The Role of Public Access Defibrillation in the Chain of Survival from Out-of-Hospital Cardiac Arrest

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Introduction

Approximately 400-460,000 cardiac arrests occur out of the hospital in the United States each year. (1) Despite major advances in the Emergency Medical Services (EMS) system, overall survival from out-of-hospital cardiac arrest (OHCA) remains poor, averaging only 5-8% in most communities. (2) Sudden death is the first manifestation of underlying cardiovascular disease in the majority of patients with OHCA. (3) A ventricular tachyarrhythmia (ventricular tachycardia or ventricular fibrillation) has been documented to be the triggering event in up to 80% of cases. (4)

The purpose of this chapter is to discuss the concept, history, and role of Public Access Defibrillation (PAD) in the chain of survival from out-of-hospital cardiac arrest in the United States.

Public access defibrillation and the “chain of survival”

In 1991, the American Heart Association introduced the "chain of survival" metaphor to represent the sequence of events that ideally should occur to maximize the odds of successful resuscitation from cardiac arrest in adults. (5) The links in the chain include early access (recognition of the problem and activation of the EMS system by a bystander), early CPR, early defibrillation for patients who need it, and early advanced cardiac life support (ACLS).

In the United States, only about 3% of all out-of-hospital cardiac arrest victims survive to leave the hospital with neurological functioning intact. (5) However, there is substantial variability in the odds for survival among various geographic locations and in different subsets of patients. The outcome of resuscitation is strongly influenced by the patient's initial cardiac rhythm. The likelihood of survival is relatively high if the initial rhythm is VT or VF (particularly if the VF is "coarse", the arrest witnessed, and prompt CPR and defibrillation provided). The best outcomes from VT/VF in adults occur regularly in the electrophysiology laboratory, where prompt defibrillation (typically within 20-30 seconds of arrhythmia onset) from pulseless VT/VF results in virtually 100% survival. The next best outcomes are in cardiac rehabilitation programs, where defibrillation is provided within the first minute or two, and survival is approximately 85-90%. Survival from out-of-hospital VT/VF treated by police officers equipped with automated external defibrillators (AEDs) in Rochester, MN has av-

eraged 50% with a median time from collapse to defibrillation of about 5 minutes. (6) Outcomes in many locations with EMS systems that cannot provide defibrillation until 10 minutes or more after patient collapse typically yield survival rates of <10%. Thus, survival from cardiac arrest due to ventricular tachyarrhythmias is highly dependent on the time interval from collapse to defibrillation. For every minute delay from the patient's collapse to defibrillation the chance for survival diminishes by approximately 7-10%. (5)

The primary rationale for PAD is that there are many densely populated public areas where conventional EMS systems cannot respond within an acceptable response time interval to provide early defibrillation. In the majority of such locations, it is not physically possible to reach victims in a short period of time (<3 minutes from collapse) using any reasonable, cost-effective strategy for deployment of EMS system resources.

History of PAD in the United States

The concept of public access defibrillation emerged in 1990 from the American Heart Association's (AHA) "Future of CPR" Task Force led by Dr. Leonard Cobb of Seattle, Washington. This group recognized that the majority of out-of-hospital cardiac arrests occur in the home. However, for those events occurring in a public place, they reasoned that the use of automated external defibrillators (AEDs) by laypersons could shave precious minutes off of the time interval from collapse to defibrillation. Based on the Task Force's report, the AHA established an AED Task Force, led by Dr. Myron Weisfeldt of New York City.

