Is Cluster Analysis the Appropriate Statistical Method for Planning the Optimal Locations for Automated External Defibrillators?

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Abstract. The Automated External Defibrillator (AED) is an intuitive device used by witnesses of an incident without medical training in cases of sudden cardiac arrest. Its operation consists in delivering an electrical pulse to the cardiac conduction system, as a result of which normal heart rate is restored. The lack of awareness in society concerning the usefulness of the device and the inadequate deployment of AEDs result in their too infrequent application by witnesses of incidents. The aim of this paper is to verify whether cluster analysis is the appropriate statistical method to determine the appropriate deployment of AED devices on the basis of cases of sudden cardiac arrest in out-of-hospital conditions. The initial cluster analysis showed the validity of using the method in question for planning the appropriate locations of AEDs.

Introduction

Sudden cardiac arrest is the failure of the heart to pump effectively, which leads to cessation of circulation, secondary apnea, and in consequence, to irreversible damage to the brain. The condition is one of the most common causes of death in Europe. The number of cases of sudden cardiac arrest in European countries is 55-113/100,000 or 350,000–700,000, depending on the definition used (Berdowski et al., 2010; Grasner et al., 2011; Grasner & Bossaert, 2013). Acting according to the chain of survival, i.e. early recognition and call for assistance by witnesses of the incident, early commencement of cardiopulmonary resuscitation, early defibrillation

and post-resuscitation care, gives greater chances of saving the person who has suffered sudden cardiac arrest (Andres, 2016). There are four heart rhythms that occur during cardiac arrest, i.e. asystole, pulseless electrical activity (PEA), ventricular fibrillation (VF), and pulseless ventricular tachycardia (pVT). These rhythms are divided into those that do not require defibrillation, i.e. asystole and PEA, and those in which defibrillation is essential in order to restore normal hearth rate, i.e. VF and pVT (Kański, 2013). During the first minutes of a sudden cardiac arrest, ventricular fibrillation occurs in 76% of cases (Berdowski et al., 2011; Weisfeldt et al., 2010). At the same time, among those occurring in sudden cardiac arrest patients, the rhythm in question is the one carrying the best prognosis. Performing defibrillation within 3–5 minutes since the loss of consciousness results in a survival rate of 50–70%. Each minute of defibrillation delay lowers the probability of survival by 10–12% (Waalewijn et al., 2001). The time of arrival of a medical rescue team to the place of the incident is usually too long (Andres, 2016). The fundamental factor that improves survival in cases of out-of-hospital cardiac arrest is the interaction between the medical dispatcher and the witness of the incident who performs cardiopulmonary resuscitation (CPR). Another decisive factor is the immediate use of the Automated External Defibrillator (AED), i.e. the intuitive device that will carry the witness of the incident through the whole CPR procedure, as well as recognize the heart rhythm and enable the performance of defibrillation in a person suffering from sudden cardiac arrest in the VF or pVT mechanism.

The aim of this paper is to perform an initial epidemiological and demographic analysis of cases of sudden cardiac arrest within the city of Białystok and verify whether cluster analysis (Milewska et al., 2013) is an appropriate statistical method for determining the optimal locations of AED devices. Their current deployment is not based on any scientific studies. According to the latest guidelines of the European Resuscitation Council, an analysis of the number of past cases of cardiac arrest in a given area and a characteristic of the immediate vicinity of these places are helpful in the appropriate deployment of AEDs (Chan et al., 2013; Folke et al., 2009).

Changes made to the current locations of AEDs and an appropriate selection of locations for AED devices to be purchased in the future would make it possible to improve survival and the safety of the citizens and all other persons staying in the area of the city of Białystok.

Materials and Methods

Approx. 13,500 exit cards of the Medical Rescue Team of the Regional Medical Rescue Service in Białystok from a four-month period (January–April) in 2018 constituted the research material. The study covered the area of the city of Białystok, i.e. 102.1 km^2, with a population of approx. 297,000 (Główny Urząd Statystyczny, 2018). The inclusion criterion were cases in which sudden cardiac arrest occurred according to the codes specified in ICD10 – the International Classification of Diseases (I46, I49.0, R96, R98, R99). The above criteria were met by 160 cases in the study group. The material for the study was compiled in Microsoft Office Excel and then subjected to a statistical analysis in STATISTICA 13.1 software. The study was performed at the Faculty of Health Sciences of Medical University of Białystok (MUB). An initial analysis of the collected data was performed and the required assumption checked. Cluster analysis was performed to plan the optimal locations of Automated External Defibrillators. The study was approved by MUB's Bioethical Committee (R-I-002/610/2018).

Results and Discussion

Currently, there are 14 publicly available AED devices in Białystok, i.e. the so-called urban AEDs. Additionally, there are almost twenty AEDs in the city area that are owned by private businesses and public offices; they are not, however, available to the public, which is the reason for their exclusion from the comparative analysis. The map presented below (Figure 1) shows the current deployment of the urban AED devices (shown as heart-shaped graphics).

The analysis was performed for 160 cases of sudden cardiac arrest in the area of the city of Białystok. The exact location of each of the cases was determined based on the geographical coordinates (latitude and longitude) read from the exit cards of the Medical Rescue Teams. The data was entered into a Microsoft Excel spreadsheet. Then, the Statistica 13.1 statistical software was used. After performing the cluster analysis, the areas where cases of sudden cardiac arrest occurred the most commonly were obtained (Table 1).

