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Spatial Distribution of Public Access Automated External Defibrillators (AED) in the Capital City of Warsaw

Charakterystyka przestrzenna publicznego dostępu do Automatycznych Defibrylatorów Zewnętrznych (AED) w m. st. Warszawa

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Abstract

Background. Sudden cardiac arrest (SCA) is a leading cause of premature death. The most common cause of SCA is ventricular fibrillation and many lives can be saved with early defibrillation. An automatic external defibrillator (AED) is a device that analyses the cardiac rhythm and generates an electric shock. Thus far, the public access defibrillation program (PAD) has not been implemented in Warsaw. ***Aim.*** To investigate the accessibility of automatic defibrillators in the capital city of Warsaw with particular regard to the number and spatial distribution of the AED devices. ***Material and methods.*** AED devices have been identified, visualized and localized using QGIS geographic information systems. The locations were confirmed via visual inspection, telephone and/or email with the use of electronic questionnaire. Data obtained in this study helped to establish an AED database, which contains the geographic coordinates of the attributes. ***Results.*** In Warsaw, 582 AED devices are deployed in 463 locations. Distribution of defibrillators is uneven, with the largest number of AEDs in the Mokotów (n = 98) and Śródmieście districts (n = 84), and the smallest in Wesoła (n = 3) and Rembertów (n = 3). The critical radius (R_{cr}) from a hypothetical cardiac arrest site to the nearest AED was calculated to be ~333 m. It follows that in order to fully cover the Warsaw spatial grid with AED devices, public space should contain approximately 1551 devices (3.0/km^2). ***Conclusions.*** In Warsaw, the number of AEDs is insufficient and their spatial distribution is greatly uneven. While planning the deployment of AEDs one should take into account not only the critical radius R_{cr}, but also other criteria of optimal location, including the number of inhabitants within a given area, strategic places on the basis of population density, and incidence rate of sudden cardiac arrest. Our data show that there is an urgent need to develop and implement PAD programs in Warsaw and other large metropolitan areas in Poland. *Anestezjologia i Ratownictwo 2018; 12: 62-69.*

Keywords: Automatic External Defibrillator, automated defibrillation, Geographic Information Systems, public access defibrillators, sudden cardiac arrest

Streszczenie

Cel pracy. Nagły zgon jest najczęściej spowodowany migotaniem komór (VF). Dlatego życie wielu chorych z nagłym zatrzymaniem krążenia (NZK) można uratować dzięki wczesnej defibrylacji. Automatyczny defibrylator zewnętrzny (AED) jest urządzeniem, które analizuje rytm serca i na tej podstawie samoistnie generuje wstrząs

elektryczny. Jak dotąd, władze m.st. Warszawy nie stworzyły programu publicznego dostępu do automatycznej defibrylacji (PAD – *public access defibrillation*). Celem pracy było zbadanie dostępności do defibrylacji na terenie miasta stołecznego Warszawa ze szczególnym uwzględnieniem przestrzennego rozmieszczenia urządzeń AED. ***Materiał i metody.*** Przy zastosowaniu systemów geoinformacyjnych QGIS zidentyfikowano i zwizualizowano rozmieszczenie urządzeń AED. Lokalizacje AED potwierdzono wizją lokalną, telefonicznie i/lub mailowo przy użyciu elektronicznego kwestionariusza. Tym sposobem powstała baza danych AED, zawierająca współrzędne geograficzne atrybutów. ***Wyniki.*** Na terenie Warszawy rozmieszczonych jest 582 urządzeń AED w 463 miejscach. Rozmieszczenie defibrylatorów jest jednak nierównomierne. Największa ilość urządzeń AED znajduje się w dzielnicach Mokotów (98) i Śródmieście (84), natomiast najmniej jest ich w Wesołej (3) i Rembertowie (3). Wyliczono, że krytyczny promień oddalenia AED (R_{cr}), w zasięgu którego racjonalne jest użycie AED wynosi ~333 m, oraz żeby w pełni pokryć siatkę przestrzenną Warszawy urządzeniami AED, w przestrzeni publicznej powinno ich być ok. 3620 (ok.7/km^2). ***Wnioski.*** Na terenie m.st. Warszawa liczba dostępnych urządzeń AED jest niewystarczająca. Ponadto, rozmieszczenie przestrzenne defibrylatorów wykazuje znaczne zróżnicowanie i przy planowaniu rozmieszczenia defibrylatorów należy brać pod uwagę nie tylko krytyczny promień oddalenia R_{cr}, lecz także zasady optymalnej ich lokalizacji: liczbę mieszkańców na danym obszarze, strategiczne ze względu na zagęszczenie ludności miejsca, oraz częstość występowania przypadków NZK. *Anestezjologia i Ratownictwo 2018; 12: 62-69.*

