Out-of-Hospital Cardiac Arrest Bystander Defibrillator Search Time and Experience With and Without Directional Assistance: A Randomized Simulation Trial in a Community Setting

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Introduction: Probability of survival after out-of-hospital cardiac arrest (OHCA) doubles when a bystander initiates cardiopulmonary resuscitation and uses an automated external defibrillator (AED) rapidly. National, state, and community efforts have increased placement of AEDs in public spaces; however, bystander AED use remains less than 2% in the United States. Little is known about the effect of giving bystanders directional assistance to the closest public access AED.
Methods: We conducted 35 OHCA simulations using a life-sized manikin with participants aged 18 through 65 years who searched for public access AEDs in 5 zones on a university campus. Zones varied by challenges to pedestrian AED acquisition and number of fixed AEDs. Participants completed 2 searches—first unassisted and then with verbal direction to the closest AED—and we compared AED delivery times. We conducted pretest and posttest surveys.
Results: In all 5 zones, the median time from simulated OHCA onset to AED delivery was lower when the bystander received directional assistance. Time savings (minutes:seconds) varied by zone, ranging from a median of 0:53 ($P = 0.14$) to 3:42 ($P = 0.02$). Only 3 participants immediately located the closest AED without directional assistance; more than half reported difficulty locating an AED.
Conclusions: These findings may inform strategies to ensure that AEDs are consistently marked and placed in visible, accessible locations. Continued emphasis on developing strategies to improve lay bystanders' ability to locate and use AEDs may improve AED retrieval times and OHCA outcomes.
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Key Words: Out-of-hospital cardiac arrest, automated external defibrillator, defibrillation, simulation, search time.

More than 350,000 out-of-hospital cardiac arrests (OHCA) occur in the United States (US) each year, and approximately 90% do not survive.[1] The probability of OHCA victim survival doubles when a bystander immediately initiates cardiopulmonary resuscitation (CPR) and uses an automated external defibrillator (AED) rapidly.[2] Likelihood of survival is highest when CPR and defibrillation are initiated within 5 minutes of OHCA and decreases by 10% for every minute that passes; however, the median emergency medical services (EMS) arrival time in the US is 8 minutes and can be longer in rural areas.[3–5]

Up to 60% of OHCAs occurring in a public area have abnormal heart rhythms that can be treated with defibrillation.[6,7] To improve access to rapid defibrillation in these cases, AEDs have been made increasingly available in public spaces.[8–13] In 2002, the US Congress passed the Community AED Act to require placement of AEDs in federal buildings and to increase their placement in high-traffic areas, such as airports, malls, churches, sports arenas, and medical settings.[12,13] Some states now also require placement of AEDs in health clubs and gyms, schools, and day care centers,[12] and many other non-EMS first responders now also carry AEDs in their vehicles.[14]

Despite programs to increase the availability of AEDs many buildings are still not equipped with AEDs, even in dense urban areas. Furthermore, within buildings that are equipped, public access is often limited, with AEDs accessible only during certain hours, located in a locked area, or obstructed from vision.[13,15] Automated external defibrillator placement and signage are

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generally not regulated, and there is currently no requirement that AEDs be registered, further challenging identification and location.[9,16] Automated external defibrillators must be maintained regularly, and regulation of maintenance varies by state, meaning that a bystander searching for an AED may find it out for maintenance or nonfunctional.[12,15]

Large-scale interventions to increase the number of registered AEDs in the community can lead to improvements in bystander defibrillation. For example, the nationwide Danish AED Network initiative deployed resuscitation training, increased placement of public access AEDs, founded an AED registry, and initiated dispatcher-assisted guidance of bystander resuscitation efforts. This initiative was able to increase bystander defibrillation in public areas from 1% in 2001 to 15% in 2012.[17] Over this period, survival after bystander defibrillation also increased. An AED network, such as this, can be used to guide bystanders to the nearest accessible AED, monitor maintenance of existing AEDs, and guide future AED placement in the community. However, public registries or maps of AED locations in the US are uncommon and, when available, often incomplete or inaccessible to bystanders when needed. Currently, no comprehensive or systematic method exists for locating AEDs in the US.[13] Despite national, state, and local attempts to increase access to AEDs in the community, bystander AED use in nonclinical settings remains less than 2% in the US,[18] and increased availability of AEDs in public spaces alone has not been found to improve survival after OHCA.[19–21]

Providing bystanders with knowledge of AED locations can facilitate their identification and retrieval,[15] reduce time to defibrillation,[22] and, ultimately, may improve OHCA outcomes. Electronic AED maps and applications are being developed and tested to improve timely bystander location and retrieval of AEDs.[11,15] However, little is known about how much time is saved by a bystander having knowledge of the closest AED and their perceptions of the benefits this provides. In this study, we compare search times and experiences between participants with and without verbal direction to the closest public access AED during an OHCA simulation in a community setting.

