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A cross-sectional analysis of out-of-hospital cardiac arrests in a metropolitan area to determine optimal automated external defibrillator placement

Mukadder Tortumlu[1]*, Umut Payza[2], Hüsniye Ebru Çolak[3]

[1]Department of First Aid and Emergency Care, Vocational School of Health Services, Izmir Katip Çelebi University, [2]Department of Emergency Medicine, Faculty of Medicine, Atatürk Training and Research Hospital, Izmir Katip Çelebi University, Izmir, [3]Department of Geomatics Engineering, Faculty of Engineering, Karadeniz Technical University, Trabzon, Türkiye

**Corresponding author*

Abstract:

OBJECTIVES: The aim of this study is to determine the most appropriate locations for the effective use of automated external defibrillators (AEDs) by examining the locations and frequency of out-of-hospital cardiac arrests (OHCAs) in a metropolitan city in Izmir.

METHODS: This research is a retrospective cross-sectional study. The data of the study were obtained from the Emergency Health Automation System. Data belonging to OHCA cases intervened by emergency aid ambulances were analyzed. The data were recorded and mapped by matching the regions where deaths occurred with the address records. Geographic Information Systems technologies were used in mapping the data. Kernel density analysis was used to produce density maps of point cases. Data analyses were performed with IBM SPSS Statistics 25.0 Statistical Program, and binary logistic regression analysis was used to determine the factors affecting the frequency of arrest. The significance value was accepted as $P < 0.10$ for logistic regression analysis and $P < 0.05$ for other tests.

RESULTS: In the study, a total of 1790 OHCA cases were identified in public areas in the center of the metropolitan city between 2015 and 2020. Of the 1790 OHCAs, 34.5% were female and 65.5% were male. 49.4% of the deaths were seen in public areas and on streets and avenues where human movement is high. Approximately 34.5% of the deaths were seen in nursing homes. Only one cardiac arrest case was seen at the international airport in the city. The average arrival time of ambulances was found to be 7.3 min in the city center.

CONCLUSION: This study is the first AED location determination study conducted in Turkey based on OHCA cases. Each country and region should reveal its sociocultural differences and make its plans by taking population mobility into account. Instead of making decisions based solely on the number of deaths, population mobility should be the determining factor. Countries should evaluate their AED installation policies in this context.

Keywords:

Automated external defibrillator, basic life support, bystander, out-of-hospital cardiac arrest, survival

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ORCID:
MT: 0000-0001-8493-4641
UP: 0000-0002-5297-1066
HEÇ: 0000-0002-3000-1704

Address for correspondence:
Mukadder Tortumlu, Department of First Aid and Emergency Care, Vocational School of Health Services, Izmir Katip Çelebi University, Izmir, Turkey.
E-mail: mukadder.ozbek@ikcu.edu.tr

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BoxED section

What is already known on the study topic?

- The use of AEDs for OHCA cases has a great importance in survival
- It is recommended to plan the residential areas to which AEDs will be placed for each city/region by considering transportation and living conditions.

What is the conflict on the issue? Has it importance for readers?

- Despite all efforts, there is still uncertainty about the most suitable AED locations
- Survival rates remain low in countries where AEDs are not placed in appropriate locations
- It is predicted that the correct determination of the locations to be placed will increase the benefits of AEDs, have significant effects on survival.

How is this study structured?

- In this study, addresses of out-of-hospital deaths were examined retrospectively. Then, using GIS, Core Density Maps of these addresses were produced.

What does this study tell us?

- AEDs must be kept close to nursing homes where the elderly and chronic patients live
- It was observed that deaths under the age of 65 mostly occur in sports facilities, prisons, and schools/educational institutions
- Not only the densely populated areas but also the shopping centers and government buildings that have high human activity during the day must be considered in planning. When AED installation policies are determined, each country should identify its sociocultural differences.

