Employment and residential characteristics in relation to automated external defibrillator locations

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Background Survival from out-of-hospital cardiac arrest (OHCA) is generally poor and varies by geography. Variability in automated external defibrillator (AED) locations may be a contributing factor. To inform optimal placement of AEDs, we investigated AED access in a major US city relative to demographic and employment characteristics.

Methods and Results This was a retrospective analysis of a Philadelphia AED registry (2,559 total AEDs). The 2010 US Census and the Local Employment Dynamics database by ZIP code was used. Automated external defibrillator access was calculated as the weighted areal percentage of each ZIP code covered by a 400-m radius around each AED. Of 47 ZIP codes, only 9% (4) were high-AED-service areas. In 26% (12) of ZIP codes, less than 35% of the area was covered by AED service areas. Higher-AED-access ZIP codes were more likely to have a moderately populated residential area (P = .032), higher median household income (P = .006), and higher paying jobs (P =. 008).

Conclusions The locations of AEDs vary across specific ZIP codes; select residential and employment characteristics explain some variation. Further work on evaluating OHCA locations, AED use and availability, and OHCA outcomes could inform AED placement policies. Optimizing the placement of AEDs through this work may help to increase survival. (Am Heart J 2015;0:1-7.)

Cardiac arrest is usually fatal.[1–4] Using automated external defibrillators (AEDs), along with cardiopulmonary resuscitation (CPR), can dramatically increase survival in out-of-hospital cardiac arrest (OHCA) from less than 2% to greater than 50%.[5] Although most cardiac arrests occur in the home, public availability of AEDs can help support resuscitation for those arrests that happen outside residential locations.[6–8] The American Heart Association recommends that AED use occur within approximately 3 minutes of an OHCA to maximize the probability of survival.[9] For that reason, optimal distribution of these public AEDs would require that they be easily locatable for bystanders at the side of an arrest patient. However, the distribution of AEDs in most communities is unknown and is not routinely tracked or published. Requirements for AED reporting and registration vary widely by state, and it is unclear who is responsible and accountable for this essential aspect of our public health system.[10,11]

Public access defibrillation (PAD) programs seek to increase AED use by making AEDs more accessible and cost-effective, as well as providing education about AED use to the public.[12] Many of these programs have been shown to increase survival from OHCA. For example, in Stockholm, survival to 1 month topped 70% when a public AED was used compared with a 42% for first responder defibrillation.[13] Other PAD programs show similar survival gains.[14–16] In addition, location-based strategies have also been investigated. These strategies explored placement of AEDs in particular types of buildings, such as exercise facilities,[17] government buildings,[18] and schools.[19] However, these locations may not be high-risk locations for OHCAs—a study of OHCAs in Maryland found that the most frequent locations for AEDs (such as community pools and schools) had the lowest incidence of OHCAs and, conversely, the

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highest-risk OHCA locations (such as nursing facilities and assisted living facilities) had no AEDs.[20]

Although survival of a cardiac arrest is multifactorial,[21] AED access is an essential part in the chain of survival. We sought to determine AED distribution and access in a major US city relative to population-based residential and employment demographic characteristics. We reviewed AED locations across the city and correlated AED locations with population and employment density patterns. Findings from this analysis could reveal factors associated with AED presence and also reveal risks for AED deserts that represent an opportunity for public health intervention.