METHODS

Between March and June 2019, we conducted a randomized trial consisting of 35 OHCA simulation tests with adults aged 18 to 65 years. Tests were conducted in 5 zones on the University of North Carolina at Chapel Hill (UNC) campus, with 7 tests per zone. Each zone had different environmental challenges (eg, stairs, doors, crosswalks) to acquisition of a fixed, public access AED and had varying densities of AEDs (Table 1).

Before each of the 35 simulation tests, participants were consented, interviewed, and given instructions at a central location to minimize the time given to participants to acclimate to the simulation environment. Details of the questions asked during this pretrial interview have been published.[23] Briefly, participants were asked about their familiarity with the campus as well as prior knowledge of and experience with AEDs and drones. Afterward, they were escorted to the test site, where the instructions were briefly repeated, and the simulation was initiated. In each test, a pair of participants matched on sex and age group (18–34, 35–49, or 50–65 years) accompanied a life-sized manikin (Laerdal's Resusci Anne) in a simulated OHCA event. Participants were randomized on site at the location of the staged OHCA event ("event site") to perform one of 2 roles. In each simulation test, 1 participant ("caller") was instructed to stay at the event site, dial a mock 9-1-1 telephone number, and wait for a drone to deliver an AED. Upon receiving the call, the mock 9-1-1 telecommunicator followed a modified 9-1-1 telecommunicator script from our local EMS office that is in line with the American Heart Association's (AHA) 2015 guidelines for cardiac arrest basic life support sequence for untrained lay rescuers (See document, Supplemental Digital Content 1, to see the script that was used in each simulation test, http://links.lww.com/SIH/A688).[24] When instructed by the 9-1-1 telecommunicator to do so, the caller instructed the second participant ("seeker") to locate an AED in the surrounding area and return it to the event site (search 1). Both participants were blinded to the location of the event site and AEDs in the area. Each simulation test began with a research team member signaling to the 2 participants that the manikin had experienced an OHCA and concluded with each participant placing an AED next to the manikin. Search start times and AED discovery and delivery times were recorded. All times were measured using a standardized digital clock (hour:minute:second). Additional details on study design, including sample size calculations and comparisons of drone-delivered AED versus ground search times, have been published.[25] A schematic of the study design is shown in Figure 1.

At the conclusion of the first search, the seeker completed a second search from the same event site. In this second search, however, the seeker was verbally directed by a staff member to the location of the closest publicly available fixed AED and asked to obtain the AED from this known location and return it to the event site (search 2). If the participant immediately located the closest AED using the most direct path in search 1, he or she did not complete search 2. To avoid bias due to prior experience, the arrest to search start time window (ie, the

TABLE 1. Characteristics of OHCA Simulation Test Zones and Fixed AEDs in the Surrounding Area

Zone	Fixed AEDs in 600-ft Radius of Event Site, n				Average Distance to Any AED in Zone, ft	Distanceto Closest AED, ft
	Publicly Accessible at All Times	Publicly Accessible During Business Hours Only	Restricted Access at All Times	Total		
A—Courtyard of dormitory complex	0	1	0	1	512	512
B—Main campus quadrangle	1	3	1	5	488	316
C—Intermural athletic fields	3	4	0	7	353	116
D—Plaza adjacent to Student Union	1	6	0	7	254	138
E—Sidewalk next to sports arena	1	4	3	8	441	269