Introduction

The most important consequence of cardiac arrest is myocardial and neurological damage that is caused by hypoxia.[1,2] It is important to ensure the return of spontaneous circulation (ROSC) as soon as possible to avoid this damage.[3] Especially in out-of-hospital cardiac arrests (OHCAs), the time required for the medical teams to reach the scene is quite vital. In this time, cardiopulmonary resuscitation (CPR) practices that will be performed by eyewitnesses, and the use of automated external defibrillators (AEDs) is very important.[4] CPR training has been used for a long time to increase survival after OHCAs. Especially in the late century, the common use of AEDs became an important healthcare policy. Public education efforts for AED use are ongoing.

Despite the efforts of the medical teams to increase the intervention rates, teaching the CPR and AED use to the public other than healthcare staff, and the dissemination of this device, the survival rates of the victims of sudden cardiac death and the rate of discharge without neurological sequelae are quite low.[5-7] One of the most important reasons for the low survival rates is the inability to disseminate the use of AEDs at adequate levels, and the uncertainty regarding their placement in residential areas.[1,2,6,7]

It is predicted that the correct determination of the locations to be placed will increase the benefits of AEDs and have significant effects on survival. For this reason, it is recommended to plan the residential areas to which AEDs will be placed for each city/region by considering transportation and living conditions.[1,2,6,7]

The present study aimed to ensure the efficient placement and use of AEDs in residential areas by examining the locations and incidences of OHCAs in the city of İzmir, Türkiye. The results of the study will provide insight regarding the places where AEDs must be placed in similar residential areas and population distribution.

Methods

Study design

The current study was conducted in Izmir, Türkiye. Izmir is the third largest metropolitan city in Turkey. The central area of the city covers an area of about 900 km^2, and the population is about 3 million in the central area. Ethics Committee approval was obtained from Izmir Katip Çelebi University, Atatürk Training and Research Hospital, Non-Interventional Ethics Committee (13.02.2020, number: 611).

The "Emergency Calls" made to emergency healthcare services for out-of-hospital deaths in Izmir between January 1, 2015, and January 1, 2020, were analyzed in the study. The OHCAs that occurred in the city were analyzed retrospectively through the Emergency Health Automation System (EHAS), which is the 112 data system of the healthcare system. The data and localizations of deaths were analyzed from the EHAS. The areas where the deaths occurred were matched with the address records, and the data were recorded and mapped. Kernel density analysis was made to generate the density maps of cardiac arrest cases represented by dotted marking. In addition, maps were created using the mean center, central feature, and standard deviation (SD) ellipse (directive distribution) of the dotted case distribution and were marked on the map.

In the study, a dot-plot distribution map, which showed the distribution of OHCA cases (*n*: 1766) and maps, which showed the distribution densities of the cases over the geographical areas, were produced [Figures 1 and 2]. Furthermore, the mean center, central feature, and SD