Methods

Data sources

We used AED location data from a Philadelphia AED Registry (n = 2,559 devices). The registry includes devices from the MyHeartMap Challenge (MHMC; n = 852 unique devices) and subsequent contributions (n = 1707 unique devices) from AED manufacturers, distributors, and local businesses. The MHMC was a 6-week crowd-sourced contest to locate AEDs across the city of Philadelphia. Data validity (ie, if an AED was actually located at the reported address) was determined by 3 approaches. First, we compared the GPS coordinates of the AED photograph associated with the mobile phones with the GPS coordinates of the building location. If GPS coordinates were not associated with the photograph (ie, location services were not turned on when the photograph was taken, or the photograph was taken with on a non–GPS-enabled device), then the reported AED was compared with lists of locations provided prechallenge by AED device manufacturers. Reported AEDs not identified by those methods were then validated via door-to-door searches by the research team from AEDs already in the registry from prechallenge and postchallenge collection efforts (AED manufacturers, distributers, and local businesses). Most submissions (99%) were validated by comparing the GPS coordinates of the photograph with the GPS coordinates of the reported buildings and by comparing submissions with data of AED locations identified by the research team. Devices from AED manufacturers, distributors, and local businesses were validated via either calling reported locations or visiting reported locations to confirm AED placement. Although there is limited guidance and legislation as to where to place AEDs, guidelines were set forth in 2001 that direct federal buildings to have at least 1 AED onsite.[22] Pennsylvania state law requires that AEDs be placed in all public schools[23] and hotels.[24] A Philadelphia-based non-profit provides AEDs to all recreation centers within the city.[25] In addition, AEDs are placed in many areas of public transit (ie, airports and train stations).

US Census and Local Employment Dynamics (LED) data by ZIP code were used for residential and employment demographic characteristics, respectively. Variables from each data source were chosen to encompass population density, socioeconomic status, and race/ethnic composition based on previous studies.[26,27] Census characteristics include number of residents, percent of residents with a high school degree or above, percent of residents unemployed, median household income, and percent of African Americans (categories of other race/ethnicities were too small to explore in these data by ZIP code). Employment characteristics were used from the LED database, which combines data from the US Census Bureau with state labor market information agencies. State labor market agencies send information to the US Census Bureau regarding local labor market conditions, including wages, industry locations, hiring figures, and other relative labor data. For this study, the data we use include number of employees/jobs, the percent of jobs where a high school education is needed, percent of jobs paying at least $40,000 per year, and percent of African American employees.

AED access

To estimate AED access in each ZIP code, we created a "service area" for each AED location. Each area was then defined as all space within 400 m of the AED. We estimated that 400 m corresponded with a 3- to 4-minute walk. The AED service areas were spatially overlaid on ZIP code tabulation area boundaries obtained from 2010 Census Bureau TIGER/Line shapefiles, and the proportion of the ZIP code within 400 m of an AED calculated as the ratio of the total ZIP code area within an AED service area to the total ZIP code area. We report these as a percentage of the ZIP code covered by the AED service area relative to the total area of the ZIP code. In addition, we separate ZIP codes into tertiles based on AED access, creating a "low" (third tertile), "medium" (second tertile), and "high" (first tertile) group of ZIP codes. ZIP codes were classified as AED "deserts" or "cold spots" with less than 38% of their area within 400 m of an AED (third tertile). ZIP codes with more than 65% of their area covered by an AED service area were classified as AED high density areas (first tertile).

Statistical analysis

We used ArcGIS (Version 10.1; Redlands, CA) software to map AED locations, residential and employment characteristics, and access measures. Automated external defibrillator access by ZIP code was related to Census and LED characteristics. Analysis of variance was used to analyze the differences between residential and employment characteristic group means. The median test was used to test differences between groups for medians. All statistical analyses were performed with STATA version 12, College Station, TX.[28]

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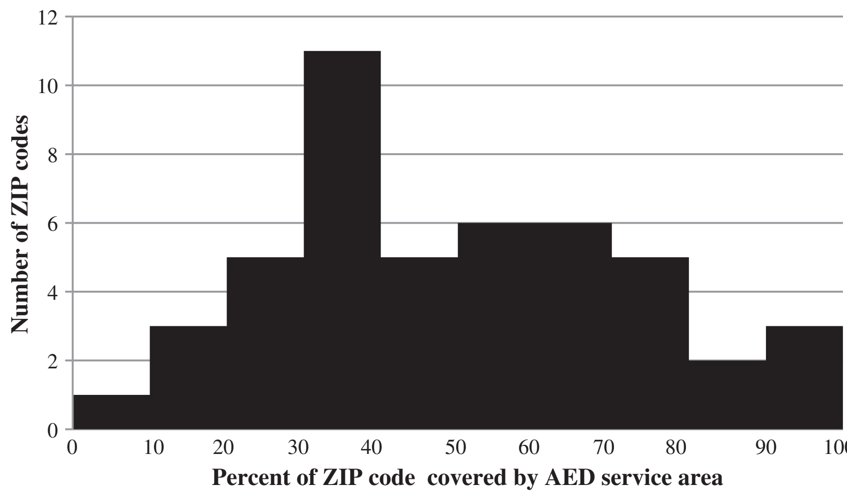
Figure 1



