

Public Access Defibrillation in Out-of-Hospital Cardiac Arrest

A Community-Based Study

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Background—The dissemination and use of automated external defibrillators (AEDs) beyond traditional emergency medical services (EMS) into the community has not been fully evaluated. We evaluated the frequency and outcome of non-EMS AED use in a community experience.

Methods and Results—The investigation was a cohort study of out-of-hospital cardiac arrest cases due to underlying heart disease treated by public access defibrillation (PAD) between January 1, 1999, and December 31, 2002, in Seattle and surrounding King County, Washington. Public access defibrillation was defined as out-of-hospital cardiac arrest treated with AED application by persons outside traditional emergency medical services. The EMS of Seattle and King County developed a voluntary Community Responder AED Program and registry of PAD AEDs. During the 4 years, 475 AEDs were placed in a variety of settings, and more than 4000 persons were trained in cardiopulmonary resuscitation and AED operation. A total of 50 cases of out-of-hospital cardiac arrest were treated by PAD before EMS arrival, which represented 1.33% (50/3754) of all EMS-treated cardiac arrests. The proportion treated by PAD AED increased each year, from 0.82% in 1999 to 1.12% in 2000, 1.41% in 2001, and 2.05% in 2002 ($P=0.019$, test for trend). Half of the 50 persons treated with PAD survived to hospital discharge, with similar survival for nonmedical settings (45% [14/31]) and out-of-hospital medical settings (58% [11/19]).

Conclusions—PAD was involved in only a small but increasing proportion of out-of-hospital cardiac arrests. (*Circulation*. 2004;109:1859-1863.)

Key Words: heart arrest ■ defibrillation ■ automated external defibrillator ■ cardiopulmonary resuscitation

Out-of-hospital cardiac arrest accounts for hundreds of thousands of deaths annually in the United States.^{1,2} Estimates are that 5% or less of all persons suffering cardiac arrest are resuscitated successfully and subsequently discharged alive from the hospital.^{3,4} The “chain of survival” outlines opportunities to improve outcome through prompt activation of 9-1-1, early cardiopulmonary resuscitation (CPR), rapid defibrillation, and timely advanced life support.⁵ Although all the links in the chain of survival are important, rapid defibrillation appears to be the most critical, with survival declining by $\approx 5\%$ to 10% with each minute of delay.^{6,7}

The automated external defibrillator (AED) provides the possibility to decrease the interval from collapse to attempted defibrillation by enabling persons outside the traditional emergency medical services (EMS) response system who are

typically not trained in rhythm recognition to deliver life-saving therapy. Various approaches have incorporated the AED in an effort to improve survival from out-of-hospital cardiac arrest. In the Public Access Defibrillation trial, a rigorous program of trained citizen first responders equipped with AEDs in specific high-risk sites improved survival by ≈ 2 -fold.⁸ In other specific settings, such as gaming establishments, airports, or airplanes, the placement of AEDs and training of personnel appear to offer survival advantages.^{9–12} Police-responder programs may also increase survival.^{13–15} Finally, specialized community-responder programs in select European communities have demonstrated potential survival improvements.¹⁶

However, the optimal strategy of community-wide AED distribution is not yet certain. High-risk sites have been identified.^{17,18} Some groups have mandated AED placement,

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whereas others have voluntarily instituted an AED program.^{19,20} In some instances, AEDs have been prescribed for patients with heart disease.²¹ The reasons and motivations for instituting an AED program may differ across groups or persons. Similarly, the actual dissemination of AEDs beyond EMS use into the community is likely to be heterogeneous. We investigated a community experience with AED dissemination and use in a US metropolitan community to evaluate the frequency and outcome of PAD AED use.

Methods

Study Design, Population, and Setting

This investigation was a cohort study of out-of-hospital cardiac arrest cases due to underlying heart disease that were treated by "public access defibrillation" between January 1, 1999, and December 31, 2002, in Seattle and surrounding King County, Washington. Public access defibrillation was defined as out-of-hospital cardiac arrest treated with AED application by persons outside the traditional first-responder EMS. Thus, cases treated by non-EMS AEDs, regardless of location or AED operator, were considered PAD AEDs. The study was approved by the investigators' Institutional Review Board.