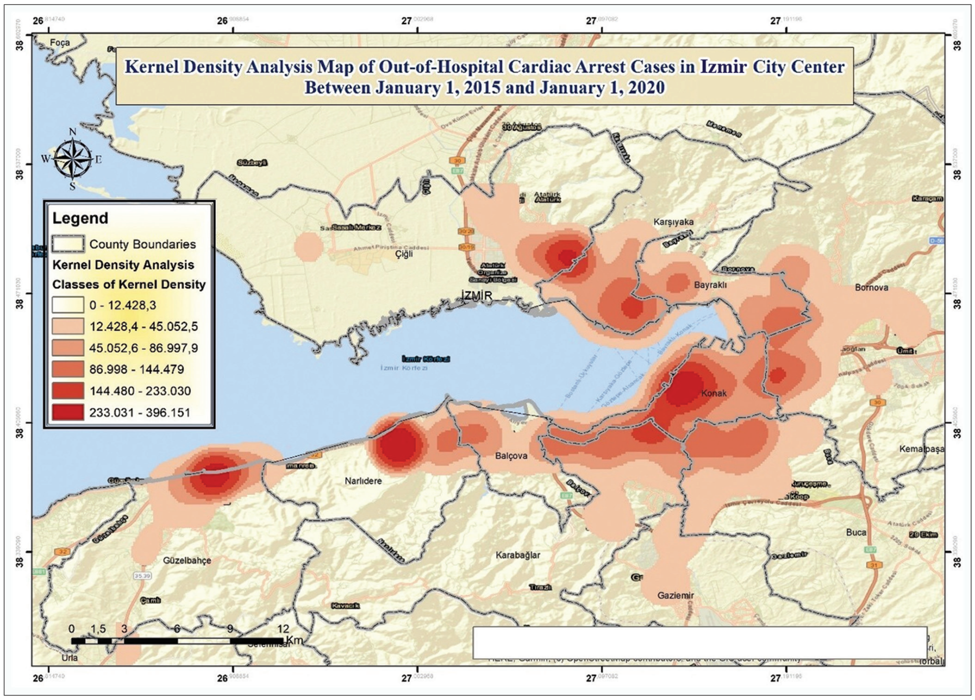

Figure 1: Core density analysis map of out of hospital cardiac arrest cases in the city center of İzmir, Türkiye

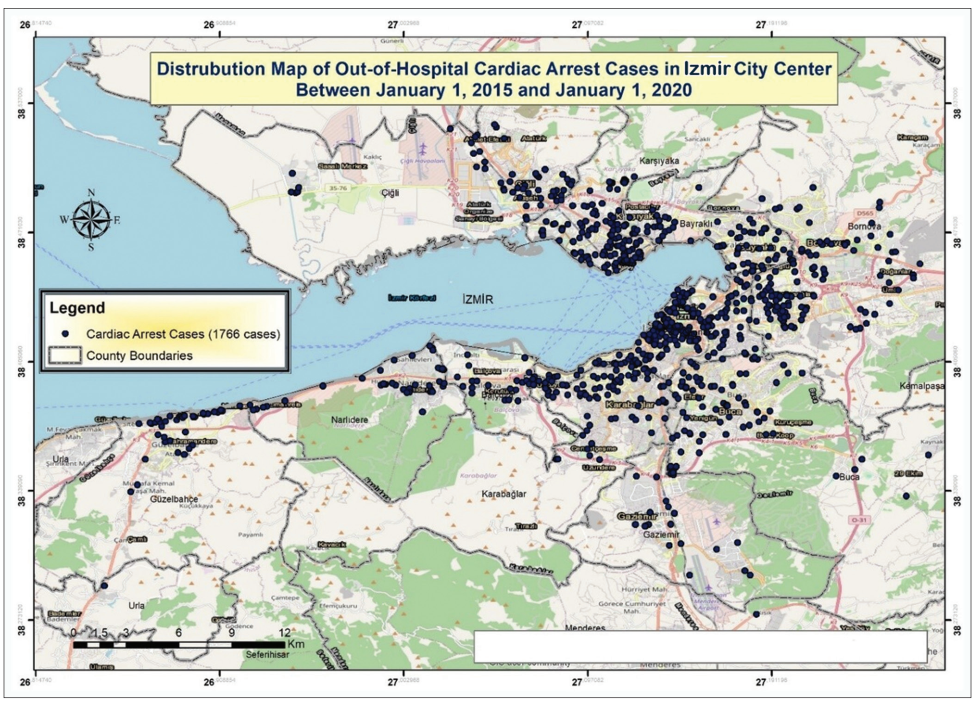

Figure 2: Dot plot distribution of out-of-hospital cardiac arrest cases in the city center of İzmir

ellipse (skewed distribution) of the point case distribution were produced and shown on the map [Figure 3].

Patients and setting

In the present study, out-of-hospital deaths in which emergency and rescue ambulances of the Ministry of Health intervened were analyzed. Exclusion criteria were applied in the study. OHCAs under 8 years of age, traumatic, occurring at home or on private property, and with an undetermined address were excluded. All other OHCAs occurring in public places were included.