Słowa kluczowe: Automatyczny Defibrylator Zewnętrzny, publiczny dostęp do AED, systemy geoinformacyjne QGIS, nagłe zatrzymanie krążenia

Introduction

The leading cause of death in Poland in 2015 was cardiovascular disease (over 46% of all deaths) [1]. The use of an Automatic External Defibrillator (AED) by a witness ("*casual rescuer*") of sudden cardiac arrest (SCA) within the first few minutes of an event increases the chances of survival by as much as 49-75%, if the cause of cardiac arrest is tachyarrhythmia (e.g. ventricular fibrillation) [2]. Delay in undertaking cardiopulmonary resuscitation (particularly chest compression) and use of defibrillation decreases the probability of survival by 10-12% with every passing minute [3,4]. Therefore, information on the deployment of AEDs in public spaces, the widespread accessibility of these devices under the Public Access Defibrillation (PAD) program, and knowledge of first aid rules are of paramount importance for improving healthcare and safety of people in urban and rural areas, and should be standard in a modern state. According to such norms, the AEDs should be placed wherever the time difference between the incoming call and the arrival of the rescue team is extended due to topographic or architectural reasons (e.g. the time for a city with population > 10 000 inhabitants is > 8 min), or the places where the probability of SCA occurrence is greater than 1 incident per every 2 years [5,6]. Furthermore, defibrillators should be deployed in such a manner that they can be used within 3 to 5 minutes [20]. For these reasons in highly developed countries (USA, Canada, Japan, Western European countries) AEDs are usually installed in health centres, workplaces, schools, airports, train stations, trains, hotels, social welfare centres, shopping centres, swimming pools, sports facilities, etc.

It should be noted that the availability of AEDs does not decrease the mortality rate of SCA per se unless the remaining lifesaving links of the so-called "Chain of Survival" are coupled.

This chain consists of:

1. Early access to care through early response and notifying the emergency services (telephone number 999 or 112).
2. Early CPR (cardiopulmonary resuscitation) provided by a bystander to maintain the blood supply to the heart and brain, and thus gaining time to prevent brain damage and death, which occur within 4-6 minutes of cardiac arrest.
3. Early defibrillation to restore cardiac function.
4. Early advanced care provided first by the ambulance team (paramedics).
5. Further care provided by the hospital staff.

Additionally, appropriate follow-up is important in improving survival from SCA, and that in selected

cases may include use of an implantable cardioverter defibrillator (ICD). This portable, pacemaker-like device is implanted under the skin and is connected to patient's heart with insulated wires. The ICD senses the heart rhythm, provides a shock if needed, and sometimes paces the heart.

According to the American Heart Association, patients who were given cardiopulmonary resuscitation and defibrillation in the first 3-4 minutes of the cardiac arrest, and the advanced rescue operations (e.g. emergency ambulance) within the subsequent 5 minutes have the highest probability for survival. However, many favourable coincidences need to happen for such scenario to occur outside the hospital environment. Despite these reservations, the subject literature confirms the relevance and effectiveness of the locally implemented PAD programs. In 2010 the ROC (Resuscitation Outcomes Consortium) covering more than 200 such programs, published data on nearly 14,000 cases of bystander-initiated cardiopulmonary resuscitation. Among 4,403 victims of SCA who did not receive defibrillation before EMS arrival (Emergency Medical Services), only 9% were rescued. In contrast, in the group of 289 people who received defibrillation using an AED during CPR, the corresponding percentage was 24% [16]. In recent years, the percentage of cases in which AED was used during bystander-initiated cardiopulmonary resuscitation has increased [19]. Nonetheless, not all published reports are optimistic [17,18].

In the United States, 200,000 AEDs are being sold annually [16]. In Japan, over 300,000 defibrillators were installed in the past five years (for example, on vending machines); while in the small Netherlands there are over 90,000 of them.

Poland follows the global trend and AED devices appear in the public space in increasing numbers. However, Warsaw's municipal government authorities have not created any official PAD program yet. The aim of this study was to investigate the availability of automatic defibrillation devices in Warsaw with particular regard to their spatial distribution.