King County including Seattle has a population of \approx 1.75 million persons and comprises urban, suburban, and rural areas. Seventy-six percent of inhabitants are white, 11% Asian, 6% Hispanic or Latino, and 5% black.²²

Community-Responder AED Program

In 1996, a community conference was held to discuss issues surrounding the dissemination of AEDs beyond EMS. Participants identified the existing EMS system as an integral part of any AED program. Liability concerns were cited as a potential obstacle preventing AED dissemination and EMS participation and leadership. The passage of Washington state law in 1999 outlined the necessary steps for AED program liability protection. The law addressed requirements for training, maintenance, medical supervision, and EMS notification (available at www.leg.wa.gov/RW/index.cfm?fuseaction=section§ion=70.54.310).¹⁹

After passage of the law, the Seattle Fire Department Medic One and the Emergency Medical Services Division of Public Health–Seattle and King County developed a voluntary Community Responder AED Program in Seattle and King County. The Community Responder AED Program was designed to facilitate a coordinated effort that would comply with Washington State law and ensure an optimal response during a cardiac arrest. A program manager was designated (B.W.) to coordinate the Community Responder AED Program. The manager is a health professional (nurse) certified as a CPR and AED instructor.

The manager's responsibilities include program announcement and publicity, enrollment, and follow-up. Announcement and publicity is achieved through a variety of methods. To make potential AED owners aware of the Community Responder AED Program, printed informational packets were developed and distributed to local hospitals, clinics, institutions such as libraries, and public meeting sites, as well as to EMS agencies and AED manufacturers. The program maintains a telephone contact number.

Enrollment in the Community Responder Program requires that potential PAD AED entities fulfill AED and CPR training requirements, notify local EMS and emergency 9-1-1 dispatch, acquire medical direction, and develop a plan for ongoing training, AED maintenance, and program notification should AED use occur. The program manager either provides CPR and AED training or directs entities to certified training organizations. The initial training includes recommendations for retraining and AED maintenance. The AED site information is registered with local EMS and dispatch. As a result, in case of a 9-1-1 call for cardiac arrest, dispatch is automatically alerted that an AED is available on site and can relay this information to the caller and responding EMS. The entity is directed to notify the program in the event of an AED use. Medical

supervision is provided by agreement with the King County EMS Medical Program Director or the Medical Director of Seattle Fire Department Medic One (at no cost). Medical supervision is responsible for approving medical authorization for device placement and use, reviewing events within the context of ongoing EMS surveillance for out-of-hospital cardiac arrest, and addressing other issues that may arise as part of the program. In addition, the program conducts periodic follow-up via a written survey that inquires about ongoing training and maintenance and any AED use. For those who do not respond to the mailed survey, a phone contact is attempted. Taken together, response is \approx 75%.

EMS System

Citizens in Seattle and King County access EMS by calling 9-1-1. Seattle and surrounding King County are served by a 2-tiered EMS response system.²³ First and second tiers of EMS complete standard medical incident reports for every EMS-treated cardiac arrest case that includes information regarding demographic, clinical, and event characteristics. Death certificates or hospital records for each patient are reviewed to determine survival to hospital discharge. In this investigation, Seattle EMS classified the cause of the cardiac arrest on the basis of the information provided by the EMS incident report, whereas surrounding King County used a combination of incident reports, death certificate information, and the hospital discharge diagnosis. This approach to classification was consistent for the 4 years of the study.

Data Collection

For each participating entity in the Community Responder AED Program, information was collected during registration that included site name and address, site coordinator, medical supervisor, device location, number of persons trained, and type of training, as well as plans for maintenance and ongoing training. Information about cardiac arrest involving PAD AEDs was collected from 3 possible sources: the EMS report, a direct contact between the EMS agency and Community Responder program manager, and/or a direct contact between the PAD AED entity and the program manager. For all events, EMS attempted to review the AED electronic record.