Data collection

The demographic data were analyzed retrospectively by using the EHAS, and case forms were created. Detailed address data of the patients were mapped along with

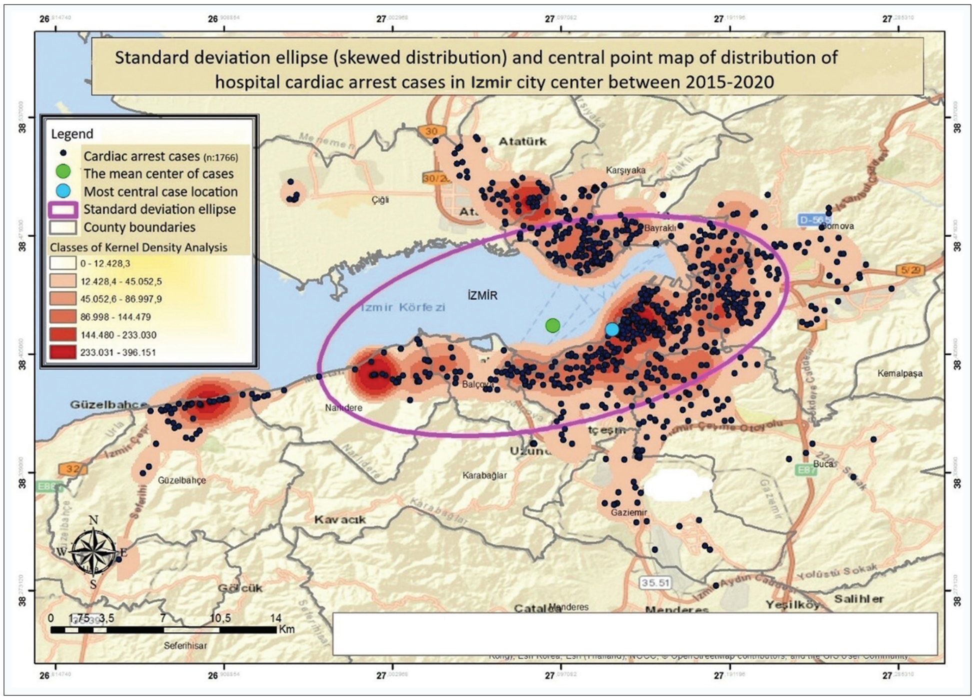

Figure 3: Standard deviation ellipse and central point map of distribution of out-of-hospital cardiac arrest cases in İzmir city center

demographic data over the localization data of the ambulance team arriving at the scene. A total of 13 main locations and sublocations where OHCAs occurred are shown in Table 1.

Mapping

Geographic Information Systems (GIS) technologies were used in the mapping work in this study. The address data of the cases were mapped with ArcGIS Desktop 10.4 software by using Izmir Metropolitan Municipality GIS Database. The marking with a dot in coordinates was created with the "Geocoding" of GIS. Of the 1790 OHCA cases obtained by analyzing the EHAS database, 1,200 were displayed as points on a map using the GIS system. For the 566 OHCA cases whose addresses did not match the GIS data layers and whose coordinate data could not be generated in the system, location determination was performed using Google Earth Pro technology. Kernel density analysis was used to produce the density maps of point cases. In the Kernel density analysis, the density of sample points within the study area was determined by the number of samples falling within a certain radius.[8]

Statistical analysis

The IBM SPSS Statistics 25.0 Statistical Program was used for the analysis of the data. Descriptive statistics were given as the number of units (n), percentages (%), mean ± SD ($\bar{x}$ ± SD), median, minimum and maximum values, and percentile values. The relations between the dependent and the independent variables were checked with the Chi-square analysis if the independent variable was categorical. In case numerical variables were detected, the normality of the data and the number of groups were tested with the ındependent two-sample t-test, Mann–Whitney U-test, one-way analysis of variance, Kruskal–Wallis analysis, and Kolmogorov–Smirnov and Shapiro–Wilk tests. The non-parametric Dunn–Bonferroni comparison test was applied because the age of the patients did not fit the normal distribution. Binary logistic regression analysis was used to determine the factors that affected the frequency of arrests. The significance value was taken as $P < 0.10$ for logistic regression analysis and $P < 0.05$ for other tests.

