ORIGINAL ARTICLES

TIME TO FIRST SHOCK BY EMERGENCY MEDICAL TECHNICIANS WITH AUTOMATED EXTERNAL DEFIBRILLATORS

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ABSTRACT

The interval from collapse to electrical rescue shock is a critical determinant of successful defibrillation in cardiac arrest. In order to achieve the earliest possible defibrillation, many emergency medical services (EMS) systems equip first-responding units with an automated external defibrillator (AED). **Objective.** To measure the time from on-scene emergency medical technician (EMT) recognition of cardiac arrest to AED application and shock in ventricular fibrillation (VF) arrest. In addition, the authors sought to understand the reasons for delays. **Methods.** Using the AED recordings and written EMS reports, the authors conducted a retrospective cohort study of all persons who experienced an EMS-attended VF cardiac arrest in which an AED was applied and a shock delivered by an EMT, from January 1999 through December 2000 (n = 177). Based on the bimodal distribution of times, two groups were assembled: no delay (time to shock ≤ 90 seconds) and delayed (time to shock > 90 seconds). Patient and event characteristics associated with delay status were determined using Mantel-Haenszel methods. **Results.** The median (25th, 75th percentile) time from cardiac arrest recognition to shock was 51 (43, 64) seconds. Ninety-four percent (n = 166) of the cohort received a shock within 90 seconds. Delayed shock was associated with unwitnessed arrest status (odds ratio = 9.3, 95% confidence interval = 2.3, 36.8) and nursing home location (odds ratio = 10.0, 95% confidence interval = 2.1, 47.5). **Conclusion.** The findings suggest that a 1-minute goal and a 90-second minimum standard for time to first shock are appropriate for EMT AED defibrillation in the field. **Key words:** emergency medical technician; heart arrest; ventricular fibrillation; prehospital care; cardiopulmonary resuscitation; automated external defibrillator.

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Out-of-hospital cardiac arrest is a leading cause of death in the United States.[1] The most common initial rhythm in cardiac arrest is ventricular fibrillation (VF), for which electrical defibrillation is the only effective therapy.[1,2] The interval from collapse to electrical rescue shock is the most critical determinant of successful defibrillation, with shorter intervals leading to improved survival.[3]

In order to achieve the earliest possible defibrillation, many emergency medical services (EMS) systems equip first-responding basic life support (BLS) units with an automated external defibrillator (AED). The AED enables the emergency medical technician (EMT), typically not trained in assessing heart rhythms, to provide defibrillation before paramedic arrival, and thus improve the chances of successful resuscitation.[4] The purpose of this study was to measure the time from on-scene, EMT recognition of cardiac arrest to AED application and shock in VF arrest based upon the experiences of a mature EMS system. In addition, we sought to understand the reasons for delays.

METHODS

Study Design, Setting, and Population

A retrospective cohort study was conducted to determine the time for AED application and shock in out-of-hospital VF cardiac arrest. The study was approved by the investigators' institutional review board. The study area was suburban King County, Washington, excluding the city of Seattle. King County EMS is a 2-tiered response system that serves 1.1 million people in the greater suburban Seattle area. The first tier of

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TABLE 1. Time Intervals (in Seconds) of Automated External Defibrillator Operation (n = 177)

	Power On to Patches Applied	Patches Applied to Shock Advised	Shock Advised to Charged	Charged to First Shock	Total Interval
Average ± standard deviation	32 ± 14	18 ± 21	5 ± 2	3 ± 5	58 ± 28
Median (25th, 75th %)	30 (24, 40)	13 (10, 17)	5 (4, 6)	3 (1, 4)	51 (43, 64)

response is provided by fire department-based personnel with EMT and BLS training. Each unit is equipped with an AED. The second tier of response is provided by paramedics with training in advanced life support (ALS). In a suspected cardiac arrest, BLS and ALS units are dispatched simultaneously and upon scene arrival follow the American Heart Association BLS and ALS guidelines.[5] The BLS unit typically arrives on scene several minutes before ALS. In King County, EMTs have used AEDs since 1985.[4] Currently, approximately 1,800 EMTs in the King County EMS system are trained and certified in AED operation. Protocol directs EMTs to turn the AED on at the scene as soon as they identify a potential cardiac arrest patient and narrate details of the incident during resuscitation. The highest priority for EMTs once on the scene of a suspected cardiac arrest victim is to apply the AED and defibrillate (if appropriate). Because the BLS unit typically has at least two EMTs, one EMT may perform cardiopulmonary resuscitation (CPR) while waiting for the second EMT to apply the AED.

