The Sapienza University of Rome network of automated external defibrillators: a prototype webMap developed to speed access to community defibrillators and increase survival from out-of-hospital cardiac arrest

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Abstract. – OBJECTIVE: In Italy, only around 10% of people who experience out-of-hospital cardiac arrest (OHCA) survive. A large portion of OHCA events in public settings are characterized by an initial shockable rhythm, which requires prompt defibrillation. We aimed to create a system to quickly locate nearby public access automated external defibrillators (AEDs) on the campus of Sapienza University of Rome, the largest public university in Europe.

MATERIALS AND METHODS: We developed the AED webMap through a 6-step process involving the: 1) collection of information and geographical coordinates for each AED from the university management system; 2) development of a new geolocation database; 3) integration of information contained in the new database with data provided by university departments; 4) geolocation of AEDs in the Google MyMaps environment; 5) graphic representation of all AEDs on digital map templates using specific symbols, with pop-ups containing additional information for each AED; and 6) publication of the webMap on the university website.

RESULTS: The AED webMap was published on the university website (https://www.uniroma1.it/it/pagina/defibrillatori-sapienza-in-rete) and facilitates prompt identification of nearby AEDs by providing: 1) detailed AED geolocalization with interactive pop-up information for each AED, including whether the AED is located internally or externally; 2) the option to use different base maps (e.g., digital street map); 3) calculation and display of the route to reach the chosen AED; and 4) the possibility to migrate towards multiple platforms.

CONCLUSIONS: The webMap can help bystanders quickly identify, locate, and reach nearby AEDs present on the campus of the largest public university in Europe, a measure that could help speed defibrillation and maximize the life-saving potential of AEDs in the event of OHCA.

Key Words:
Automated external defibrillator, Sudden cardiac arrest, Geolocation, resuscitation, Public health, webMap.

Introduction

Sudden cardiac arrest is a major burden of disease in Western Europe and the United States, where it accounts for 10-20% of all natural deaths[1,2]. In Italy, sudden cardiac arrest results in approximately 20,000 deaths yearly and is the leading cause of mortality in males aged 20-60 years[3]. Sudden cardiac arrest is preceded by a sudden loss of consciousness that occurs within one hour of symptom onset in people with or without known heart disease[4]. One significant challenge is that sudden cardiac arrest occurs most often in the community, where it is referred to as out-of-hospital cardiac arrest (OHCA)[1]. Only approximately 10% of patients who experience OHCA in Italy survive[5]. Prompt bystander cardiopulmonary resuscitation (CPR) and defibrillation are the most promising early intervention strategies to increase OHCA survival rates[6,7]. However, a recent Italian study[6] found that bystander CPR was performed in only 26% of OHCA events, while bystander defibrillation was performed in a mere 3%.

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Defibrillation is known to improve outcomes in OHCA characterized by shockable rhythms such as pulseless ventricular tachycardia or ventricular fibrillation, with the latter being the most common dysrhythmia in OHCA[8]. One study[9] found that nearly 60% of OHCA collapses that happen in a public place are characterized by a shockable rhythm. In the presence of a shockable rhythm, CPR can provide perfusion and oxygenation to the tissues until defibrillation is able to be performed, but defibrillation is necessary to restore a viable cardiac rhythm and prevent brain damage[7]. With prompt defibrillation, OHCA survival rates can increase to approximately 40%[10]. Defibrillation can be performed in the community setting using public-access automated external defibrillators (AEDs). AEDs are able to analyze a patient's electrical rhythm and deliver a pre-programmed shock if a shockable rhythm is detected[11]. Italian law currently provides for the installation of AEDs in public places and allows bystanders without specific training to use an AED in the event of suspected OHCA and in the absence of medical professionals[12]. However, research has shown that existing AEDs are underutilized in the event of OHCA, with a noted barrier to their use being their frequent location in buildings that are closed on evenings and weekends[13]. In order to enable early defibrillation, it is necessary to increase prompt population access to community AEDs[14]. Defibrillation must be administered within 3-5 minutes in order to have the highest probability of success[15]. The probability of survival decreases by approximately 7-10% per minute until defibrillation is started in the absence of CPR and by 3-4% per minute if CPR is performed until defibrillation[16]. The installation of AEDs should thus be complemented by a system that makes their position known to the public and allows them to be reached as quickly as possible at any time of day in order to maximize their life-saving potential[17].

This study describes the implementation of a geo-referenced system (webMap) to identify the nearest available AEDs at Europe's largest public university, Sapienza University of Rome. This webMap also provides information on whether the AED was located internally or externally, which could be useful for OHCA collapses outside of normal office hours. This paper describes the developmental steps, presents webMap, discusses its public health impact within the broader context of measures targeting early links in the chain of survival for OHCA, and highlights future perspectives for similar applications.

Materials and Methods

Operative Steps

The Sapienza AED webMap was developed through a six-step process (Figure 1).