Results

Characteristics of participants

A total of 22.908 OHCAs were determined for the study in Izmir between January 1, 2015 and January 1, 2020, and 14,898 of these deaths occurred in the city center. A total of 367 cases were under 8 years of age, and 522 cases were identified as trauma-related deaths. Furthermore, 68 OHCA cases were followed in medical centers with AEDs. The location data of 200 cases were found insufficient and were excluded from the study. A total of 1790 OHCA occurred in the city center where the study was planned; 87% of the deaths (n: 12.019) occurred in homes and private areas of the person.

A total of 34.5% (n: 618) of OHCA cases were female, and 65.5% (n: 1172) were male. The mean age of the women was 77 ± 16.1, and the mean age of the men was 64.7 ± 16.4. In our study, the most common

Table 1: Localizations where out-of-hospital cardiac arrest cases are detected and recorded

1. Nursing homes (Elderly Nursing Homes/Nursing Homes/Disabled Nursing Homes)
2. Streets/Alleys/Highways
3. Public areas
Culture art house/cinema/theater
Sanctuaries
Public education centers
Indoor/outdoor parking lot
Other Health Institutions with no AEDs
Public Baths
Restaurants
Coffeehouses/cafes
Docks
Public beaches
Public Bazaars (Food Bazaars/Market Places)
Cemeteries
Squares
Wedding halls
Bus stations
Shopping centers/malls
4. Public transportation
Subway station/Train stations
Public buses
5. Accommodation facilities/Hotels
6. Workplaces/industry
Offices/Workplaces (Factory, Large Workplace, etc.)
Industries/"Otokent"
7. In-vehicle
8. Schools/educational institutions
9. Recreation areas
Playgrounds/Amusement parks
Green areas (Picnic areas)
Fair areas
10. Public Buildings (Government Houses/County Governor's Offices/Courthouses/Directorates)
11. Prisons/Correctional facilities
12. Sports institutions/areas
Fitness (Gyms/Sports Complexes)
Astroturf Fields/Stadiums
Swimming pools
13. Airports

AED: Automated external defibrillator

locations for OHCA cases were nursing homes, with a rate of 34.5% (618). The mean age of the deaths here was 81 years (SD = 10). Second, the highest number of OHCAs was detected in locations such as streets/alleys/highways, with a rate of 32.3% (577). The average age at death in this location was 62 years (SD = 16). Public areas were the third-most common location for OHCA with a rate of 17.1% (304). The average age of death in public areas was 64 years (SD = 15). The OHCA rate in public transportation is 3.7% (66), with an average age of 65 (SD = 12); the OHCA rate in accommodation facilities/hotels is 2.4% (42), with an average age of 56 (SD = 18). These locations are followed by workplaces/industry, in-vehicle, school/educational institutions, recreation areas, public buildings, prisons/correctional facilities, sports institutions/areas, and airports. Among 13 main locations, the only location where the average age of the fatalities was above 65 years was found to be nursing homes. In all other locations, the average age of death was 65 years and below. Only one death was recorded at the airport located in the city center in a 5-year period [Table 2].

The mean time for the arrival of the ambulances to the scene from the first call to the emergency call center was determined to be 7.3 min (SD = 4).

Main outcomes and maps

The map showing the distribution density of OHCA cases (n: 1766) in geographical regions produced at the end of the study is given in Figure 1. The point–plot distribution map showing the distribution of OHCA cases is also shown in Figure 2. In addition, the mean center, central feature, and SD ellipse (skewed distribution) of the point case distribution are shown in Figure 3.