Aim

The aim of this study was to investigate the accessibility of AEDs in the capital city of Warsaw with particular regard to their spatial distribution.

Material and methods

The following data were obtained in the course of this study.

- **AED number and deployment in Warsaw.** The starting point for this study was to gather information about the number and location of AEDs deployed in various districts of Warsaw by public institutions, private companies and public facilities as of 15.09.2016. These data were obtained directly from these entities as well as on the basis of personal observations made from October 2015 through September 2016.
- **AED distribution database** was determined via visual inspection, telephone and/or e-mail with the help of questionnaire. Geocoordinates of each device were determined using the Quantum GIS software. It belongs to the free and open source software for geospatial group (FOSS4G), and is available under the licence of GNU GPL.
- **AED critical radius (R_{cr})**, defined as the minimal distance within which the use of an AED might be effective, was calculated under the assumption that a person, who was asked by the rescuer to bring the defibrillator, is rushing to the nearest AED location at the speed of 10 km/h (2.78 m/s) and that it would take him/her 4 minutes to get back with the AED. Hence, the critical radius (R_{cr}) has been calculated according to the following formula:

  $$R_{cr} = \frac{V \times t}{2}$$

  where:
  V - movement velocity 2.78 m/s (10 km/h); t – time to AED usage 240 seconds (4 min).
- **Average density of AED devices available in Warsaw** has been calculated according to the following formula:

  $$\varrho_{AED} = \frac{\text{number of AEDs devices}}{\text{area of Warsaw [km}^2\text{]}}$$

  where area of Warsaw is assumed to be 517.24 km^2 [data derived from reference 8].
- **Number of AED devices needed to uniformly cover the geographical grid of the city** was calculated based on the estimated metropolitan area of Warsaw and the calculated R_{cr} value. **Publicly available information related to** initiatives resembling PAD programs in Poland have been collected and reviewed.

Results

The PAD programs have been implemented and are being pursued in only few cities and municipalities in Poland. The first known program was started in the city and municipality of Trzebinia (Małopolskie Voivodeship), where in 2007 20 AEDs were deployed in public places and 500 volunteer rescuers received training on how to use an automated external defibrillator (AED). A few people have been saved within several months after launching this program [7]. The initiative of Koleje Wielkopolskie, which was the first railway carrier in Europe to have all their trains equipped with AED defibrillators, may also be viewed as a PAD program. Recently, other railway carriers followed the lead including, among others, PKP Intercity and Koleje Mazowieckie. There is also an ongoing debate about installing AEDs in buses and trams. Lastly, it is worth mentioning that the Warsaw's taxicab service ELE TAXI, has 55 mobile AEDs and rescuers who received first-aid education and training.

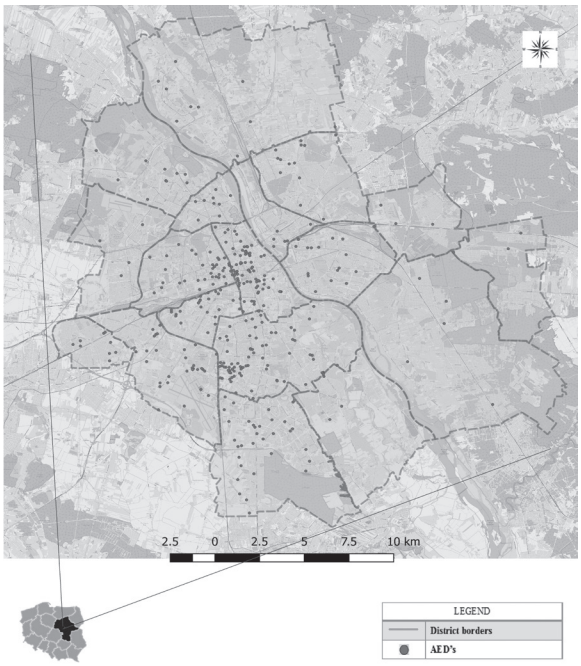

Figure 1. AED distribution in the capital city of Warsaw

source: www.google.pl/maps, accessed 12.06.2016

Figure 2. Visualization of the critical radius of AED distance on the example of selected Warsaw area