The points were plotted on the city plan of Białystok, according to the corresponding geographical coordinates. According to the latest guidelines of the European Resuscitation Council, after performing an analysis of the number of past cases of cardiac arrest in a given area, the points thus
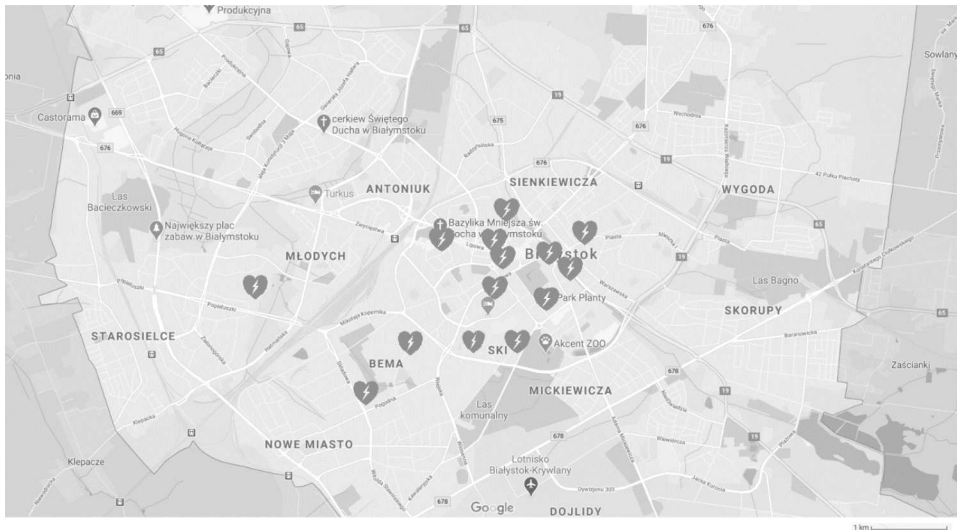
Figure 1. The current deployment of urban AED devices in Białystok

Table 1. Geographical coordinates of places where cases of cardiac arrest occurred the most commonly

	Latitude	Longitude	Number of cases	Percent (%)
1	53.14146	23.17975	18	11.250
2	53.12857	23.09548	10	6.250
3	53.12275	23.16494	22	13.750
4	53.13319	23.18711	17	10.625
5	53.11290	23.13686	7	4.375
6	53.10705	23.20356	6	3.750
7	53.13954	23.12711	15	9.375
8	53.15324	23.09421	4	2.500
9	53.12267	23.21247	5	3.125
10	53.13759	23.15101	26	16.250
11	53.15242	23.12695	10	6.250
12	53.11555	23.09117	11	6.875
13	53.09671	23.23898	1	0.625
14	53.16001	23.19296	8	5.000

Figure 2. The optimal deployment of AED devices in Białystok

plotted correspond to the optimal locations of AED devices. The map below (Figure 2) shows the locations of those places where sudden cardiac arrest occurred in the period in question (small circular graphics) and the optimal deployment of AED devices within the area of the city of Białystok (square graphics).

The current (heart-shaped graphics) and optimal (circular graphics) locations of AED devices were plotted on the city plan of Białystok according to the geographical coordinates. As can be seen in the figure below (Figure 3), the points do not overlap.

On the basis of the above initial cluster analysis, the following conclusion was formulated: the current deployment of the Automated External Defibrillators in the area of Białystok probably does not correspond to the places where the number of occurrences of cardiac arrest is the most common.

The performed analysis also shows that by far the largest number of cases of sudden cardiac arrest in the area of Białystok occurred in the flat or in the family home. In the study group ($n = 160$) – 84.38% of the cases of sudden cardiac arrest occurred in the flat or in the family home. The other 15.62% of the cases occurred in public places, workplaces, shops, clinics, nursing homes, and in the detoxification detention centre.

A search for methods that would enable the planning of the optimal locations of AED devices is ongoing. An example is the paper published in 2014 that presents a project whose aim was to introduce automated

Figure 3. Current and optimal deployment of AED devices in Białystok

external defibrillation in the Tricity area (Łopaciński, 2014). It makes use of the rule that stipulates that AEDs should be deployed in places where at least one case of sudden cardiac arrest occurred within the last 2 years (data for 2010–2011). Only those cases that occurred in public places were taken into consideration.

Performing cluster analysis in order to determine the optimal deployment of AEDs seems a valid solution, including not only public places but also flats and houses, i.e. those places where sudden cardiac arrest occurs the most often. Moreover, cluster analysis, preparing a characteristic of the immediate vicinity, and properly drawn conclusions make it possible to plan the optimal locations of AED devices, considering the equipment constraints.

Conclusions

The initial cluster analysis was performed to plan the optimal locations of Automated External Defibrillators. The analysis showed non-optimal deployment of AEDs in the area of Białystok. The method proved appropriate; however, according to the guidelines of the European Resuscitation Council, in order to determine the most beneficial locations for AEDs, the study should be performed on a larger number of past cases and a characteristic of the immediate vicinity of these places should be prepared (Chan et al., 2013;

Folke et al., 2009). Making use of the results of this study and changing the existing AED locations would make it possible to improve survival and the safety of the citizens and all other persons staying in the area of the city of Białystok.

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