Discussion

Disseminating the use of AEDs to increase survival in deaths that occur outside the hospital is an important public healthcare policy all over the world.[1,2,9] Cardiac causes make up the majority of out-of-hospital deaths.[10] Engdahl *et al*. also reported in their studies that the most common cause of death was heart-related. In the same study, they emphasized that deaths due to arrhythmia have increased among young people in recent years.[11] Furthermore, in England, 28.729 EMS-treated OHCA cases were reported in 2014 (ie, 53 cases per 100.000 of the resident population) with only 7.9% surviving to hospital discharge.[12] In the current multicenter study conducted by Şener *et al*., the discharge rate was determined as 4.4%.[5] Despite the significant resources allocated for the placement of AEDs, which are recommended for use to increase survival, especially in arrhythmias, the success of their use in public areas is low.[13] Weisfeldt *et al*. reported that AEDs were used in only 2.1% of more than 13000 emergency healthcare system calls.[14] It was emphasized that in order to restore spontaneous circulation (ROSC), it is necessary to identify the areas where deaths occur and place AEDs in these appropriate locations. However, the failure in locating AEDs was shown to be the reason for the low success rates.[15,16] In the study that was conducted by Moon *et al*., which examined the success of AEDs over the emergency call system, it was reported that the use was limited in cases that occurred in areas where AEDs were not placed properly.[17] In order to increase usage rates, it is necessary to effectively plan the locations where AEDs will be placed. In planning; separate analyses should be conducted for rural and

Table 2: Distribution of out-of-hospital cardiac arrest case scenes and sociodemographic characteristics of patients

Case scene	Frequency (*n*=1790), *n* (%)	Female (*n*=618), *n* (%)	Male (*n*=1172), *n* (%)	Age±SD	*P*
Nursing homes	618 (34.5)	365 (59.1)	253 (40.9)	81.6±10.8	
Streets/alleys/highways	577 (32.3)	130 (22.5)	447 (77.5)	62.7±16.5	0.001
Public areas	304 (17.1)	78 (25.6)	227 (74.4)	64.1±15.3	
Public transportation	66 (3.7)	12 (18.2)	54 (81.8)	65.9±12.9	
Accommodation facilities/Hotels	42 (2.4)	3 (7.1)	39 (92.9)	56±18	
Workplaces/Industry	40 (2.2)	3 (7.5)	37 (92.5)	57.9±14.9	
In-vehicle	39 (2.1)	5 (12.8)	34 (87.2)	60.7±12.5	
School/educational institutions	35 (1.9)	13 (37.1)	22 (62.9)	53.5±21.7	>0.05
Recreation areas	26 (1.5)	5 (19.2)	21 (80.8)	62.5±16.8	
Public buildings	16 (0.9)	3 (18.8)	13 (81.2)	61.1±20.8	
Prisons/correctional facilities	14 (0.7)	0	14 (100)	52.4±12.3	
Sports institutions/areas	11 (0.6)	0	11 (100)	51.1±16.4	
Airports	1 (0.05)	0	1 (100)	57	

SD: Standard deviations

urban areas, taking into account differences in population distribution, geographical conditions, and socioeconomic variables.[14-18] In a recent study conducted in our country, it was determined that bystander CPR rates were low, and AED use was almost nonexistent.[5]

According to our records, mortality rates in public buildings, schools, and malls make up approximately 6% of all deaths. However, deaths in streets and alleys in areas where public buildings, large malls, and educational areas are densely populated account for 32% of all deaths. Furthermore, the incidence of deaths in these areas is increasing with the dense presence of public transportation centers and stops and the high daily population mobility. Weisfeldt *et al*. stated in their study that deaths occurred more frequently in shopping centers, sports fields, entertainment centers, and squares in Western societies than in Eastern societies. It was observed that deaths increase in societies where social activity areas are intense. The study of Weisfeld emphasized that the mean age of these deaths was also low.[14] Sasaki *et al*. conducted a study in Osaka, Japan, in 2011, and reported that the incidence of OHCA occurred mostly in subway/train stations, and the use of train/subway stations, which make up an important part of the public transportation system of the area, increased the incidence of death.[19] Similarly, a study conducted in Arizona reported that deaths were concentrated in transportation hubs with high population mobility, on streets, in parks, and especially inside transportation vehicles.[17] One of the remarkable results of our study was that the mean age of death in these areas that have high population mobility was low. The only place where OHCAs are seen in people over 65 is in nursing homes, while in the remaining 12 major places, OHCAs are seen in people under 65. In the out-of-hospital medical management of cardiac arrests at young ages, effective CPR and the use of early defibrillation increased neurological survival.[20] For this reason, increasing the number of AEDs in areas where the low mean age at death increases may also increase the success of survival.

