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Use of Automated External Defibrillators in US Federal Buildings:

Implementation of the Federal Occupational Health Public Access Defibrillation Program

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Abstract

Objective—Federal Occupational Health (FOH) administers a nationwide public access defibrillation program in US federal buildings. We describe the use of automated external defibrillators (AEDs) in federal buildings and evaluate survival after cardiac arrest.

Methods—Using the FOH database, we examined reported events in which an AED was brought to a medical emergency in federal buildings over a 14-year period, from 1999 to 2012.

Results—There were 132 events involving an AED, 96 (73%) of which were due to cardiac arrest of cardiac etiology. Of 54 people who were witnessed to experience a cardiac arrest and presented with ventricular fibrillation or ventricular tachycardia, 21 (39%) survived to hospital discharge.

Conclusions—Public access defibrillation, along with protocols to install, maintain, and deploy AEDs and train first responders, benefits survival after cardiac arrest in the workplace.

Early defibrillation coupled with cardiopulmonary resuscitation (CPR) can dramatically improve survival after cardiac arrest.^{1–3} Successful resuscitation depends on the rapid response of bystanders—both trained and untrained—to initiate CPR and locate the nearest automated external defibrillator (AED) before the arrival of emergency medical services (EMS).^{4–6} Public access defibrillation programs have placed AEDs in public locations, such as airports, casinos, and schools.⁷

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Although the effectiveness of AEDs has been demonstrated, best practices for establishing public access defibrillation programs have not been established.^{4,8} Currently, there is a major gap in implementation. In the United States, fewer than 4% of patients with out-of-hospital cardiac arrest receive treatment with AEDs from bystanders.⁹ Survival rates remain poor, even in urban areas that provide quick response by EMS.^{9,10} To optimize usage, the devices should be appropriately placed to enable rapid access.^{8,10-12}

Cardiac arrest has been reported as the cause of 15% of deaths in the workplace.¹³ The US Occupational Safety and Health Administration recommends that employers install AEDs, estimating that 160 of the 400 sudden cardiac deaths reported in the workplace each year could be prevented.¹³ The American College of Occupational and Environmental Medicine offers guidelines for the placement of AEDs in occupational settings.¹⁴ Nevertheless, few studies have been published regarding defibrillation in such settings.¹⁵⁻¹⁷

In May 2000, President Clinton directed the Department of Health and Human Services to develop guidelines for the placement of AEDs in all US federal buildings.¹⁸ The guidelines were published in 2001 in collaboration with Federal Occupational Health (FOH). Since that time, FOH has assisted federal agencies with the implementation of public access defibrillation programs in accordance with the guidelines.

Federal Occupational Health provides occupational health and wellness services to federal employees, working in partnership with federal agencies.¹⁹ The agency operates worksite health centers that provide clinical services, ensures compliance with Occupational Safety and Health Administration regulations, and offers preventive health and wellness services to federal employees. In addition, FOH oversees more than 3250 AEDs located in approximately 1000 locations across the nation. Management of this program includes (1) physician oversight of AEDs, (2) training of employees in CPR and AED use, (3) equipment purchase and maintenance, and (4) site-specific consultations for AED protocol development in accordance with guidelines.

Since 1999, FOH has monitored usage of AEDs in federal buildings under their supervision. This study characterizes the implementation of a nationwide public access defibrillation program and evaluates patient outcomes after out-of-hospital cardiac arrest in the workplace.

METHODS

Study Design, Participants, and Settings

This study is a 14-year (1999 to 2012) retrospective review of the FOH AED program database. The database includes all reported events in which an AED was brought to a medical emergency in government buildings monitored by FOH. The medical emergencies include cardiac arrest as well as other acute illnesses. In this study, we define *event* as any reported occasion in which an AED was brought to a patient in a medical emergency. The term *usage* refers to events in which the AED was successfully activated and applied to the patient, regardless of whether a shock was administered.

The FOH database records characteristics for each event, as well as characteristics of patients and first responders. Patients include federal employees, nonfederal employees, and visitors to federal buildings who experienced a medical emergency. First responders include FOH staff, such as nurses who provide care at on-site health clinics (health units), as well as nonmedical employees, managers, and security officers.

Participation of US federal agencies in the FOH AED program is voluntary; not all federal agencies choose to participate. In this study, only the buildings of participating agencies are represented. The buildings include facilities owned by the federal government, as well as corporate-managed buildings leased to federal agencies. The types of buildings are offices, museums, and federal courthouses.

