS "<=2),
type="l",ylim=c(0,1),lwd=1.5)
lines(ttems,pred.fit6BYS$fit,type="l",lty=2,lwd=1.5,col=1)
lines(ttems,pred.fit6EMS$fit-1.96*pred.fit6EMS$se.fit,col=1,lty=3)
lines(ttems,pred.fit6EMS$fit+1.96*pred.fit6EMS$se.fit,col=1,lty=3)
lines(ttems,pred.fit6BYS$fit-1.96*pred.fit6BYS$se.fit,col=1,lty=3)
lines(ttems,pred.fit6BYS$fit+1.96*pred.fit6BYS$se.fit,col=1,lty=3)
legend(legend=c("Bystander Shock","EMS
Shock"),col=c(1,1),lty=c(2,1),x=3,y=0.25)
#dev.off()
#Plot on log odds scale
pred.fit6EMSlo <-
predict(fit6,newdata=data.frame(emsFirstRigWithDtmMin=ttems
,byshk=0,sitecode="TOR",sex=1,racecat=3,agecat2=4,byscpr=1),type="link",se.fit=T
)
pred.fit6BYSlo <-
predict(fit6,newdata=data.frame(emsFirstRigWithDtmMin=ttems
,byshk=1,sitecode="TOR",sex=1,racecat=3,agecat2=4,byscpr=1),type="link",se.fit=T
)
#pdf("F:\\ROC\\Cardiac\\Bystander
AED\\Results\\TimePlotsLinearLogOdds.pdf")
plot(ttems,pred.fit6EMSlo$fit,xlab="Time to EMS",ylab="Log Odds of
Survival",
type="l",lwd=1.5,ylim=c(-2,2))
lines(ttems,pred.fit6BYSlo$fit,type="l",lty=2,lwd=1.5,col=1)
```

```
lines(ttems,pred.fit6EMSlo$fit-1.96*pred.fit6EMSlo$se.fit,col=1,lty=3)
lines(ttems,pred.fit6EMSlo$fit+1.96*pred.fit6EMSlo$se.fit,col=1,lty=3)
lines(ttems,pred.fit6BYSlo$fit-1.96*pred.fit6BYSlo$se.fit,col=1,lty=3)
lines(ttems,pred.fit6BYSlo$fit+1.96*pred.fit6BYSlo$se.fit,col=1,lty=3)
legend(legend=c("Bystander Shock","EMS
Shock"),col=c(1,1),lty=c(2,1),x=3,y=0.4)
#dev.off()
pred.fit6.4812 <-
predict(fit6,newdata=data.frame(emsFirstRigWithDtmMin=rep(c(4,8,12),2)
,byshk=rep(0:1,each=3),sitecode="TOR",sex=1,racecat=3,agecat2=4,byscpr=1),
type="response",se.fit=T)
logit(pred.fit6.4812$fit)
exp(logit(pred.fit6.4812$fit[4:6])-logit(pred.fit6.4812$fit[1:3]))
#Model predictions over different variable combinations
pred.fit6good <-
predict(fit6,newdata=data.frame(emsFirstRigWithDtmMin=ttems
,byshk=0,sitecode="VAN",sex=0,racecat=1,agecat2=1,byscpr=1),type="response",se.
fit=T
)
pred.fit6bad <- predict(fit6,newdata=data.frame(emsFirstRigWithDtmMin=ttems
,byshk=0,sitecode="DAL",sex=1,racecat=2,agecat2=7,byscpr=0),type="response",se.
fit=T
)
#pdf("F:\\ROC\\Cardiac\\Bystander
AED\\Results\\TimePlotsLinearExtremes.pdf")
plot(ttems,pred.fit6good$fit,xlab="Time to EMS",ylab="Probability of
Survival",
type="l",ylim=c(0,1),lwd=1.5)
lines(ttems,pred.fit6bad$fit,type="l",lty=2,lwd=1.5,col=1)
#dev.off()
cbind(ttems,pred.fit6good$fit,pred.fit6bad$fit)
#At 8 minutes, 77.4% survival in good group, 3.7% in bad
# At 9 minutes, it's 74.3% and 3.1%
# That's 3.1% and 0.6% absolute decrease
# And 4% / 16% relative decrease
(0.743/0.257)/(0.774/0.226)
(0.031/0.969)/(0.037/0.963)
lor.ems <- c(summary(fit6)$coef[2,1],summary(fit6)$coef[2,1]-
1.96*summary(fit6)$coef[2,2],summary(fit6)$coef[2,1]+1.96*summary(fit6)$coef[2
,2]
)
or.ems <- exp(lor.ems)
bys.coef <- summary(fit6)$coef[2,1]+summary(fit6)$coef[23,1]
bys.var <- summary(fit6)$coef[2,2]^2+summary(fit6)$coef[23,2]^2
lor.bys <- c(bys.coef,bys.coef1.96*sqrt(bys.var),bys.coef+1.96*sqrt(bys.var))
or.bys <- exp(lor.bys)
pred.fit6EMSex4 <- predict(fit6,newdata=data.frame(emsFirstRigWithDtmMin=4
```

```
,byshk=0,sitecode="VAN",sex=1,racecat=3,agecat2=4,byscpr=1),type="response",se.