The 1992 AHA Guidelines on Cardiopulmonary Resuscitation and Emergency Cardiac Care included the following statement regarding the PAD concept:

> *"The placement of automated external defibrillators (AEDs) in the hands of large numbers of people trained in their use may be the key intervention to increase the survival chances of out-of-hospital cardiac arrest patients…The widespread effectiveness and demonstrated safety of the AED have made it acceptable for nonprofessionals to effectively operate the device. Such persons must still be trained in CPR and use of defibrillators. In the near future, more creative use of AEDs by nonprofessionals may result in improved survival…Participants in the national conference recommended that (1) AEDs be widely available for appropriately trained people, (2) all fire-fighting units that perform CPR and first aid be equipped with and trained to operate AEDs, (3) AEDs be placed in gathering places of more than 10,000 people, and (4) legislation be enacted to allow all EMS personnel to perform early defibrillation."*

In 1994, the Task Force held its first PAD Conference in Washington, DC. At this landmark gathering, the conference participants affirmed the need for further research on the concept and encouraged the AHA to support additional discussion on the subject. The Task Force published an official AHA "Statement on Public Access Defibrillation" in 1996, declaring that:

> *"Early bystander cardiopulmonary resuscitation (CPR) and rapid defibrillation are the two major contributors to survival of adult victims of sudden cardiac arrest. The AHA supports efforts to provide prompt defibrillation to victims of cardiac arrest. Automatic external defibrillation is one of the most promising methods for achieving rapid defibrillation. In public access defibrillation, the technology of defibrillation and training in its use are accessible to the community. The AHA believes that this is the next step in strengthening the chain of survival. Public access defibrillation will involve considerable societal change and will succeed only through the strong efforts of the AHA and others with a commitment to improving emergency cardiac care.*
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> *Public access defibrillation will include (1) performance of defibrillation by laypersons at home and by firefighters, police, security personnel, and nonphysician care providers in the community; and (2) exploration of the use of bystander-initiated automatic external defibrillation in rural communities and congested urban areas where resuscitation strategies have had little success…*
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In 1996, the AHA worked with key members of the United States Congress to introduce legislation intended to remove legal barriers to implementation of early layperson defibrillation using AEDs. Termed the “Cardiac Arrest Survival Act”, the bill underwent numerous modifications before it was finally passed into law in 2000.

The Second PAD Conference was held in 1997 in Crystal City, Virginia. This congress was truly international in scope and further defined the various “levels” of potential AED use in a community, the minimum training requirements, regulatory issues, likely cost-benefit, and need for a prospective, multicenter, randomized clinical trial.

The International Liaison Committee on Resuscitation (ILCOR) issued a Statement on Defibrillation in 1997, stating that:

> “A first responder is defined as a trained individual acting independently with a medically controlled system. In the community this may include police, security officers, lifeguards, airline cabin attendants, railway station personnel, volunteers who render first aid, and those assigned to provide first aid at their workplace or in the community and who are trained in the use of an AED.

- *Establish acceptance, support, and coordination by responsible community medical and EMS authorities.*
- *In some specific situations consider combining training programs for bystander defibrillation with training in BLS, with careful monitoring of results.*
- *Arrange for review of all clinical applications of an AED by a medically qualified program coordinator or a designated representative.*
- *Plan for critical program evaluation at two levels: individual clinical uses and overall EMS system effects.*
- *Use only AEDs; practical considerations render manual defibrillators inadvisable for lay use.*
- *Continue innovations to produce simple, lightweight, economically priced, and highly reliable AEDs.”* [11]

An AHA PAD Research Task Force was established in 1997, co-chaired by Dr. Joseph Ornato from Richmond, Virginia and Dr. Barbara Riegel from San Diego, California. This effort culminated in the funding and execution of the “PAD trial”, the single largest randomized, multicenter clinical trial on this subject to date.

Early Clinical Experience with PAD

Prior to the PAD trial, the evidence supporting the broad implementation of PAD was limited, consisting mainly of relatively small case series with and without historical controls from airlines, casinos, and law enforcement services documenting the ability of properly trained “layperson” first responders to use AEDs appropriately, safely, and effectively. In this early experience, the laypersons who used AEDs were generally trained individuals employed in positions that regularly require them to “take command” in an emergency. It was clear whether laypersons without such a role could use these devices safely and effectively, although limited experience at several major US airports suggested that the “fire extinguisher” model may have merit.