Percent of ZIP code area within AED service area. The vertical axis shows the percent of each ZIP code within a 400-m radius service area of ZIP code AEDs. The horizontal axis is the number of ZIP codes.

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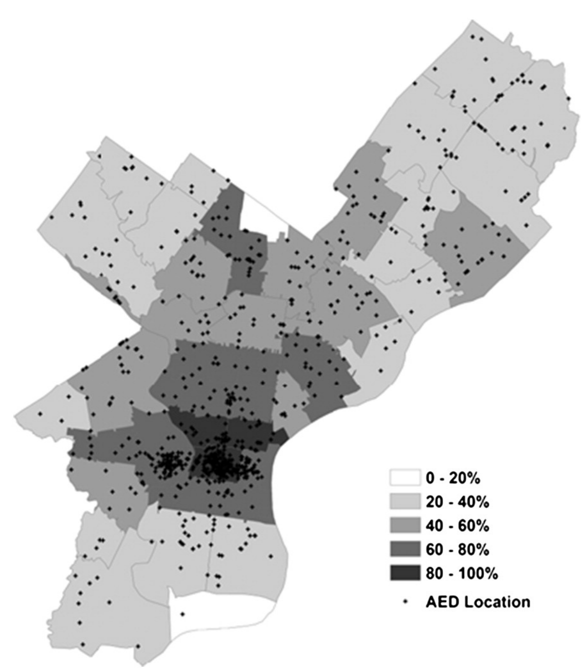
Results

Automated external defibrillators are widely distributed across the city, with high-density areas in the center of the city with the largest population. Automated external defibrillator access varied, ranging from 6% coverage to greater than 90% coverage by ZIP code, with most ZIP codes having between 30% and 60% coverage (Figure 1). In only 9% of ZIP codes would an individual be within 400 m of an AED for all points within that ZIP code. On average, 52% of the area within a ZIP code had access to an AED. In 8 ZIP codes, only 30% of the area is covered by an AED service area. Figure 2 displays AED access across ZIP codes. Central ZIP codes, with higher densities of jobs and residents, also have higher percentages of AED coverage than less-dense outer ZIP codes, where there are many AED cold spots.

Table shows the overall distribution of residential and employment characteristics, as well as these ZIP code characteristics delineated by tertiles—low, medium, and high AED access. High-access ZIP codes tend to have higher median household incomes (P = .006) and a slightly higher percent of high school graduates (P = .028); however, these ZIP codes also have a lower median residential population (P = .032) and higher percent of unemployed residents

Figure 2



Proportion of ZIP code within AED service area, 400-m radius. Each dot represents an AED location. Darker areas represent a higher percent of the ZIP code within an AED service area.

(P = .007). However, only one employment characteristic differed by ZIP code access—high-access ZIP codes tend to have a higher percent of employees earning more than $40,00 than low- or medium-access ZIP codes (P = .008).

Table. Summary statistics by ZIP code AED access and residential and employment characteristics