fit=T
)
pred.fit6EMSex5 <- predict(fit6,newdata=data.frame(emsFirstRigWithDtmMin=5
,byshk=0,sitecode="VAN",sex=1,racecat=3,agecat2=4,byscpr=1),type="response",se.
fit=T
)
(0.6272469/(1-0.6272469))/(0.6660148/(1-.6660148))
#####################################################
# Log time
#####################################################
fit7 <-
glm(alive~log(emsFirstRigWithDtmMin)+byshk+log(emsFirstRigWithDtmMin)*bys
hk
+sitecode+as.factor(sex)+as.factor(racecat)
+as.factor(agecat2)+as.factor(byscpr),
family=binomial,data=baed1,subset=use2)
summary(fit7)
########################################
# Comparing the OR for time to EMS for bystander, EMS shocked cases
########################################
summary(fit6)$coef
summary(fit6)$cov.u[,3]
summary(fit6)$cov.u[,23]
logoddsdiff <- function (x) {0.249385540+0.129603346*x}
varlogoddsdiff <- function(x) {0.1159034461 + x^2*0.002901601 + -
0.0171632365*x}
lowci <- function(x) {
logoddsdiff(x)-1.96*sqrt(varlogoddsdiff(x))
}
hici <- function(x) {
logoddsdiff(x)+1.96*sqrt(varlogoddsdiff(x))
}
ttems[165]
exp(c(logoddsdiff(x=4),lowci(x=4),hici(x=4)))
exp(c(logoddsdiff(x=8),lowci(x=8),hici(x=8)))
exp(c(logoddsdiff(x=12),lowci(x=12),hici(x=12)))
```

Supplemental Table 1 (Characteristics of arrest for selected additional populations)

		Private Unwitnessed Shockable Arrest		Private Bystander Witnessed Shockable Arrest		Public Unwitnessed Shockable Arrest	
		No AED Shock	AED Shock	No AED Shock	AED Shock	No AED Shock	AED Shock
		N =2,161	N =65	N =4,176	N =127	N =613	N =78
Age (years)	median (Q1,Q3)	66 (55, 77)	66 (54, 79)	65 (55, 77)	67 (55, 75)	61 (52, 70)	62 (50, 69)
Male	n (%)	70%	69%	75%	78%	86%	87%
Race							
White	n (%)	26%	48%	25%	50%	28%	26%
Black	n (%)	11%	5%	8%	3%	9%	4%
Other	n (%)	2%	3%	2%	6%	3%	1%
Unknown	n (%)	61%	45%	65%	40%	61%	69%
Bystander CPR							
Yes	%	43%	100 %	57%	96%	50.7%	100.0 %
No	%	55%	0%	41%	4%	47%	0%
Missing	%	2%	0%	2%	0%	2%	0%
EMS response time (min)	median (Q1,Q3)	5.4 (4.2, 7.0)	6.3 (5.2, 7.7)	5.7 (4.5, 7.2)	5.8 (4.1, 8.0)	5.2 (3.8, 6.8)	5.9 (4.0, 8.2)
Epinephrine	n (%)	87%	83%	80%	59%	84%	76%
Dose	mean (sd)	3.9 (2.4)	3.6 (1.7)	3.9 (2.5)	3.4 (2.0)	3.7 (2.6)	4.1 (2.4)
Location Type							
Street/highway	%	--	--	--	--	44%	10%
Public building	%	--	--	--	--	6%	14%
Place of recreation	%	--	--	--	--	8%	29%
Industrial place	%	--	--	--	--	7%	12%
Other public	%	--	--	--	--	35%	35%
	%	93%	63%	95%	66%	--	--

Home/residence							
Farm/ranch	**%**	**0%**	**0%**	**0%**	**0%**	**--**	**--**
Healthcare facility	**%**	**0%**	**0%**	**0%**	**0%**	**--**	**--**
Residential institution	**%**	**6%**	**32%**	**4%**	**20%**	**--**	**--**
Other private	**%**	**0%**	**5%**	**1%**	**14%**	**--**	**--**
Site							
Alabama	**%**	**3%**	**0%**	**3%**	**2%**	**2%**	**0%**
British Columbia	**%**	**12%**	**5%**	**15%**	**2%**	**14%**	**17%**