Statistical Analysis

Descriptive statistics were used to assess the duration of exposure and use of PAD AEDs according to location type, the proportion of cardiac arrests that were treated by a PAD AED, and characteristics of the PAD AED cases. A χ^2 analysis with test for trend was used to determine whether the proportion of arrests treated by PAD AEDs increased over the 4 years of the study.

Results

A total of 475 AEDs were registered in the Community Responder AED program, 102 in the year 1999, 136 in 2000, 155 in 2001, and 82 in 2002. The AEDs were located in a variety of settings (Table 1). A total of 4004 persons underwent initial training in CPR and AED skills with a median of 5 trained per site.^{1,14} All sites were registered with emergency dispatch centers.

In the years 1999 through 2002, a total of 2124 treated cardiac arrests cases were screened in Seattle, with 1767 (83.2%) considered to be due to heart disease, whereas in surrounding King County, a total of 3037 treated cases were screened, with 1987 (65.4%) considered to be due to heart disease, which resulted in a total of 3754 treated cardiac arrest cases due to underlying heart disease. During the 4 years from 1999 through 2002, 50 cases of out-of-hospital cardiac arrest due to heart disease were treated by PAD AEDs before EMS arrival, for an overall incidence of 4.9 PAD AED treated arrests per 100 AED-years (Table 1). The proportion of all

TABLE 1. Percent Distribution of AEDs in the Community Responder AED Program by Setting in Seattle and King County 1999–2002

| Location Type | AEDs, % (n) | AED-Years | Events | Incidence* |
|----------------------------|-------------|-----------|--------|------------|
| Business | 36.8 (175) | 392 | 18 | 4.6 |
| Police | 12.0 (57) | 169 | 4 | 2.4 |
| Medical | 11.0 (52) | 136 | 15 | 11.0 |
| Private | 10.7 (51) | 77 | 0 | 0 |
| Recreational | 9.9 (47) | 89 | 6 | 6.7 |
| Government | 9.3 (44) | 90 | 2 | 2.2 |
| School | 7.4 (35) | 43 | 1 | 2.3 |
| Senior center/nursing home | 2.9 (14) | 26 | 4 | 15.4 |
| Total | 475 | 1022 | 50 | 4.9 |

*Incidence is No. of events per 100 AED-years.

EMS-treated cardiac arrests that were treated by PAD AEDs increased each year from 0.82% (8/974) in 1999 to 1.12% (11/980) in 2000, 1.41% (13/923) in 2001, and 2.05% (18/877) in 2002. Comparable figures were 1.56% (3/192) in 1999, 3.03% (5/165) in 2000, 5.88% (11/187) in 2001, and 5.23% (8/153) in 2002 for nonmedical public setting arrests and 2.42% (4/165) in 1999, 2.83% (6/212) in 2000, 1.30% (2/154) in 2001, and 4.23% (7/166) in 2002 for out-of-hospital medical setting (ie, nursing home, doctor's office, dialysis center, non-EMS medical transport) arrests. Twenty-two percent (11/50) of the PAD AED-treated cases were not registered in the Community Responder AED Program. Nine of these events occurred in medical clinics. On the basis of a follow-up survey of a sample of sites during 2000 and 2001, a PAD AED was applied for an event other than cardiac arrest in a similar number of cases: 15 nonarrest events compared with 13 actual cardiac arrest events among the sampled sites during the time period. No adverse outcomes were reported from the AED application in these nonarrest events.

Characteristics of the 50 cardiac arrest cases treated initially by PAD AED are presented in Table 2. Overall, 76% (38/50) were admitted to the hospital and 50% (25/50) were discharged alive from the hospital, with most discharged to home. Among persons presenting with presumed ventricular fibrillation (PAD shock advised), 81% (34/42) were admitted to the hospital and 55% (23/42) were discharged alive. Eleven persons regained a pulse before EMS arrival (all after an AED shock). Of these 11, 10 were discharged alive from the hospital. When stratified by location, 48% (13/27) who experienced the arrest in a public nonmedical location, 58% (11/19) in an out-of-hospital medical setting, and 25% (1/4) in a private residential setting were discharged alive. Survival was similar across the AED operator groups: 54% (14/26) for medically trained operators, 50% (9/18) for lay operators, and 50% (2/4) for police (the operator was unknown in 2 cases).