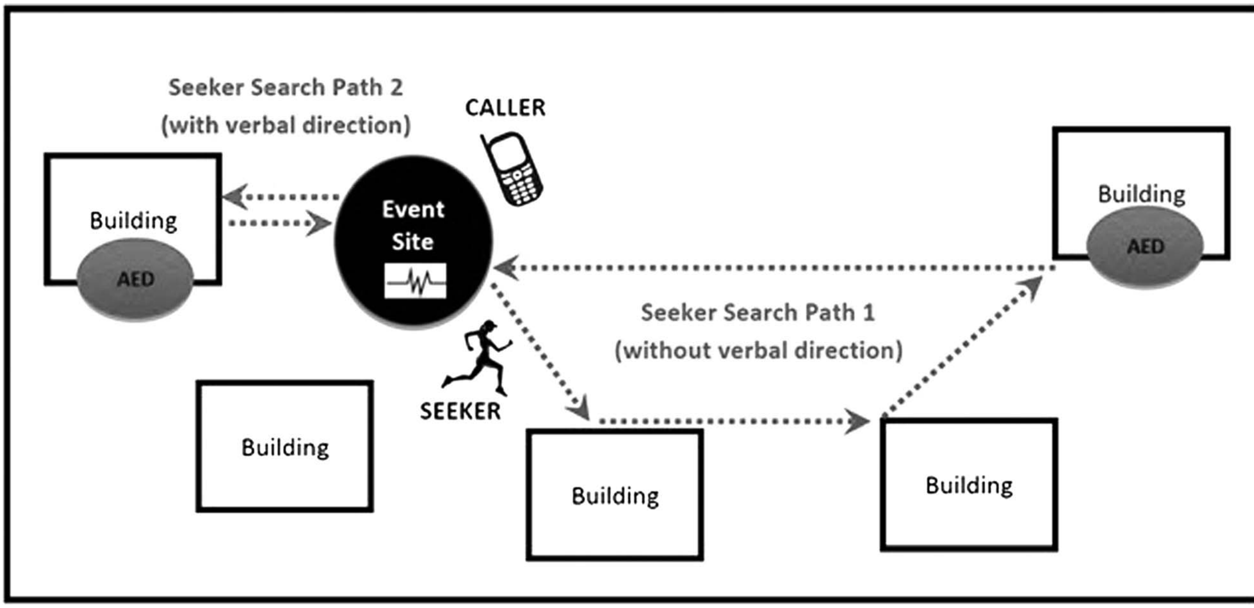

FIGURE 1. Schematic of an OHCA simulation test, with example seeker search paths without (Search 1) and with (Search 2) verbal direction.

elapsed time between time of onset of the mock OHCA and the time in the OHCA script in which the caller is instructed to ask the seeker to "go find an AED") from the first search was added to total elapsed times for both search 1 and search 2.

The routes that participants took to locate a fixed AED were tracked using the MapMyWalk application.[26] Posttrial surveys probed participants' experience searching for an AED, including search strategies and cues.[23] The UNC Institutional Review Board approved the trial protocol and consent forms (UNC IRB Number 18-0039), and all tests were conducted in accordance with UNC Public Safety guidelines.

Automated External Defibrillator and Event Site Geolocation

We established the location of AEDs in each zone using a list available from UNC's Department of Environment, Health, and Safety that was confirmed by a manual search of the area within 600 ft (200 yd) of event sites. Building managers confirmed the presence AEDs in buildings with restricted access. We manually entered GPS coordinates of AEDs and event sites using the "Coordinates–GPS Formatter" mobile phone application and used ArcGIS (ArcMap desktop, Version 10.6) to plot the coordinates.[27,28] Additional details have been published.[25]

Pretest and Posttest Surveys

All participants were surveyed individually by trained research staff before and after each test. Pretest surveys included questions querying participants' previous experience and comfort level with CPR and AEDs. Posttest surveys focused on participants' experience searching for an AED. Staff entered responses into REDCap on site.[29] The primary analyst (A.M.J.) analyzed qualitative posttest survey data and organized responses thematically. A second team member (M.E.G.) reviewed themes, and areas of disagreement were discussed until consensus was reached.

Statistical Analysis

We computed elapsed time between several components of each AED search in minutes:seconds. Summary statistics include median time intervals with interquartile ranges. Data from the pretest and posttest surveys are reported as frequencies and percentages. A Likert scale was used for participants' rating of confidence levels and comfort levels with various aspects of their search experience. Differences in median search times in searches 1 and 2 were compared using the Mann-Whitney test.