	Overall		Low access		Medium access		High access		
	Mean/ Median*	SD/IQR	Mean/ Median	SD/IQR	Mean/ Median	SD/IQR	Mean/ Median	SD/IQR	*P*
Residential characteristics									
Total population*	31,853	19,589-45,647	29,972	14,404-32,206.5	45,647	31,379-57,125	27,777	12,340-35,783	.032
% HS graduates	72.8	11.9	78.5	7.1	67.5	10	72.7	15.7	.028
% Unemployed	5.7	2.6	4.2	2.1	6.2	2.2	6.9	2.7	.007
Median household income*	32,248	16,151-46,520	24,625.5	18,777-35,625	28,679	26,655-35,650	38,142.5	34,212-44,202.5	.006
% African American	40.2	33.8	34.5	35.7	43	34	43.5	34.3	.712
Employment characteristics									
No. of Jobs*	7837	4322-13,234	4969	2737-8666.5	7855	4771-10,550	12,982	7262-48,188	.180
% HS education needed	91.3	1.9	91.5	1.3	90.6	2.1	92	2.2	.133
% Above $40,000	37.2	9.3	34.2	7.9	35	5.8	43.5	11.5	.008
% African American employees	33.7	12.5	31.5	13.6	35	12.8	34.6	11.3	.686

Abbreviation: IQR, Interquartile range.
*These variables are reported as medians and associated IQRs to account for skewness.

Discussion

This study has several important findings. To the best of our knowledge, this is the first study to identify that there is significant variation in AED access in a major urban city using a comprehensive data set of AEDs. Second, several residential characteristics and 1 employment characteristic were related to AED access, which may be helpful in explaining variation in access.

Variation in AED access was geographically displayed with more central city ZIP codes as AED hot spots. In outlying areas of the city where ZIP codes tended to be geographically larger, AEDs tended to be sparser. These outlying areas typically had a greater concentration of residential housing or industrial zoned properties, relative to the central city area. In addition, many of the AED hot-spot ZIP codes also contained transportation centers (eg, train station, airport). Areas of high population movement have been found to be associated with OHCA incidence[29] and, thus, areas where AEDs may be more likely to be located. Finally, government buildings tend to have AEDs, and these buildings tend to be located in the center city area. As such, areas with low AED coverage may contain fewer public entities mandated and/or willing to purchase an AED available to the public.

Although previous studies have evaluated residential characteristics or community-level characteristics in relation to AEDs and OHCAs, we extended the analysis to include employment characteristics. One employment characteristic—salary—was related to AED access across ZIP codes. Areas that employ individuals with higher salaries tend to have greater AED access. Similar results have been found by other researchers with regard to bystander CPR—the likelihood of bystander CPR was significantly less in low-income neighborhoods and minority communities.[30] Also, other health resources, including accident and emergency care and fire stations, are less accessible in disadvantaged neighborhoods.[31]

Although only 1 employment characteristic was related, several residential characteristics were related to AED access. High-AED-access ZIP codes had higher median household income, but they also had a moderately populated residential area and had the highest unemployment. This may be due to residents with higher incomes living outside the central city area in less densely populated areas. In addition, medium-access ZIP codes had the highest population of residents, potentially due to areas of the city surrounding the center with mixed use—both residential areas next to business areas. Further investigation of these trends will help inform the placement of AEDs.

This shows that further investigation is needed to not only explore AED placement and geographic penetration but also determine the locations of AEDs with respect to how likely they are to be used in an emergency situation. Optimal placement of AEDs, coupled with the willingness of laypersons to use them, is crucial when determining how to increase OHCA survival given that onsite AEDs greatly increase the survival of cardiac arrest patients compared with dispatched AEDs.[21,32] Our measure of AED access solely accounts for distance to a device. There are many other variables that contribute to whether this AED will actually be usable by a willing bystander. These include device visibility, availability for public use, and public knowledge of how to use the device. Unlike other emergency equipment, such as fire extinguishers, AEDs do not have universal signage or standard areas of placement.[33] Prior work has illustrated that AEDs can be easily and effectively used by untrained laypersons and are located in many public places, such as schools, office buildings, and restaurants. Knowledge of first-aid training, as well as resuscitation training, has been found to increase OHCA survival. For example, Denmark's initiatives to

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mandate resuscitation training in schools, increase first-aid training, and distribute self-instruction kits for CPR have led to a dramatic increase in OHCA survival rates.[34]

Furthermore, the density of and access to AEDs can inform policy and practice of optimal AED placement. As such, PAD may be cost-effective in areas with a high probability of OHCA. Given that an estimated 20% of cardiac arrests occur in public places,[12] strategically placing OHCAs in high-risk areas may be cost-effective. A study of a PAD program in Europe, where AEDs were placed in municipal buildings, showed that locations of cardiac arrests over a period of 10 years were not within reasonable distance to AEDs. In fact, none of the placed AEDs were used when an OCHA occurred.[10] Thus, it is not clear that more AEDs will alter outcomes as AED use is multifactorial and likely dependent on location-, bystander-, and individual-level characteristics.