The study cohort consisted of all EMS-attended out-of-hospital VF cardiac arrests in which an AED was applied and a shock delivered by an EMT, not in the presence of a paramedic, for the 24-month period of January 1999 through December 2000 (n = 277). Cases were identified from the medical incident report forms that are completed by EMTs and paramedics for each cardiac arrest. This surveillance system has been in place since 1975.[6] Specifically, we screened the reports for cases in which EMTs delivered a shock using an AED. More recently, EMTs submit an electronic AED record of the arrest (either a cassette tape or an electronic data card) when not under the direct supervision of a paramedic. This electronic record was matched to the medical information report form. Of the 277 cases that were eligible based on review of the medical incident report form, 100 cases were excluded: 26 because the AED was applied prior to turning on the device, 46 because of a damaged AED record (i.e., missing audio or electrocardiographic portion of the recording, double recording where the AED did not erase properly as it recorded, or a broken tape), and 28 because the AED record was missing; leaving 177 cases (64%) with complete information.

Data Collection

Data were collected by review of the AED record of voice and ECG information as well as review of the medical incident report form. The elapsed time was assessed using the AED record for the following four

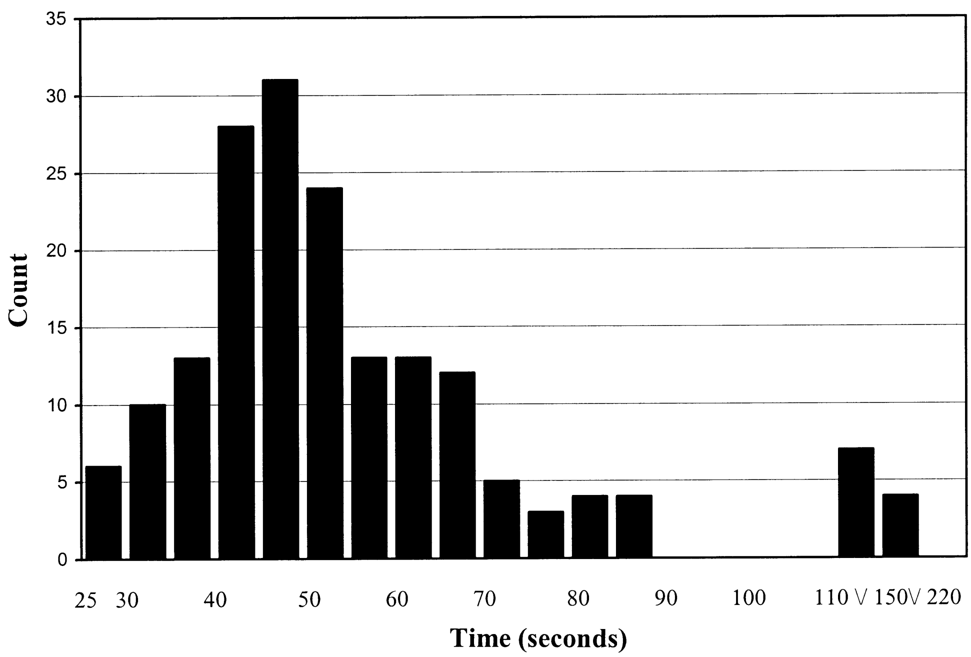

FIGURE 1. Distribution of interval from automated external defibrillator power on to first shock.

time intervals: 1) AED power-on to application of electrode patches, 2) patch application to shock advised, 3) shock advised to AED charged, and 4) AED charged to first shock delivered, with the primary outcome being the interval from power on to first shock delivered. (There was no case in which the AED was turned on prior to scene arrival.) An attempt was made in each incident to qualitatively discern any source of delay in the operation of the AED. Additional information regarding patient, event, and EMS characteristics was collected from the medical incident report form. Survival to hospital discharge was ascertained from the King County Emergency Medical Services Cardiac Arrest Surveillance System database.