Defibrillation Protocols

Protocols to purchase, install, and maintain devices, as well as site-specific emergency response plans, are developed in collaboration between FOH and the partner agency. Automated external defibrillators are placed at locations deemed appropriate and accessible by FOH staff, and schedules for regular maintenance and battery checks were instituted. At most sites, mock drills are conducted to ensure that AED placement and the established protocols are effective.

At each site, first responders trained in CPR and defibrillation are designated. In the event of an emergency, employees are educated to alert EMS, as well as the first responders who will bring an AED to the patient. The protocol requires that AEDs be brought to all medical emergencies, regardless of etiology. After an event involving an AED, the protocol requires first responders to report details of the event to FOH staff. The number of unreported events is not known.

Data Collection

The FOH staff reviews each reported event. The staff records information in the AED database regarding patient characteristics, etiology of the event, response characteristics, and patient outcomes. The data collection process and data sources are described hereafter.

- *Patient characteristics:* For events that involved employees as victims, demographic information is reported by managers, fellow employees, nurses, and other first responders. For nonemployees, information is collected from witnesses, employees, and family members.
- *Event etiology:* Event etiologies are defined in accordance with the Utstein recommendations for uniform reporting of out-of-hospital cardiac arrest.²⁰ Federal Occupational Health staff analyzes AED data cards to determine the initial presenting cardiac rhythm, when available. Interviews with scene witnesses and hospital providers also inform patient diagnosis.

A diagnosis of cardiac arrest is given to patients with (1) a shockable rhythm, either ventricular fibrillation or ventricular tachycardia, on initial presentation; (2) a sudden witnessed collapse with loss of pulse and respiration regardless of initial presenting rhythm; or (3) asystolic rhythm after an unwitnessed collapse. Per the

Utstein recommendations, cardiac arrests are presumed to be due to cardiac etiology if this is likely based on the best available information.²⁰ When a known noncardiac cause of cardiac arrest can be determined, such as exsanguination or trauma, the patients are classified with cardiac arrest due to noncardiac etiology.

In addition to cardiac arrest events, AEDs are involved in the response to other medical emergencies. Other events are classified as either (1) acute cardiac illness not resulting in cardiac arrest or (2) other noncardiac acute illness.

- *Response characteristics:* After each reported event, witnesses and first responders are interviewed to describe the circumstances before, during, and after the incident. Interviews specify whether the patient was witnessed to have collapsed or to have become acutely ill. Interviews also determine the location of the event within the building, whether or not bystanders and first responders performed CPR, and whether the device malfunctioned.

Witnesses and first responders provide estimates of response time intervals between patient collapse and first responder arrival, initiation of CPR, and first shock. Because of variation in these estimated time intervals, the supervising FOH medical director reviews the estimates to determine their accuracy and adjusts them appropriately. The AED data card provides further information on whether a shock was indicated, the total number of shocks administered, and the total time that the device was activated or turned on.

- *Patient outcomes:* *Return of spontaneous circulation (ROSC)* is defined as the recovery of any spontaneous palpable pulse, as specified by the Utstein recommendations.²⁰ The recovery of pulse may last for any duration and can occur before or after arrival of EMS. Interviews with first responders determine whether ROSC is achieved at the scene. With the consent of the patient or family member, the outcome of survival after hospital discharge is primarily determined through contact with patients, family members, coemployees, or hospital staff. When outcomes are not known or unable to be obtained, they are recorded as unknown.

Data Analysis

Summary statistics are used to tabulate data for patient characteristics (age and sex), event etiology (patient diagnosis and initial presenting rhythm), response characteristics (event location, whether or not the event was witnessed, initiation of CPR, AED activation, shock indication, the number of shocks administered, and response time intervals), and patient outcomes (ROSC and survival to hospital discharge). Data are presented as percentages or medians with range and standard deviation. All statistical analyses are performed with Stata, version 12 (StataCorp, College Station, TX). The institutional review board of the University of Pennsylvania approved this study.

RESULTS

From 1999 to 2012, more than 3250 AEDs were installed in US federal buildings and catalogued by the FOH AED program. Over this period, there were 132 reported medical

emergencies in which first responders brought an AED to the scene of the event. These events are summarized in the flowchart provided as Figure 1, which is adapted from the Utstein template for reporting cardiac arrest data.²⁰

Patient Characteristics

Table 1 provides patient characteristics. For all events involving an AED, the median age of patients was 54 years (range, 18 to 83 years; SD = 11 years). For patients with cardiac arrest due to cardiac etiology, the median age was 55 years (range, 34 to 83 years; SD = 10 years) and 70% (67) were men.