RESULTS

We conducted simulation tests, 18 with women and 17 with men. These included 15, 11, and 9 tests across the 3 age strata (18–34, 35–49, and 50–65 years), respectively. Three participants (1 each in zones B, C, and D) directly found the closest AED along the most direct path in search 1 and did not complete search 2. Seven of the 35 trials were conducted as a single participant as his or her own control due to a coparticipant not appearing for the trial.

Automated External Defibrillator Retrieval Times

In all 5 zones tested, the median time from onset of the search for an AED in a fixed location to delivery of an AED to the manikin was lower when the bystander received verbal directions to the location of the closest public access AED (Table 2). The time saved (minutes:seconds) in searches 1 and 2 varied by zone, ranging from a median of 0:53 ($P = 0.14$) in zone D (central campus plaza; 6 AEDs within 600 ft) to 3:42 ($P = 0.02$) in zone A (dormitory courtyard; 1 AED within 600 ft). Significant time savings were also noted in the median retrieval time (3:37, $P < 0.01$) in zone E (sports arena sidewalk; 8 AEDs within 600 ft), despite it having the highest overall AED density.

The median elapsed time from simulated OHCA to the seeker initiating the AED search ranged from 1:21 in zone C to 1:37 in zone A. During this time interval, the participants laid down the manikin, the caller dialed the mock 9-1-1 operator, and the seeker initiated CPR and started the AED search when instructed by the caller. When this initial interval was added to the search/retrieval times for search 1, the total median time from simulated OHCA to AED delivery was within the AHA's target of 5 minutes in only 2 zones (C and D), the

TABLE 2. Median (Interquartile Range) Elapsed Time in Minutes:Seconds of AED Delivery From Search for AED in Fixed Locations for Search 1 and Search 2, by Test Zone

	Zone A (n = 7)	Zone B (n = 7)	Zone C (n = 7)	Zone D (n = 7)	Zone E (n = 7)
Arrest to search start	1:37 (1:31–1:44)	1:35 (1:28–1:44)	1:21 (1:10–1:25)	1:30 (1:07–1:31)	1:31 (1:28–1:46)
Search 1					
Search start to AED Found	3:28 (2:50–4:15)	2:59 (1:03–6:02)	2:12 (1:28–4:51)	0:39 (0:35–1:31)	3:59 (3:10–5:26)
AED found to AED delivery	1:33 (1:13–1:56)	1:00 (0:44–1:30)	0:59 (0:54–1:23)	0:22 (0:15–0:25)	2:06 (1:56–2:22)
Total: arrest to delivery	**7:00 (4:49–7:44)**	**5:46 (3:12–9:05)**	**4:35 (3:47–7:29)**	**2:56 (2:18–3:18)**	**7:56 (6:44–8:45)**
Search 2					
Search start to AED Found	0:56 (0:45–1:34)	0:50 (0:41–1:02)	1:16 (1:00–1:37)	0:18 (0:15–0:23)	1:15 (1:00–1:35)
AED found to AED Delivery	0:52 (0:49–1:14)	0:51 (0:41–1:13)	1:00 (0:52–1:16)	0:16 (0:15–0:18)	1:33 (1:12–1:50)
Total: arrest to delivery	**3:18 (3:07–4:33)**	**3:03 (3:02–4:20)**	**3:30 (3:24–4:10)**	**2:03 (1:53–2:07)**	**4:19 (3:43–5:04)**
Difference in median total time*	**3:42 (P = 0.02)**	**2:43 (P = 0.09)**	**1:05 (P = 0.08)**	**0:53 (P = 0.14)**	**03:37 (P < 0.01)**

*Search 1 total time–search 2 total time; Mann-Whitney P values, 2-sided, α = 0.05.
The bold entries signify summary times.

zones with the highest number of publicly available, accessible AEDs. In search 2, total median times were less than 5 minutes for all 5 zones, ranging from 4:19 in zone E to 2:03 in zone D. In search 1, 57% (n = 20) of participants delivered the AED within the AHA's target of 5 minutes, compared with all but one (n = 34, 97%) of those in search 2.

Participant Perceptions

In pretest surveys, 24 (68.6%) of participants reported ever having had AED training, 33 (94.2%) reported feeling confident or very confident that they knew what an AED looked like, and 27 (77.1%) reported feeling confident or very confident that they knew how to use an AED.