Survival for all cases of out-of-hospital cardiac arrest due to heart disease in Seattle and King County from 1999 through 2002 was 14.6% (548/3754), whereas survival was 24.3% (419/1722) for all witnessed arrests, 29.0% (202/697) for public-setting arrests, and 17.5% (245/1399) in public plus out-of-hospital medical settings. EMS first-tier response

TABLE 2. Characteristics of Cases Treated by PAD AEDs (n=50)

| Characteristic | Value |
|--------------------------------------------------------------------------------------|------------|
| Age, y, median (25th %, 75th %) | 64 (54,75) |
| Male, n (%) | 38 (76) |
| Location, n (%) | |
| Public nonmedical | 27 (54) |
| Out-of-hospital medical | 19 (38) |
| Home/private residence | 4 (8) |
| Witnessed, n (%) | 46 (92) |
| Bystander CPR, n (%) | 50 (100) |
| Person who applied and operated AED, n (%) | |
| Nurse/physician/other medical | 26 (52) |
| Lay responder | 18 (36) |
| Police | 4 (8) |
| Unknown | 2 (4) |
| Presumed VF rhythm, n (%) | 42 (84) |
| No. of PAD shocks before EMS arrival, median (25th %, 75th %)* | 1 (1, 3) |
| Interval from 9-1-1 call received to EMS dispatch, min, median (25th %, 75th %)† | 1 (1, 2) |
| Interval from EMS dispatch to scene arrival, min, median (25th %, 75th %)† | 4 (3, 6) |
| Combined interval from call received to scene arrival, min, median (25th %, 75th %)† | 5 (5, 7) |
| Admitted to hospital, n (%) | 38 (76) |
| Survival to hospital discharge, n (%) | 25 (50) |
| Discharge location, n (%)‡ | |
| Home | 22 (88) |
| Nursing home/rehabilitation center | 3 (12) |

VF indicates ventricular fibrillation.

*Among those persons who received a PAD shock (n=42).

†Interval information available for 40 cases (interval from 9-1-1 call received to EMS dispatch), 46 cases (interval from EMS dispatch to scene arrival), and 38 cases (combined interval from call received to scene arrival).

‡Among those discharged alive after hospitalization (n=25).

interval from time of dispatch to scene arrival was 5.7 ± 2.5 minutes in King County and 3.7 ± 1.6 minutes in Seattle.

Discussion

During the 4 years of study, a variety of groups and individuals undertook an AED program. A small but increasing proportion of out-of-hospital cardiac arrests were treated by PAD AEDs. Survival was 50% in cases treated by PAD AED, a figure considerably better than most EMS systems and similar to other out-of-hospital PAD AED programs in specialized settings.^{3,9,10}

In this community, the surveillance of PAD AED use required a coordinated effort that was guided by EMS. The undertaking initially required legislation that in part outlined legal requirements for AED ownership and consequently provided liability protection to involved parties. In response, EMS developed a Community Responder AED Program and registry that provided important services aimed at ensuring proper response in case of a cardiac arrest. Surveillance was

also aided by an advanced EMS system with an established practice for reporting and reviewing cardiac arrest. Finally, surveillance required participation by other potential stakeholders, most notably the entities that adopted AED programs and AED manufacturers, local agencies involved in layperson education for heart emergencies, and community leaders.