Table I. List of AEDs in specific districts of Warsaw

District	Area [km^2]	Population	AED	AED needed
Bemowo	25	118057	4	75
Białołęka	73	109062	11	219
Bielany	32	131934	14	96
Mokotów	35	218911	98	105
Ochota	10	84280	31	30
Praga-Południe	22	178309	17	66
Praga-Północ	11	67279	9	33
Rembertów	19	23812	3	57
Śródmieście	16	120091	84	48
Targówek	24	123677	14	72
Ursus	9	56490	8	27
Ursynów	44	148385	26	132
Wawer	80	72921	5	240
Wesoła	23	24073	3	69
Wilanów	37	30703	4	111
Włochy	29	39940	28	87
Wola	19	138462	31	57
Żoliborz	9	49056	11	27
Total	**517 km^2**	**1735442**	**401***	**1551**

* The list excludes the AEDs of the mobile services, i.e., the National Fire Service and ELE TAXI, as well as the equipment located at Warsaw Chopin Airport

Although Warsaw has no official PAD program in place, its development is underway. In fact, the city has considerable resources with 582 AEDs deployed in 463 locations (as of 15.09.2016).

The density of AED devices in Warsaw was found to be 1.13/km^2.

Figure 1 shows the spatial characteristics of AED devices in Warsaw based on the data generated using the QGIS systems. The number of AEDs is inadequate and their distribution in various districts of Warsaw is uneven.

Figure 2 shows the visualization of the critical radius R_{cr} of the AED distance in selected areas of the city. Based on empirical results and data on real time of effective use of AED, the critical radius was found to be 333 m according to the following formula.

$$R_{cr} = \frac{2.78 \text{ m/s} \times 240 \text{ s}}{2}$$

R_{cr} ℜ333 m

According to these calculations, the practical use of AED is reasonable within the area of 0.35 km^2 and in order to cover the spatial grid of Warsaw with sufficient number of AEDs there should be approx. 1551 devices in a public space (approximately 3/km^2) [8].

$$P = \pi \times 0.333^2$$
$$P = 0.35 \text{ km}^2$$

where P = circular area with the calculated radius R_{cr}

Additionally, it was established that in particular districts of Warsaw the density of AED defibrillators varies considerably, as a result of which the R_{cr} criterion is not fulfilled. This is depicted in Table 1 and Fig. 3. The greatest number of AEDs is in the Mokotów (n = 98) and Śródmieście (n = 84) districts, while the smallest in Wesoła (n = 3) and Rembertów (n = 3). The AEDs of the mobile services, i.e., the National Fire Service and ELE TAXI, as well as the equipment located at Warsaw Chopin Airport, are not included in this list.

When discussing the development of the PAD program for Warsaw, data on mortality rates due to cardiovascular disease and the number of SCA instances should be taken into consideration. In 2015 in the Mazowieckie Voivodeship these rates were 100/100,000 and 10.69/1000 inhabitants, respectively [8]. The electronic questionnaire, which was sent to the administrators of premises equipped with AEDs included, among others, questions on whether they would make AED

devices available in the event of a sudden death threat, or when the cardiac incident occurred near their location such as a parking lot or a neighbouring street. The geographic interpretation of these locations was found to be consistent with information shown in figure 1.

* The list excludes the AEDs of mobile services, i.e., the National Fire Service and ELE TAXI, as well as the equipment located at Warsaw Chopin Airport

Figure 3. Graphical AED quantity comparison in Warsaw

Discussion

It is generally accepted that one of the critical elements of the PAD program is the deployment of the AED devices in such manner that the distance between one AED and another and AED delivery time are as short as possible. Of equal importance is availability of volunteers trained in CPR and use of an AED. The latter has prompted us to ask the respondents (administrators of premises equipped with AEDs) whether their staff members received this kind of training. Since 74% of the respondents answered affirmatively, it appears that more attention should be given to training of local populations in providing medical first-aid, CPR and the use of an automated defibrillation. Lastly, the efficiency and cost-effectiveness of the PAD program depend, to great extent, on the ability to quickly alert rescue volunteers, who may be present in the vicinity of an SCA event. Here, certain legal impediments may play a role like, for instance, the issue of sharing personal data by dispatchers of Emergency Medical Services with volunteers, or integrating Decision Support Systems (DSSs) with the IT applications used by the volunteer rescuers. The good news is that applications which, in addition to the AED deployment map, allow the dispatchers to determine whether there are any volunteers near the event site have already been developed. "Staying Alive" is an example of such applications. In the course of this work, we have enriched it with our own database on more than 400 AEDs in Warsaw [9]. However, the Polish version of the application does not have the ability to notify (summon) the volunteers who are the closest to the event.