Home lay person AED use

Clinical experience with the use of AEDs by lay persons dates back to the late 1980s, when Dr. Mickey Eisenberg and his colleagues trained family members of 59 patients who had survived out-of-hospital cardiac arrest in King County, Washington. Ninety-seven survivors of out-of- hospital VF were enrolled in the study; 59 patients received AEDs, and 38 patients were controls. During the study period, seven deaths occurred in the hospital without preceding out-of-hospital cardiac arrest or from non-cardiac causes. There were fourteen out-of-hospital cardiac arrests, ten in the AED group and four in the control group. There was only one long-term survivor, who was actually in the control group. In the AED group, among the ten cardiac arrests for which the device was available, it was applied to only six patients. Only two of these patients were in VF; one was resuscitated with residual neurological deficits and survived several months. These study results suggested that there might be only a small potential for in home lay person use of AEDs to save high risk patients. However, the specific devices used in the project were early generation AED technology and not engineered for optimal lay person application based on today’s standards. In contrast, Swenson et al. reported three successful resuscitations out of five cardiac arrests in 48 patients whose families had been trained to use an AED.

Lay person AED use at large public gatherings

More encouraging results have been obtained when community first responders have been trained to use AEDs in public places. For example, 160 security officers were trained to use these devices at Vancouver's World Expo 1986. Five cardiac arrests occurred among the 22.1 million visitors. The AED was correctly applied in all cases by security personnel. In two cases, the initial rhythm was VF and defibrillation was successful. Both patients had a pulse and were regaining consciousness by the time EMS personnel arrived on the scene.

Police AED use

Dr. Roger White and his colleagues have shown that police officers who are trained and equipped to use AEDs can further enhance survival from out-of-hospital cardiac arrest compared to that which can be achieved by conventional EMS services. They retrospectively studied the outcome of all consecutive adult patients with non-traumatic cardiac arrest treated in Rochester, Minnesota from November 1990 through July 1995. In that city, a centralized 911 center dispatched police and an ALS ambulance simultaneously for suspected cardiac arrest cases. Accurate intervals were obtained by synchronizing all defibrillator clocks with the 911 dispatch center clock. The personnel who arrived first delivered the initial shock. In patients for whom shocks were delivered by police initially, paramedics provided additional treatment if needed. Main outcome measures were time elapsed before delivery of the first shock, restoration of spontaneous circulation (ROSC), and survival to discharge home. Of 84 patients, 31 (37%) were shocked initially by police. Thirteen of the 31 demonstrated ROSC, without need for ALS treatment. All 13 survived to discharge. The other 18 patients required ALS; 5 (27.7%) survived. Among the 53 patients first shocked by paramedics, 15 had ROSC after shocks only, and 14 survived. The other 38 needed ALS treatment; 9 survived. Call-to-shock time for all patients was less in the police group than in the paramedic group (5.6 versus 6.3 minutes, p= .038). For all patients, the call-to-shock time interval was shorter in those with ROSC after shocks only than in those who needed ALS (5.4 versus 6.3 minutes, p= .011). Survival to discharge was 49% (41 of 84), with 18 of 31 (58%) in the police defibrillation group and 23 of 53 (43%) in the paramedic group. The call-to-shock time interval was shorter for survivors than non-survivors (5.8 vs. 6.4, p = .020). Neither ROSC nor discharge survival was significantly different between police and paramedic-shocked patients. The presence of ROSC after an initial shock and the call-to-shock time intervals were major determinants of survival, whether the first shocks were administered by police or by paramedics. When ROSC occurred after shocks only, 27 of 28 (96%) patients survived, whereas 14 of 56 (25%) patients who needed additional ALS interventions survived (p= .001). This study showed that a high discharge-to-home survival rate could

be obtained when early defibrillation was provided by police and paramedics. When initial defibrillation attempts resulted in ROSC, the overwhelming majority of patients survived (96%). Even brief (e.g., one minute) decreases in the call-to-shock time interval increased the likelihood of ROSC from shocks only, with a consequent decrease in the need for further ALS intervention.