Limitations

There are several limitations to consider. First, the MHMC registry of installed AEDs in Philadelphia County may not contain all of the AEDs in this area—to the best of our knowledge, no US registries include all AEDs with mechanisms in place to continuously validate locations. However, the data in the MHMC database were collected by the public via crowdsourcing, the database uniquely includes AEDs that are likely to be available and accessible to the public and more readily locatable in an emergency. We believe that this is to-date the most comprehensive data set of AEDs in Philadelphia given the crowdsourcing nature of the MHMC and many additional sources of AED data (eg, canvassing, local business contributions, AED manufacturers, and crowdsourcing).

Similarly, we were unable to incorporate a measure of "public" compared with "private" access AEDs. However, because a significant proportion of the data were collected through a crowdsourced database, these AEDs were most likely to be the most accessible to the public. Thus, the calculation of AED access is compelling because our database is heavily based on public reporting of AEDs.

Although mobile AEDs may be important to consider and we were unfortunately unable to do that in this article, it is unclear in the literature the extent to which mobile devices would actually increase OHCA survival. In rural areas, the time it would take for a mobile AED to reach a patient may not be feasible. However, in urban residential areas, mobile AEDs carried by police, firefighters, and first responders that can easily maneuver to an OHCA may be an option, and we did not account for these locations. Thus, identifying areas of higher risk for cardiac arrests will be important to effectively and efficiently distribute both mobile and fixed AEDs.

Although this study was conducted in a large urban city and findings may be generalizable to areas similar to this, these findings may not be generalizable to all cities or urban areas. Given differential placement of AEDs based on state- and local-level laws and regulations, the relationship between characteristics and AED placement may be different.

The data used were also cross sectional, so it has information about AED locations at one point in time. There may be more AEDs installed after the database was created, as well as AEDs that were uninstalled. Similarly, Census and LED data are a snapshot of demographic characteristics of employees and thus do not track changes in these variables over time, or at different times of the day when population density may be more or less depending on day of the week (ie, work week vs weekend).

Analysis was conducted at the ZIP code level due to the availability of employment data at this geography. A more granular analysis (within the Philadelphia region) would likely dilute the variation in employment variables. A smaller unit of analysis (such as the block group) was not available with the LED data.

Lastly, we were not able to include the floor level of AEDs in the analysis. In areas of the city that have buildings with several floors, not all AEDs would be located on the first floor. In many buildings, AEDs where located on every floor, up to the 42nd floor of one particular building.

Despite these limitations, this study shows the vast variation in placement of AEDs across an urban area and characteristics of these areas. This work illustrates the need for more studies that use randomized trials, natural experiments, or other innovative study designs to investigate placement of AEDs as well as knowledge and use of AEDs in public spaces. Other studies have found that education regarding AEDs is limited, and using these findings to further our knowledge of the link between AED knowledge, placement, and use.

Conclusion

Automated external defibrillator access varied significantly across an urban city. Automated external defibrillators were more likely to be located in select areas across the city, including moderately populated residential areas, areas with higher median household income, and areas where employees have a higher average salary. Factors contributing to AED access are likely multifactorial and include measures of visibility and availability. Policies that address distributing public AEDs to areas where there is a dearth of AEDs may increase OHCA survival, along with public education and training. Indeed, studies show that a wider placement of AEDs in large cities is needed; however, placement of AEDs should be carefully considered to maximize their effectiveness. To improve survival from usually fatal cardiac arrest, a further understanding of AED density and access is needed to optimize this vital link in the chain of survival.

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