Event Etiology

Cardiac arrest due to cardiac etiology occurred in 73% (96) of all events involving an AED. An additional 2% (3) of patients were deemed to have cardiac arrest due to known noncardiac etiologies, including ruptured aortic aneurysm and pulmonary embolus.

In 8% (11) of all events, the patient suffered an acute cardiac illness that did not result in cardiac arrest. These illnesses included acute myocardial infarction and supraventricular tachycardia. In these cases, the AED was applied for monitoring even though the patient remained conscious throughout the event. An additional 17% (22) of events were considered due to noncardiac illness. These incidents included drug overdose, choking, vasovagal syncope, and concussion. Because of the uncertainty of the diagnosis, AEDs were applied to these patients after FOH protocol. The devices did not administer shocks to any patient who did not experience cardiac arrest.

Table 1 summarizes the initial presenting rhythm for patients with cardiac arrest due to cardiac etiology. Ventricular fibrillation was present in 69% (66) of patients. An additional 3% (3) of patients presented with ventricular tachycardia. Fourteen percent (14) of patients with cardiac arrest presented in asystole, 11 of whom suffered unwitnessed collapses. For 7% (seven) of patients with cardiac arrest, the initial presenting rhythm represented pulseless electrical activity with other rhythms such as sinus bradycardia. The initial presenting rhythm was unable to be obtained for 7% (seven) of patients with cardiac arrest.

Response Characteristics

Table 1 provides the locations of cardiac arrest due to cardiac etiology. Workspace settings such as cubicles, conference rooms, or break rooms were the setting of 46% (44) of all cardiac arrests. Another 17% (16) of cardiac arrests occurred in public areas, such as building entrances, cafeterias, and elevator lobbies. Thirteen percent (13) of cardiac arrests occurred in outdoor locations such as parking lots. Outdoor events included instances when passersby arrested, and first responders were called to bring the AED out of the building. Nine percent (nine) of arrests occurred in restrooms, and 5% (five) occurred in on-site fitness facilities. In 2% (two) of arrests, the patient visited the on-site health unit, requesting medical attention, before arresting.

In 70% (67) of cardiac arrests due to cardiac etiology, the patients were seen or heard to collapse. In the unwitnessed events, the patients were discovered at varying intervals from

the time that they were last seen. Thirty-eight percent (11) of the unwitnessed cardiac arrests presented with asystole. Defibrillatory shocks were given to 41% (12) of patients who were not witnessed to collapse. Of the nine arrests that occurred in restrooms, 78% (seven) were unwitnessed.

Table 2 provides additional characteristics of the responses to witnessed cardiac arrest events. Bystanders or first responders initiated CPR in 93% (41) of witnessed cardiac arrest events, for which these data were available. In 87% (58) of witnessed cardiac arrests, the AED advised defibrillation. When defibrillation was indicated, shocks were administered in all but 9% (five) of events. In two of those events, EMS arrived before the AED administered a shock. In two events, the device malfunctioned due to lack of battery charge. In one event, the reason for not administering a shock was not known.

Table 3 provides estimated median time intervals between collapse and moments during the response to witnessed cardiac arrests. The median interval between collapse and first responder arrival was 3 minutes (range, 1 to 22 minutes; SD = 4 minutes). The median interval between collapse and first defibrillatory shock was 5 minutes (range 3 to 23 minutes; SD = 5 minutes). According to AED data cards, the median total duration over which the devices were activated was 9 minutes (range, 2 to 54 minutes; SD = 10 minutes).

Patient Outcomes

Of the 54 patients with witnessed cardiac arrest due to cardiac etiology who presented with ventricular fibrillation or ventricular tachycardia, 22 (39%) survived to hospital discharge. In addition, two (4%) patients who were alive on admission died in the hospital before discharge. Survival was not known for an additional three patients (6%).

Of all 96 patients who presented with cardiac arrest due to cardiac etiology, 24 (25%) survived to hospital discharge. The survival rate for witnessed cardiac arrests was 31%, and the survival rate for unwitnessed cardiac arrests was 7%.

Return of spontaneous circulation occurred in 37% (25) of all witnessed cardiac arrest events, and ROSC was unknown for an additional 12% (eight) of witnessed cardiac arrest events (Table 2). When a shock was administered in a witnessed cardiac arrest, ROSC was achieved in 41% (22) of events.

Seventy-six percent (19) of patients who achieved ROSC ultimately survived, and survival was unknown for an additional 8% (two) of patients who achieved ROSC. There were no patients who survived after failing to achieve ROSC, although there were three for whom survival was unknown.