Statistical Analysis

The time interval to first shock was plotted for each cardiac arrest patient. A bimodal distribution for time to first shock emerged with the majority of cases requiring ≤90 seconds and a second group requiring ≥113 seconds (no first shocks occurred within the 91 to 112-second interval). Thus, for the purposes of investigating potential causes for delay, the cohort was separated into two time-to-shock groups based on the bimodal distribution for time to first shock: ≤90 seconds (no delay) and ≥113 seconds (delayed). The univariable association between delay group and patient, event, and EMS characteristics was assessed using the t-test for continuous variables and chi-square or Fisher's exact tests for categorical variables. Variables assessed included patient age and gender, bystander CPR status, witness status, location, arrest before EMS arrival, responding EMS district, and time of day. For variables associated with delay group at ($p < 0.1$), Mantel-Haenszel odds ratios (ORs) and 95% confidence intervals (95% CIs) were calculated.[7] Mantel-Haenszel methods were also used to determine the independent association of variables of interest while controlling for other variables that might represent potential confounders. Because the number in the delay group was relatively small, only one variable (in addition to the variable of interest) was controlled for in each model. Data were analyzed using SPSS 10.0 (Chicago, IL).

RESULTS

The age, gender, witness status, location, and survival of the aforementioned excluded cases (n = 100) were similar to the assessed cohort (n = 177) (data not shown). Figure 1 displays the bimodal distribution of the interval from AED power-on to first shock. The average interval (± standard deviation) was 58 ± 28 seconds with a median (25th, 75th percentile) of 51 (43, 64) seconds. The majority of time was required for the interval between power on and the application of patches followed by shorter durations for the three subsequent intervals leading to the first shock (Table 1).

TABLE 2. Patient, Event, and Emergency Medical Services (EMS) Characteristics According to Delay Status*

	No Delay (n = 166)	Delayed (n = 11)	p-value
Gender—male, n (%)	127 (77%)	9 (82%)	0.50
Age, average ± SD	64.2 ± 15.8 yr	68.6 ± 13.8 yr	0.40
Witnessed, n (%)	129 (78%)	3 (27%)	0.001
Bystander CPR, n (%)	88 (53%)	7 (64%)	0.60
Location, n (%)			0.01
Private	113 (68%)	6 (55%)	
Public	47 (28%)	2 (18%)	
Nursing home	6 (4%)	3 (27%)	
Arrest before EMS arrival, n (%)	161 (97%)	11 (100%)	1.0
Night event (2300–0700)	35 (21%)	4 (36%)	0.30
Survival to hospital discharge, n (%)	47 (28%)	1 (9%)	0.30

*No delay defined by time interval from power on to first shock ≤90 seconds. Delayed group defined by time interval >90 seconds. CPR = cardiopulmonary resuscitation.

Eleven of 177 cardiac arrest cases (6%) had a delayed time to first shock. Patient and event characteristics according to delay group are shown in Table 2. A delayed time to first shock was more common when the cardiac arrest occurred in the nursing home compared with other locations (OR = 10.0, 95% CI = 2.1, 47.5) and when the arrest was unwitnessed (OR = 9.3, 95% CI = 2.3, 36.8). The odds ratio for nursing home location changed only slightly when controlling for witness status by Mantel-Haenszel methods (OR = 10.7, 95% CI = 1.7, 67.2). Similarly, the association of witness status and delay group was only slightly altered when controlling for nursing home location (OR = 8.3, 95% CI = 2.1, 32.3). Comparable results were evident for nursing home location and witness status when other categorical variables (i.e., age > or ≤ 75 years) were controlled for using Mantel-Haenszel methods.

The qualitative assessment of the 11 delayed cases revealed three potential areas of delay. In five patients, the delay occurred during the analysis. Typically the AED was not able to analyze the rhythm because of motion artifact with intermittent repositioning of the patient. In three patients, specific patient factors (i.e., shaving the chest in order for the pads to adhere, clearing emesis from the patient's chest and face) appeared to contribute to the delay. In two patients, an operator/equipment issue may have contributed to delay: one required that the AED battery be changed on scene to deliver the shock, and in the second case there was confusion as to the presence of a pulse.

DISCUSSION

In an EMS system with a mature experience in AED operation, we found that the average interval from EMT on-scene recognition of a cardiac arrest victim to first shock was slightly less than 1 minute and that the vast majority (94%) of patients were shocked within 90 seconds. Delayed shock was associated with unwitnessed arrests and nursing home location. In addition, qualitative assessment of delay identified a mix of arrest, patient, and operator factors that may be important.