A heterogeneous collection of medical, government, police, and business groups and individuals undertook an AED program according to the Community Responder registry. Although the registry was voluntary, most events treated by PAD AEDs, especially those outside physicians' clinics, were registered with the program, which suggests that the registry may have been representative of AED dissemination into the community. Importantly, some sites have been identified as high risk, such as dialysis centers or nursing homes.¹⁷ Other sites presumably possess lower risk. In this regard, the overall incidence of PAD AED use in this experience was 5 per 100 AED-years of exposure, a figure less than the projected rate used to design the PAD Trial. The variety of sites likely reflects different factors that may influence the decision to undertake an AED program, including scientific reports, an entity's past experience or knowledge of cardiac arrest, personal preferences, economic considerations, and legal requirements.^{17–21,24–27}

As might be expected during the initial years of community-wide AED dissemination, PAD AEDs were used in only a small proportion of arrests. The proportion, however, increased each year and to some extent may reflect the increase in the cumulative total of PAD AEDs in the community. Whether this temporal trend of increasing PAD AED use will continue is uncertain. Importantly, the community-wide dissemination of PAD AEDs is not necessarily constrained to public location sites that might ultimately limit the public health implications of PAD AEDs.²⁸ In the present cohort, some AEDs were situated in private locations, and actual cardiac arrests that occurred in the home were treated by PAD AEDs. Ultimately, a multifaceted strategy of AED dissemination that uses a variety of responders and locations may enable the greatest involvement of PAD AEDs.^{13,16,29,30}

Half of the 50 persons treated with PAD AEDs survived to hospital discharge, with similar survival for nonmedical and out-of-hospital medical settings and when the AED was operated by a nonmedical or medical provider. The high level of survival appears to be the consequence of both the predominance of ventricular fibrillation as the presenting rhythm and the high rate of conversion of ventricular fibrillation to a perfusing rhythm. In contrast to most EMS systems that report less than 50% of cardiac arrest cases in ventricular fibrillation, 84% of cardiac arrest victims presented in ventricular fibrillation in the present investigation, a proportion similar to the EMS circumstance with extremely short response intervals or PAD responder programs in gaming establishments and airports.^{9,10} The difference is likely in part the result of the time-dependent deterioration of ventricular fibrillation to asystole.³¹ In addition, survival among those presenting in ventricular fibrillation was $\approx 50\%$, consistent with prior experience that ventricular fibrillation can be corrected more readily soon after collapse and subsequently

becomes more difficult to treat.⁶ Taken together, the findings suggest that many cardiac arrests could be treated with defibrillation if an AED could be applied within minutes of the collapse and that survival might be better than traditional experience.

This investigation has limitations. Although the study community comprised a heterogeneous population that may be representative of other communities, AED dissemination and the EMS system may differ from other communities, factors that may influence the generalizability of the findings. We did not have complete information on every case and in some instances had to rely on surrogate measures. For example, the AED electronic recording was not available in some instances, so that the presence of ventricular fibrillation was determined on the basis of whether the AED provided a shock. Prior reports have demonstrated that AEDs have a high level of accuracy for identifying ventricular fibrillation.³² In addition, although we are unaware of any cases of out-of-hospital cardiac arrest that occurred where a PAD AED was present but not accessed or applied, these situations may have occurred. The investigation had minimal power to evaluate for differences in patient, event, or therapy characteristics between survivors and nonsurvivors treated with PAD AEDs. Neurological outcome was not collected routinely for the survivors outside of Seattle, although the location of discharge (most to home) suggests that neurological function was satisfactory in most cases.

Given the considerable challenge of improving survival from out-of-hospital cardiac arrest, no particular strategy is likely to constitute a single best approach. Rather, efforts to strengthen each link in the chain of survival may incrementally improve outcomes. Careful surveillance and review will be an important part of assessing the potential community impact of technological, research, and programmatic advances in resuscitation. Studies to date support the use of AEDs and CPR by nontraditional responders as an approach that may improve survival from cardiac arrest. The results of this investigation suggest that the dissemination of PAD AEDs has had a small impact in out-of-hospital cardiac arrest. The impact of this strategy may ultimately depend on economic, scientific, public preference, and health policy considerations that will influence the extent and location of AED distribution, as well as the infrastructure to support and coordinate such programs.

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