DISCUSSION

In this study, we reviewed a database of reported events involving AEDs in US federal buildings over the past 14 years. The implementation of a national workplace public access defibrillation program resulted in a 25% survival rate after cardiac arrest. For those patients who were witnessed to collapse and presented with a shockable rhythm, the survival rate increased to 39%.

The few published studies that have examined AEDs in occupational settings have primarily surveyed occupational physicians.^{17,21} This study demonstrates that outcomes for defibrillation in the workplace were similar to survival rates in other settings.^{1,22,23} An analysis of more than 13,000 out-of-hospital cardiac arrests demonstrated survival to be 24% after application of an AED, or nearly identical to the pooled survival rate in a review of 49 studies.^{3,24} Implementation of national AED programs in the United Kingdom and Denmark showed that survival varied from 15% to more than 50%.^{25,26}

Prior reports have suggested that cardiac arrests in the work-place are distinct from events occurring in other public places.²⁷ It has been suggested that people who arrest at work tend to be younger and in good health, resulting in relatively higher hospital discharge rates.^{16,28} This distinction is complicated by both a scarcity of evidence as well as the lack of clear definition of which settings constitute workplaces.

A key feature that distinguishes workplaces from other settings may be the opportunity for employers to implement structured systems to facilitate the chain of survival. Although AEDs are effective when used, overall rates of defibrillation before the arrival of EMS remain dismal.^{3,9} A comprehensive workplace AED program that purchases, locates, and maintains devices while preparing employees to respond to medical emergencies can increase use. Federal Occupational Health achieved many of the recommendations set forth by the American College of Occupational and Environmental Medicine regarding workplace AED programs.^{14,18}

Specifically, FOH established a management system that assumed responsibility for the entire program, as well as individual locations. The agency collaborated with medical directors, EMS systems, and local managers to develop site-specific plans. Before installation, building blueprints were reviewed to identify efficient locations for AED placement. Written protocols detailed emergency response plans. These protocols designated and trained first responders at each site that bystanders could contact immediately after notification of EMS. Importantly, FOH encouraged retraining of first responders to maintain and update their skills. Although first responders took primary responsibility for initiating CPR and defibrillation, all employees were educated regarding the indications for AED usage.

Critical to the management system were records for employee training, device maintenance, and analyses of each event. These additional data offer secondary metrics for system effectiveness and guidance for best practices, beyond patient outcomes. Attempts to record response times, while difficult, can inform future planning. An important secondary metric is the rate of device malfunction. In two events, the device failed due to battery problems despite attention to AED maintenance. Automated external defibrillator use in response to events other than cardiac arrest demonstrates integration of the devices into the overall response plan to medical emergencies.

Information on locations of cardiac arrest in the workplace could advise placement of AEDs. Nearly half of the cardiac arrests occurred in workspaces, such as the patient's office. A smaller percentage occurred in public areas such as building lobbies, where AEDs are often

placed. Nevertheless, placement of devices at entrances may have benefited patients with cardiac arrest who arrested outside of buildings, including employees and passersby. A high proportion of unwitnessed cardiac arrest events occurred in the restroom. In this study, a far higher percentage of patients with cardiac arrest who were witnessed to collapse survived than those who were not.

LIMITATIONS

This study had several limitations. First, we are unaware of cardiac arrests that did not involve the use of an AED. The total incidence of cardiac arrest in US federal buildings is unknown. Second, there may have been events involving AEDs that were not reported to FOH, despite efforts to contact clients who implemented this program. Furthermore, it is likely that other US federal buildings installed AEDs without FOH supervision, because participation in this program was voluntary.

Third, it was not possible to collect all data for all events. For example, data were often missing regarding the bystander initiation of CPR. Similarly, the ROSC outcome was unspecified for 15% of cardiac arrests. These gaps are partly due to the difficulty of obtaining accurate data in the prehospital emergency setting, which is often rushed and ambiguous.⁹ The data collected in this study often relied on later accounts of witnesses, first responders, and EMS providers, all of whom are subject to recall bias. To improve standardization of data collection, an international registry for occupational AEDs has been proposed.²⁷

A fourth similar limitation is that response time intervals were collected as estimates from first responders. Although these time intervals were reviewed by the medical staff after the event, these times should be interpreted with caution and are likely biased toward faster response times. A fifth limitation is that we were unable to ascertain survival beyond hospital discharge or determine neurological status on discharge.

Finally, an important factor that was not measured in this study may have been the culture of awareness and preparation specific to these workplaces. Education, training, and response protocols were thought to be critical to the implementation of this program; future studies should measure employee knowledge, responsibility, and willingness to act as additional outcomes that determine the effectiveness of public access defibrillation programs.