In posttest surveys, 26 (74.3%) reported having asked for help in their initial search from a bystander not involved in the study, 4 (11.4%) reported having had someone offer help without being asked, and 18 (52.4%) felt that it was easy or very easy to find an AED. Open-ended questions probed participants' feelings and thoughts in search 1 as well as details on their search strategy and thought process.

Automated External Defibrillator Search Experience

The most common feelings that participants reported were those of being "anxious," "stressed," "panicked," or having a sense of urgency about their search, with several describing not knowing where to look. A few, however, reported feeling calm or prepared for their search (eg, because of training or because when they asked for assistance in locating an AED, they received help).

Many participants reported feeling "disappointed" or "frustrated" with different aspects of the search. Several expressed frustration that nonstudy bystanders did not know where an AED was when they asked for help. Some participants encountered buildings that were locked or inaccessible; others felt that AEDs were in locations that were not clearly marked or difficult to find.

A few participants reported feeling grateful to have had more than 1 bystander responding to the simulated event, so that 1 participant could stay with the "victim" and continue CPR. Upon finding an AED, participants overwhelmingly expressed relief and even joy. Many still felt a sense of urgency to deliver the AED to the event site quickly.

Automated External Defibrillator Search Strategy

Some participants described starting their search in the closest buildings. Others decided to prioritize populated areas, public buildings, or places with an information desk or staff available. Several felt that athletic buildings would have AEDs available. Some described relying on their prior knowledge or familiarity with campus in prioritizing where to look. Many participants tried to enter buildings that were locked or required authorized entry. An example of 1 participant's search paths for searches 1 and 2 is provided in Figure 2.

Within buildings, participants reported looking for AEDs mounted on a wall near the entryway, near a fire extinguisher or fire alarm, near an entrance desk or lobby, near a bathroom, or in main hallways. Some reported looking for signage or a bright color. A few reported looking on walls at eye level.

DISCUSSION

Timely defibrillation is 1 of the 5 links in the AHA's Chain of Survival: from calling 9-1-1, to early CPR, to rapid defibrillation, to effective advanced life support, and to integrated postacute care.[30] The AHA aims to implement programs that enable defibrillation within 5 minutes after collapse.[31] In this simulation study, even in the AED-rich setting of a university campus and among a study population with experience and confidence with AEDs, approximately half of participants felt that it was difficult or very difficult to locate a fixed, public access AED. In nearly half of the tests without verbal direction, participants were unable to deliver an AED within the AHA's target of 5 minutes. Receiving verbal direction to the closest public access AED resulted in time savings of approximately 1 to 4 minutes. Given that the likelihood of survival decreases by 10% each minute after the onset of arrest, these time savings may be critical.

Although time savings were greatest in the study zone with only 1 AED within 600 ft and lowest in the zone with the most plentiful AEDs, the relationship between AED density and unassisted retrieval times was not consistent and was only statistically significant in 2 of the 5 zones ($P < 0.05$). In the zone with 8 public access AEDs within 600 ft, unassisted search and retrieval times were long. In this zone, although 5 of these 8 were publicly accessible during the time of the tests, participants noted frustrations with barriers to AED access, such as needing to cross roads or climb stairs, to access locked or inaccessible buildings, and poor AED signage.

Interventions to date have focused on increasing access to AEDs in high-traffic public areas; however, findings from this simulation study highlight that even when multiple AEDs are nearby, lay bystanders have difficulty finding and returning

FIGURE 2. Example search path for AED in fixed locations, without (Search 1, Panel 1) and with (Search 2, Panel 2) verbal direction to closest AED location, Zone B. Under Armor, Inc. MapMyWalk. 2019.

them to a victim in a timely manner, contributing to even more "missed opportunities."[28] Strategies to direct a bystander to the location of the nearest AED may improve outcomes. One strategy currently in development is a mobile phone application to help lay bystanders locate the closest public access AED. Programs designed to alert and dispatch nearby CPR-trained laypersons via mobile phone have increased rates of bystander CPR, and similar programs are in the process of being tested for their ability to improve AED retrieval times in places with accessible AEDs.[32–35] Because many states do not require a registry of AEDs to be maintained, up to half of AEDs deployed in OHCA are unregistered.[36,37] To address this, some EMS agencies have partnered with the "PulsePoint AED" application, which uses crowdsourcing to populate its electronic map of public access AEDs, enabling users to upload pictures and confirm accessibility.[38,39]

Another strategy to decrease AED search and retrieval time is more similar to the methods used in our simulation study, using directions from the 9-1-1 dispatcher. A recent simulation study found that verbal direction to the nearest public access AED was more effective than either no directional assistance or assistance via an AED geolocation mobile application.[11] Current barriers to this strategy include lack of systematically registered and maintained AEDs and integration with 9-1-1 dispatch systems. As highlighted by the findings in this study, strategies to direct bystanders to the closest AED will also need to take into consideration potential access barriers, such as roads, stairs, locked doors, and AED signage, which is not currently regulated or systematic.