Dallas-Fort Worth, Texas	**%**	**16%**	**12%**	**12%**	**4%**	**14%**	**6%**
Milwaukee, Wisconsin	**%**	**8%**	**2%**	**5%**	**6%**	**5%**	**4%**
Ottawa, Ontario	**%**	**16%**	**12%**	**17%**	**11%**	**13%**	**14%**
Pittsburgh, Pennsylvania	**%**	**3%**	**15%**	**3%**	**13%**	**2%**	**8%**
Portland, Oregon	**%**	**7%**	**18%**	**8%**	**17%**	**6%**	**12%**
San Diego, California	**%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Seattle, Washington	**%**	**10%**	**23%**	**10%**	**32%**	**14%**	**9%**
Toronto, Ontario	**%**	**26%**	**12%**	**28%**	**13%**	**29%**	**31%**

AED = automatic external defibrillator; Min = minutes; CPR = cardiopulmonary resuscitation; EMS = emergency medical services; Q1,Q3=boundaries of the interquartile range

Supplemental Table 2: Outcomes among selected additional populations

		Private Unwitnessed Shockable Arrest		Private Bystander Witnessed Shockable Arrest		Public Unwitnessed Shockable Arrest	
		No AED Shock	AED Shock	No AED Shock	AED Shock	No AED Shock	AED Shock
		N =2,161	N =65	N =4,176	N =127	N =613	N =78
Duration of resuscitation (min)	Median (Q1,Q3)	29.0 (20.3, 38.9)	26.5 (20.8, 35.0)	28.6 (16.0, 38.8)	18.9 (7.6, 32.1)	26.3 (17.0, 35.0)	27.5 (12.3, 37.5)
Prehospital ROSC	n (%)	1053 (48.7%)	32 (49.2%)	2564 (61.4%)	102 (80.3%)	311 (50.7%)	45 (57.7%)
Pulses at ED arrival	n (%)	759 (35.1%)	23 (35.4%)	1972 (47.3%)	85 (66.9%)	229 (37.4%)	35 (44.9%)
Admitted to hospital	n (%)	784 (36.6%)	24 (37.5%)	2068 (50.2%)	79 (63.7%)	284 (47.1%)	33 (45.8%)
Survived to discharge	n (%)	343 (15.9%)	13 (20.0%)	1155 (27.7%)	61 (48.0%)	154 (25.1%)	24 (30.8%)
Transported to the ED		N =1523	N =45	N =3375	N =113	N =546	N =66
Induced hypothermia[1]	n (%)	569 (41.4%)	17 (48.6%)	1420 (46.8%)	41 (51.3%)	207 (42.3%)	22 (44.9%)
Diagnostic Catheterization[1]	n (%)	137 (10.0%)	7 (20.0%)	360 (11.9%)	19 (23.5%)	56 (11.5%)	8 (16.3%)
PTCA[1] - PCI, right?	n (%)	175 (12.7%)	3 (8.6%)	574 (18.9%)	17 (21.0%)	88 (18.0%)	7 (14.3%)
Admitted to hospital		N =784	N =24	N =2068	N =79	N =284	N =33
CCU/ICU (days)[2]	Median (Q1,Q3)	5.0 (2.0, 9.0)	9.0 (5.0, 11.0)	6.0 (3.0, 10.0)	5.0 (4.0, 11.0)	6.0 (3.0, 11.0)	7.0 (5.0, 11.0)
Hospitalization (days)[2]							
Survived	Median (Q1,Q3)	13.0 (8.0, 22.0)	12.0 (8.0, 22.0)	12.0 (7.0, 20.0)	10.0 (4.0, 15.0)	14.0 (9.0, 22.0)	13.0 (7.0, 20.0)
Did not	Median	3.0	6.5	3.0 (1.0,	2.5 (1.0,	3.0 (1.0,	6.0 (4.0,

survive	**(Q1,Q3)**	**(1.0, 5.0)**	**(2.0, 8.5)**	**6.0)**	**3.5)**	**7.0)**	**7.0)**
[1] Of those trasnported to the ED.							
[2] Initial continuous, of those admitted to the hospital.							
AED = automatic external defibrillator; Min = minutes; ROSC = return of spontaneous circulation; CCU= cardiac care unit; ICU = intensive care unit; Q1,Q3 = Boundaries of the interquartile range; MRS = modified Rankin score; ED = Emergency Department							