CONCLUSION

In this retrospective study of more than 3250 AEDs installed in US federal buildings under the supervision of FOH, there were 132 reported events in which AEDs were brought to a medical emergency. Of these events, 73% were due to cardiac arrest of cardiac etiology. For all patients with cardiac arrest, survival to hospital discharge was 25%. For those patients who were witnessed to collapse and presented with a shockable rhythm, survival to hospital discharge was 39%. This study is the first to specifically examine AED usage in occupational settings in the United States. These findings demonstrate the value of public access defibrillation in the workplace, as well as evidence of the importance of developing

structured systems to purchase, locate, and maintain devices and establishing protocols to respond to medical emergencies at work.

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FIGURE 1.

Reported etiology and outcomes for all events that involved an AED in a medical emergency in US federal buildings from 1999–2012. AED, automated external defibrillator; EMS, emergency medical service; VF, ventricular fibrillation; VT, ventricular tachycardia. Adapted from the Utstein style template for reporting data on out-of-hospital cardiac arrest.

TABLE 1**Patient and Response Characteristics**

	All Events (<i>n</i> = 132)	Cardiac Arrest due to Cardiac Etiology (<i>n</i> = 96)
Age, y, median	53.5	55
Sex, <i>n</i> (%)		
Men	85 (64)	67 (70)
Women	47 (36)	29 (30)
Witnessed event, <i>n</i> (%)	102 (78)	67 (70)
Location of event, <i>n</i> (%)		
Workspace	59 (35)	44 (46)
Public area	24 (18)	16 (17)
Restroom	12 (9)	9 (9)
Health unit (clinic)	11 (8)	2 (2)
Outside of building	14 (11)	13 (13)
Fitness center	5 (4)	5 (5)
Other/unknown	7 (5)	7 (7)
Initial presenting cardiac rhythm, <i>n</i> (%)		
Ventricular fibrillation		66 (69)
Ventricular tachycardia		3 (3)
Asystole		13 (14)
Paced		1 (1)
Other		6 (6)
Unknown		7 (7)

TABLE 2

Response Characteristics and Patient Outcomes for Witnessed Cardiac Arrests due to Cardiac Etiology

	Witnessed Cardiac Arrests due to Cardiac Etiology (n = 67)	Discharged Alive (n = 22 [*])	Not Discharged Alive (n = 41)
Bystander performed CPR, n (%)			
Yes	41 (61)	15 (68)	24 (59)
No	3 (5)	1 (5)	1 (2)
Unknown	23 (34)	6 (27)	16 (4)
Shock administered before EMS arrival, n (%)			
Yes	53 (79)	20 (90)	29 (71)
No [†]	5 (8)	1 (5)	4 (10)
Not indicated [‡]	9 (13)	1 (5)	8 (20)
Number of shocks administered by FOH AED, n (%)			
0	1 (1)	—	1 (2)
1	28 (42)	11 (50)	16 (39)
2	10 (15)	5 (23)	3 (7)
3	8 (12)	4 (2)	4 (10)
4	8 (12)	1 (5)	7 (17)
Unknown	12 (18)	1 (5)	10 (24)
ROSC at scene, n (%)			
Yes	25 (37)	19 (86)	4 (10)
No	34 (51)	0 (0)	32 (78)
Unknown	8 (12)	3 (14)	5 (12)

* There were 4 additional events for which survival to hospital discharge was not known.

[†] Defibrillation occurred after EMS arrival.

[‡] Initial presenting rhythm was neither ventricular fibrillation nor ventricular tachycardia.

AED, automated external defibrillator; CPR, cardiopulmonary resuscitation; EMS, emergency medical service; FOH, Federal Occupational Health; ROSC, return of spontaneous circulation.

TABLE 3

Response Time Intervals, in Minutes, for Witnessed Cardiac Arrests due to Cardiac Etiology

Median Estimated Time Interval*	Witnessed Cardiac Arrests due to Cardiac Etiology (n = 67)	Discharged Alive (n = 22)	Not Discharged Alive (n = 41)
Collapse to call to first responder	1	1	1
Collapse to first responder arrival	3	2	3
Collapse to first CPR attempt	2	2	2
Collapse to first defibrillatory shock	5	4	5
Median duration of AED activation [†]	9	9	9

* Median estimated times are calculated for witnessed events only.

[†] As recorded by the device data card, the period of time starting with AED activation and ending with shutdown of the device.

AED, automated external defibrillator; CPR, cardiopulmonary resuscitation.