It was detected in our study that the most common deaths occurred in nursing homes and dispensaries. Deaths generally occur more frequently in areas where the elderly population, who need care because of chronic diseases, come together.[21] In their study, Pape *et al*. reported that the biggest deficiency in deaths in nursing homes was the lack of determination of the first rhythms and the lack of AEDs, adding that the presence of AED in nursing homes could change survival at a rate of 7%–24%.[22]

In our study, we found that the death rate was higher in men than in women. Similarly, the study by Li *et al*. also stated that mortality rates were approximately twice as high in males.[9] In the study that was conducted by Ok Ahn *et al*., this rate was 2:1 and 5:1 in Moon *et al*.'s study. It was emphasized that racial and geographical differences were effective in the distribution of gender.[17,23] In the current study, 87% of the OHCAs were monitored in homes and private properties. A study that was conducted in the United Kingdom, approximately 85% of the deaths occurred in private properties.[13] Although the use of AEDs for the deaths that occur in homes and private properties is controversial, Bardy *et al*. showed in their study AED use at home did not increase survival.[24] However, Murakami Yukiko *et al*. reported in their study that there were residential areas or blocks with high population density in the city of Osaka, where the population was dense in certain areas, and they argued that AEDs could be placed near blocks that had high population density.[18]

In the present study, no significant relations were detected between the population densities of the counties that constituted the city center and the deaths that occurred. However, some sub-characteristics were noteworthy. The use of AEDs in public health facilities was not widespread in the analysis. We detected that one-fourth of OHCAs occurred in healthcare facilities that did not have AEDs.

Each minute of delay in defibrillation reduces the success of resuscitation at the rate of 3%–5%.[25,26] In our study, we determined that the average time from the emergency call to the arrival of the ambulances at the scene was 7.3 min. Studies conducted in other countries have shown that ambulance response times vary between 9 minutes and 23 minutes.[27-30] It seems that there are differences between countries in ambulance response times. It is possible to reduce this time with the AED usage by the witnesses until the ambulance arrives at the scene.[26] This is the first study conducted in our country to determine the need for AEDs according to locations. It also bears similarities with international studies, as well as having results specific to our country. The data obtained here can be evaluated as a reference by the authorities to show the needs in the healthcare system. For this reason, it can be guiding in national health planning.

Limitations

The study data were taken from emergency healthcare services case forms. In these forms, the basic data, such as the first arrest rhythm obtained at the scene by the medical teams, CPR performed by the witnesses, whether defibrillation was performed, were not recorded.

Conclusion

AED location must be planned by considering the areas that have high human mobility and visitation to increase the efficient use of AEDs. Areas that have intense sociocultural activities, such as malls and entertainment centers or the intensity of public transportation, must be selected. In order to increase the survival of young cardiac arrest victims in particular, locations where schools, sports facilities, and shopping centers are close to each other should be determined, and these locations, common areas with AEDs, should be planned. In this way, survival rates will increase significantly.

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Author contributions statement (CRedIT statement)

UP: Conceptualization, Investigation, Methodology, Supervision, Validation, Writing – review and editing, Project administration.

EHÇ: Visualization, Data curation, Formal analysis, Methodology.

MT: Conceptualization, Investigation, Data curation, Formal analysis, Methodology, Writing – original draft.

Conflicts of interest

None Declared.

Ethical approval

The Ethics Committee of Izmir Katip Çelebi University, Atatürk Training and Research Hospital, Non-Interventional Ethics Committee was obtained for the study on February 13, 2020, with the number 611, and the Provincial Health Directorate Chief Physician Approval 112 on April 22, 2020, with the number of 42056799-619 and with decision number of 2020/19.

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