Commercial aircraft use of AEDs

In 1988, Dr. Richard Cummins from Seattle, Washington reviewed information reported to the International Air Transport Association on in-flight deaths that occurred during commercial air travel for the eight years between 1977 and 1984. Of the 120 airlines who were members of the International Air Transport Association, 42 carriers reported deaths during these eight years. A total of 577 in-flight deaths were recorded, for a reported average of 72 deaths per year. Deaths occurred at average rates of 0.31 per million passengers, 125 per billion passenger-kilometers, and 25.1 per million departures. The majority of those who died were men (66%, 382/577) and middle-aged (mean age, 53.8 years). Most of the individuals (77%, 399/515) reported no health problems prior to travel. Physicians aboard the aircraft offered medical assistance for 43% (247/577) of the deaths. More than half of the deaths (56%, 326/577) seemed related to cardiac problems. Sudden unexpected cardiac death was the cause of death in 63% (253/399) of the apparently healthy passengers and was the major cause of death during air travel. Dr. Cummins felt that these observations supported the initiation of programs to train cabin personnel in the skills of basic cardiopulmonary resuscitation and in the use of AEDs.

Soon thereafter, Dr. Michael O'Rourke began to install AEDs on international Qantas aircraft and at major terminal buildings serving that carrier. Selected flight attendants were trained in their use as well as the performance of CPR. Supervision was provided by medical volunteers or remotely by airline physicians. During a 64-month period, AEDs were used on 109 occasions: 63 times for monitoring an acutely ill passenger and 46 times for cardiac arrest. Twenty-seven episodes of cardiac arrest occurred onboard aircraft, often (11/27 unwitnessed, and they were usually (21/27) associated with asystole or pulseless idioventricular rhythm. In marked contrast, all 19 arrests that occurred in terminal buildings were witnessed; and VF was present initially in 17 (89%). Overall, defibrillation was successful initially in 21 of 23 cases (91%). Long- term survival from VF was achieved in 26% (2 of 6 in aircraft and 4 of 17 in terminals). In addition, the ability to monitor the cardiac rhythm onboard inflight aircraft aided decisions on whether the pilot needed to divert the aircraft from its planned destination to a closer airport. Aircraft diversion was avoided in most cases in which asystole or idioventricular rhythm was the initial rhythm, obviating the need for a costly,

and somewhat hazardous, emergency landing. Dr. O'Rourke concluded that AEDs onboard aircraft and in terminal buildings along with appropriate crew training are helpful in the management of cardiac emergencies. Avoidance of costly aircraft diversion in clearly futile situations enhanced the program's cost-effectiveness. Other major airline carriers eventually implemented AED programs as the new standard of safety.

Gaming casinos

In the mid-1990s, Dr. Terry Valenzuela and his colleagues began training and equipping security officers with AEDs in 26 Las Vegas/Clark County gaming casinos. Between April 24, 1997 and October 31, 1999, the AEDs had been used on 105 individuals whose initial cardiac arrest rhythm was VF and whose collapse was witnessed. Survival to hospital discharge occurred in 56/105 cases (survival rate= 53%). The collapse-to-first-shock time interval for the security officers using the AEDs was 4.4 $\pm$ 2.9 min, whereas the collapse-to-arrival of traditional EMS responders was 9.8 $\pm$ 4.3 min. It was concluded that rapid defibrillation by non-traditional layperson first responders is a viable strategy for significantly improving survival from out-of-hospital cardiac arrest due to VF.

Airports

The most exciting non-investigational clinical experience with PAD has come from Chicago's two major commercial airports. In 1998, AEDs were placed strategically throughout the terminal buildings and baggage claims areas at O'Hare (n= 33 AEDs) and Midway (n= 7 AEDs) airports. The devices were placed in locked, but accessible, visibly marked cases along the walls of the buildings. The program has a medical director, under whose authority the devices are placed. The AEDs were intended to be used primarily by trained airport employees. However, they are accessible to the public.