The interval from collapse to shock is the critical determinant in resuscitation of VF cardiac arrest. Although the time required for EMS to arrive at the scene is often a major portion of this interval, once on the scene timely therapeutic action is clearly indicated.[5] In this cohort, patients typically received a shock within 1 minute from EMT on-scene recognition of a cardiac arrest victim, and nearly all within 90 seconds. The durations in this investigation are similar to the simulated arrest experience of EMS professionals, modestly less than AED-naïve young persons in simulated arrest, and considerably less than the intervals in simulated arrests among older adults trained in AED operation.[8,9] Of note, in many training scenarios, the time-to-shock interval includes the initial patient assessment (responsiveness, airway, respirations, and pulse check). In this study, the AED was not turned on until the event was determined to be a cardiac arrest. Thus, the time-to-shock intervals in this study would have been slightly longer if an initial patient assessment interval had been included. Nonetheless, one interpretation of the results is that a reasonable goal for training and the field is 60 seconds with a minimum standard of 90 seconds. Although the EMS care of every cardiac arrest patient should be reviewed in an effort to improve patient outcomes, those in whom time to shock requires >90 seconds may deserve special attention.

Our findings provide insights that may be useful in limiting delays. It is plausible that additional time elapsed in the unwitnessed arrest while the EMT attempted to establish the circumstances of the event. Event circumstances, however, are generally unlikely to alter the initial EMS care of airway, breathing, circulation, and defibrillation. The association between delay and nursing home location may be explained by several possibilities: 1) additional outside medical personnel at the nursing home may hinder or distract the EMT care process; 2) given end-of-life preferences and the need for documentation among nursing home residents, delay may occur while the EMS personnel confirm the patient's resuscitation preferences[10,11]; or 3) the physical design of the nursing home may somehow contribute to delay. Regarding this last possibility, motion artifact that occurred during repositioning of the patient (from bed to a firmer, potentially more accessible area) contributed to the delay in two of the three delayed nursing home cardiac arrests. Finally, the qualitative assessment of delay reinforces the importance of standing clear of the patient during analysis and maintaining AED upkeep, and suggests that the EMT be prepared to overcome uncommon obstacles to pad application that might not be part of the typical training preparation.

LIMITATIONS

This study has several limitations. In the King County EMS system, AED application and defibrillation is the highest priority in the treatment of cardiac arrest. Other settings may have other protocols (e.g., 90 seconds of CPR prior to AED application) that may limit the relevance of the findings of this study.[12] Approximately one-third of eligible cardiac arrests had an incomplete AED record. These excluded cases may somehow have been different with respect to EMT AED application and shock, though they possessed similar event, EMS, patient demographic, and survival characteristics when compared with the study cohort. During the study period, EMTs did not standardly submit an electronic AED recording if paramedics and EMTs arrived on scene simultaneously. Thus, we were unable to assess the potential influence of paramedics on time to shock by EMT AED. This was a retrospective analysis that used electronic and written records to assess time to shock and investigate potential causes of delay. An investigator was not present on scene to observe the care of each arrest. Consequently, though we feel the intervals truly reflect the timing of care, the causes of delay required interpretation and should be viewed cautiously. Moreover, only a relatively small number of cases had a delayed time to shock. Thus, we had limited power to detect associations, and some characteristics important in EMT time to shock may not have been identified.

CONCLUSIONS

The findings of this study suggest that a 1-minute goal and a 90-second minimum standard for time to first shock are appropriate for EMT AED defibrillation in the field. The EMT should be cognizant of delays in attempted defibrillation and whether these delays are necessary and/or modifiable. Such efforts may aid in improving the outcome of cardiac arrest.

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The case conference format may be used for the presentation of interesting or unusual EMS encounters. This format can illustrate specific medical entities, unusual approaches to field management, or complex administrative issues that a field scenario may present. Authors should pay particular attention to the educational value of the manuscript, and avoid a purely descriptive approach. Features such as a team approach and innovative solutions to atypical problems should be stressed. While an abstract and specific section headings are not required, the following sections should be considered:

1. overall description of the scene, types of responding agencies and personnel, etc.
2. specific challenges encountered
3. solutions developed to address the challenges
4. discussion of medical issues involved, with review of the literature where appropriate
5. discussion of logistic and administrative issues

Title page, group authorship and acknowledgments page, references, and tables and figures (where appropriate) should follow the same format as for general manuscripts (see the "Manuscript Preparation" section of the "Instructions for Authors" following the text of most issues of *Prehospital Emergency Care).*