Taken together, a PAD program should be built based on the following assumptions and actions:

- identification and visualization of the existing PAD programs in the area,
- provision of adequate financing to PAD programs,
- deployment of operable AEDs in public spaces,
- organization and supervision of the management system (assembly, technical service, quality control and quality assurance),
- ensuring access to AEDs to people who understand and use them safely and effectively,
- delivering education in first-aid, CPR and on how to use an AED to local populations of various age, education, and social background.

Based on the data from this study we submit that when planning the deployment of AEDs, not only the critical radius R_{cr} should be taken into account, but also the criteria of optimal location: number of inhabitants, strategic places on the basis of population density, and the frequency of sudden cardiac arrests within a given area. Further, in calculating R_{cr} other variables such as height of buildings or number of floors and degree of availability of individual devices should also be considered.

Despite significant progress that has been made in reducing mortality due to SCA, cardiovascular diseases continue to be the principal cause of death in Poland. In this context it is worth noting, that in Poland the PAD programs are still in their infancy and there is an urgent need to (i) provide adequate financing to deploy more AED devices in public areas, and (ii) to support education and training to facilitate access to the AED network to people who are skilled in first-aid and in knowing how to use them safely and effectively.

Although, the number of AEDs in Warsaw has increased nearly 5 times in the last 8 years it is insufficient. Additionally, spatial distribution of defibrillators is strikingly uneven.

Published data on PAD programs points to the need to place AEDs in densely populated areas and places easy to locate and access them, and to provide the necessary training to people who work or live permanently in those locations. Examples of locations with potentially high risk of SCA occurrence include airports, railway/bus terminals, shopping malls, casinos, sport stadiums, etc. [13,14]. Incidentally, there are 50 AEDs at the Warsaw Chopin Airport.

The results of studies by Huig IC et al. [10] demonstrate that in all 6 Dutch cities there was a total of 130 AEDs in public space: 43 in Amsterdam, 29 in Gravenhage, 5 in Eindhoven, 28 in Rotterdam, 10 in Tilburg and 10 in Utrecht. The number of AEDs per km^2 in these cities was 0.19 AED/km^2, 0.29 AED/km^2, 0.05 AED/km^2, 0.08 AED/km^2, 0.08 AED/km^2, 0.15 AED/$km^{2,}$, respectively. According to Yoon CG et al [11] there are 206 AEDs in Busan Metropolitan City in South Korea. Their density calculated per surface area was 0.268 AED/ km^2. Compared to these data, the number of AEDs in Warsaw per one square kilometer was found to be 1.13 AED/km^2. Thus, it would seem that in Warsaw the situation is quite favorable. However, such conclusion is not justified due to highly uneven distribution of the AEDs devices in Warsaw. By comparison, in the study conducted by Griffis et al. the database consisted of 2559 AEDs located in Philadelphia's 326.1 square kilometer area, therefore there was 7.84 AED per square kilometer [12]. It has been assumed, however, that each AED device should cover an urban area that has a radius of 400 m. Therefore, the effectiveness of the PAD program and experiences of the "first responders" in Philadelphia may be quite different from those of the rescuers in Warsaw.

According to Cacko et al. [21], only 117 devices were available in Warsaw in 2009.

It is difficult to overestimate the potential benefits of the widespread availability of AEDs in the public space. In fact, published data indicate that increasing linearly the number of AEDs in urban space would increase survival of people with SCA [15]. According to Weisfeldt et al. [16], early use of the AED saves 474 human lives a year in North America [16].

Conclusion

Although, the number of AEDs in Warsaw has increased nearly 5 times in the last 8 years, it remains insufficient. Additionally, spatial distribution of defibrillators is strikingly uneven.

Implementing a successful early defibrillation program or PAD scheme is a complex endeavour. When planning the deployment of AEDs, not only the critical radius R_{cr}, should be taken into account, but also the criteria of optimal location: number of inhabitants within a given area, strategic places on the basis of population density, and the frequency of sudden cardiac arrests. In calculating R_{cr} other variables such as height of buildings or number of floors and degree of availability of individual devices should also be considered. They may be the starting point for further analyses.

Data presented in this work suggest that there is an urgent need to develop and implement PAD programs in Warsaw and other large metropolitan areas in Poland.

Conflict of interest
None

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