Over a two-year period, 21 persons had cardiac arrest, 18 of whom had ventricular fibrillation. With two exceptions, defibrillator operators were good Samaritans, acting voluntarily. In the case of four patients with ventricular fibrillation, defibrillators were neither nearby nor used within five minutes, and none of these patients survived. Three others remained in fibrillation and eventually died, despite the rapid use of a defibrillator (within five minutes). Eleven patients with ventricular fibrillation were resuscitated successfully, including eight who regained consciousness before hospital admission. No shock was delivered in four cases of suspected cardiac arrest, and the device correctly indicated that the problem was not due to ventricular fibrillation. The rescuers of 6 of the 11 successfully resuscitated patients had no training or experience in the use of automated defibrilla-

tors, although 3 had medical degrees. Ten of the 18 patients with ventricular fibrillation were alive and neurologically intact at one year.

The PAD Trial

The PAD Trial compared the number of OOH-CA patients who survived to hospital discharge from community facilities with volunteer responders who were trained to: 1) recognize the event, call 911, and perform CPR (CPR-only) vs. 2) recognize the event, call 911, perform CPR and provide early defibrillation with an on-site AED (CPR+AED). The study was conducted in 21 US and 3 Canadian cities. The sites chosen for inclusion had to provide a pool of potential volunteer responders and the ability to institute an emergency response plan capable of delivering an AED to the victim within three minutes. Potential sites that already had on-site personnel with a duty to respond to medical emergencies (e.g. law enforcement officers, firefighters, nurses and physicians) and facilities with prior AED programs were excluded from participation. Sites were randomized as a "community unit" if they had an expectation of at least one OOH-CA over the study period (the equivalent of ≥250 adults over age 50 for 16 hours a day, or a history of ≥1 witnessed OOH-CA in 2 years, on average). Eligible units were required to have clearly defined geographic boundaries and a typical emergency medical system (EMS) response time to defibrillation of 3–15 minutes. The primary patient study population consisted of individuals age ≥8 years with OOH-CA of cardiac etiology. Patients with OOH-CA due to trauma, drug overdose, or non-cardiac causes of arrest were excluded from the primary comparison, but not from safety evaluation.

Volunteer layperson rescuers without a responsibility to provide medical assistance were trained to competency and retrained periodically following American Heart Association guidelines or equivalent. FDA-approved AEDs from three manufacturers (Guidant Corporation, Indianapolis, IN; Medtronic, Inc., Minneapolis, MN; Cardiac Science/Survivalink, Inc., Minneapolis, MN; Medtronic Physio-Control, Redmond, WA; Philips Medical Systems, Heartstream Operation, Seattle, WA) were used.

The primary study outcome measure was the count of survivors of 'definite' OOH-CA in each arm. The unit of analysis was the "community unit," and the primary comparison between treatment arms used a two-sample, stratified t-test (comparing the mean number of survivors per unit within strata), with strata defined by center and by residential versus public unit within center. The Cerebral Performance Category (CPC) score at hospital discharge was used to assess functional outcome of survivors. Comparison between treatment arms was made using a Chi-Square test.

The study randomized 993 community units with an average data collection period of 22+/-5.5 (SD) months. The majority of study units (84%) were in public locations, most of which were recreational facilities and shopping centers.

Study results were analyzed on an “intention to treat” basis. Crossovers occurred in 5.3% (CPR-only) and 0.8% (CPR+AED) of community units. Approximately twice as many OOH-CA victims, 31 vs. 16, survived to hospital discharge in the CPR-AED vs. CPR-only subgroups (p= .03). Adverse events were rare and consisted mostly of transient psychological trauma to volunteers and stolen AEDs. No inappropriate shocks were given.

Conclusions

Although the PAD Trial showed that layperson using AEDs can double the number of lives saved from OOH-CA in public places compared to that which can be achieved when laypersons can only call 911 and perform CPR while awaiting EMS arrival, the strategy has a significant limitation: the majority (80-85%) of these events occur in the home rather than a public place. Widespread deployment of AEDs in public facilities meeting the same inclusion criteria as used in the PAD trial would save only 2-4,000 additional lives per year. Although meaningful, it represents <1% of the deaths from OOH-CA at present. The ongoing National Institutes of Health sponsored Home AED Trial (HAT) is attempting to determine whether the family members of high risk survivors of anterior wall myocardial infarction can save more lives when an AED is present in the home.

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