A particularly innovative potential strategy to improve access to timely defibrillation is the delivery of an AED to a lay bystander by unmanned aerial vehicles ("drones").[40] This strategy has the advantage of allowing the bystander to stay with the victim and continue CPR, while the drone delivers the AED and may serve as a particularly valuable strategy in rural areas[41–43] or places without public access AEDs (eg, in homes, where 70% of OHCAs are estimated to occur).[28] This strategy is still in the feasibility testing stages, however, in the US.[25]

Findings from this study suggest that to reach the AHA's target of lay bystander search and delivery of an AED to an OHCA victim within 5 minutes, more needs to be done. Requiring registration of AEDs and regulating maintenance, as well as standardizing placement and signage of AEDs, would aid lay bystanders in their search for public access AEDs. Our findings about bystanders' current search strategies and visual cues may inform future strategies to ensure that AEDs are consistently marked and placed in locations that are visible, accessible, and in locations that people are likely to look.

There are limitations to our study. First, study participants were not older than 65 years and were not a random sample of the general population. Because this was designed a feasibility study, it was not powered to detect differences between men and women or among age groups. In addition, our AED database was manually confirmed by study staff. A larger-scale program of alerting bystanders may not have up-to-date information of AEDs and thus complicate and even prolong the AED search with outdated information. Also a potential limitation, in this simulation, our method of directional assistance was performed in person rather than over the phone, which is likely more effective. Furthermore, although we queried in the pretest survey whether participants had familiarity with AED placement in the general campus environment, we did not query in the posttest survey whether they had familiarity with the specific zone to which they were randomized. Finally, because seekers served as their own controls, participants may have learned about their environment and potential obstacles in search 1 that may have reduced their time in search 2. However, in the particular geography of the zones that we investigated, the benefit of practicing in an undirected manner would not expect to bias the elapsed time of the directed search. Furthermore, most participants did not find the closest AED; in fact, in many of the tests, the closest AED was in a different part of the zone in which the seeker conducted search 1. Importantly, only 3 participants directly located the closest AED along the most direct path; therefore, the majority gained little information from prior experience, and in these 3 cases, the experiment was not repeated.

Our study also has notable strengths. It incorporated timing data and an evaluation of bystander perceptions and was conducted in a community setting with both male and female participants aged 18 to 65 years. In addition, the study design incorporated a modified 9-1-1 telecommunicator script from our local EMS office and followed the AHA's 2015 guidelines for cardiac arrest basic life support sequence for untrained lay rescuers.[24] This study builds on a growing body of literature informing public health interventions through community-based simulation[44,45] and may inform other simulation-based community research. Importantly, this study joins other recent studies demonstrating the utility of simulation-based research for emergency response to OHCA.[46–48] This study may serve as a valuable resource for others seeking to implement simulation as a methodology for community-based studies of quality improvement interventions. The findings from this simulation study also emphasize the importance of and opportunities for reducing bystander search times for public access AEDs and may inform strategies, such as systematized AED signage and placement, AED registration, and phone apps that are easily triggered. Findings from this study also highlight the importance of considering potential obstacles or barriers to access (eg, crosswalks, stairs, locked doors, restricted access) when making decisions in AED placement. Future studies should investigate differences in AED search times, strategies, and cues used by different subgroups of bystanders (eg, age, sex) and compare time savings, financial costs, and other factors associated with different AED placement and signage strategies.

CONCLUSIONS

In this OHCA simulation study, we demonstrated that giving a lay bystander verbal direction to the location of the nearest AED reduced the median search and delivery time in a variety of public locations with varying AED densities. Continued emphasis on developing strategies and programs to improve lay bystanders' ability to locate and use public AEDs may improve AED retrieval times and OHCA outcomes.

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