The first step involved collecting information and geographical coordinates for each AED from

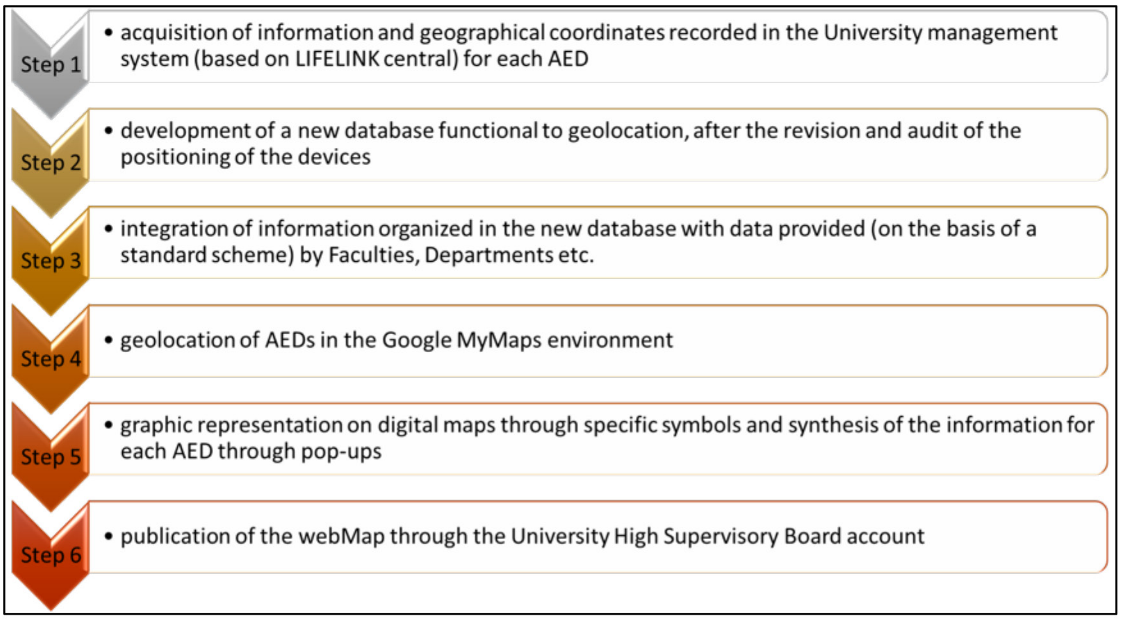

Figure 1. The six steps involved in developing the Sapienza AED webMap. Authors' elaboration.

the university management system (based on LIFELINK central).

The second step involved the development of a new geolocation database after confirming the positioning of the devices. The importance of an accurate geolocation process in a geographic information system (GIS) platform, with particular reference to geocoding, has been evidenced in medical geography, epidemiology, and public health studies[18-26].

The third step involved the integration of information contained in the new database with data provided (based on a standard scheme) by the faculties and departments of Sapienza University of Rome. The Special Office for Prevention, Protection, and High Vigilance collected comprehensive information from the managers of facilities that had an AED in order to verify the position of the AED geolocalized in a planimetry extracted by the application in progress and to gather other important information, including whether the device was internally or externally located, address (street, street number, and zip code) of the entrance closest to the device, instructions on how to most quickly reach the device through this entrance, times of public accessibility through this entrance, existence of a janitor's room or another support point near the AED and the times at which it was accessible, and any telephone number that could be called to speed up AED retrieval. If the presence of additional AEDs was identified, the database was updated accordingly.

The fourth step involved the geolocation of AEDs in the Google MyMaps environment, a user-friendly environment similar to that of well-known geobrowsers such as Google Maps and Google Earth.

The fifth step involved the graphic representation of all AEDs on digital maps using specific symbols. These AEDs could then be clicked to display a pop-up with additional information for each AED. Successive levels of zoom made it possible to identify in detail the various AEDs through progressive geographical scale changes.

The sixth step involved the publication of the webMap on the university high supervisory board account.

Results

The webMap as an Output

A webpage on the Sapienza University of Rome website (https://www.uniroma1.it/it/pagina/defibrillatori-sapienza-in-rete) displays the AED network. These AEDs are equipped with a voice guide that indicates the procedure to be performed in case of an emergency. On this webpage, it is possible to access the list of AEDs and the webMap, which provides a view of the geolocated AEDs (green squares with white hearts) (Figure 2).

By zooming in, AEDs can be geolocalized on a digital street map template and with reference to different buildings (Figure 3). The system makes it possible to use satellite imagery as an alternative template, and each AED can be selected by clicking on it. When clicked, an interactive pop-up shows the information available for that AED (address, whether it is internally or externally located, building access hours, how to access the AED within the building, and contact number) (Figure 4).

An Example of Applied Use

The webMap makes it possible to calculate and display the route to reach a chosen AED. Figure 5 shows an example of a bystander near Piazzale Aldo Moro 7 who wishes to reach the AED in the Department of Chemistry and Technologies (Dipartimento di Chimica e Tecnologie). The example uses the location of a bystander outside the Sapienza campus to highlight the possibility that someone unfamiliar with the university may also use the webMap.

By clicking on the chosen AED and then clicking on the arrow in the white diamond located in the red band at the top of the pop-up, it is possible to calculate and visualize the route to reach the selected AED (in this example, the AED in the Department of Chemistry and Technologies). The user can select the starting point by indicating an address or selecting "your position" [la tua posizione]. It is then possible to select the mode of travel, e.g., on foot. The system shows the route both on a digital street map template and using satellite imagery (Figures 6 and 7) and provides information about the time necessary to reach the chosen AED (6 minutes) and the distance (500 meters).

Discussion

At less than 10%, the global OHCA survival rate remains dismally low[27]. Improved survival depends in part on correctly implementing early links in the so-called "chain of survival"[15]. In 1991, Cummins et al[28] described the chain of sur-

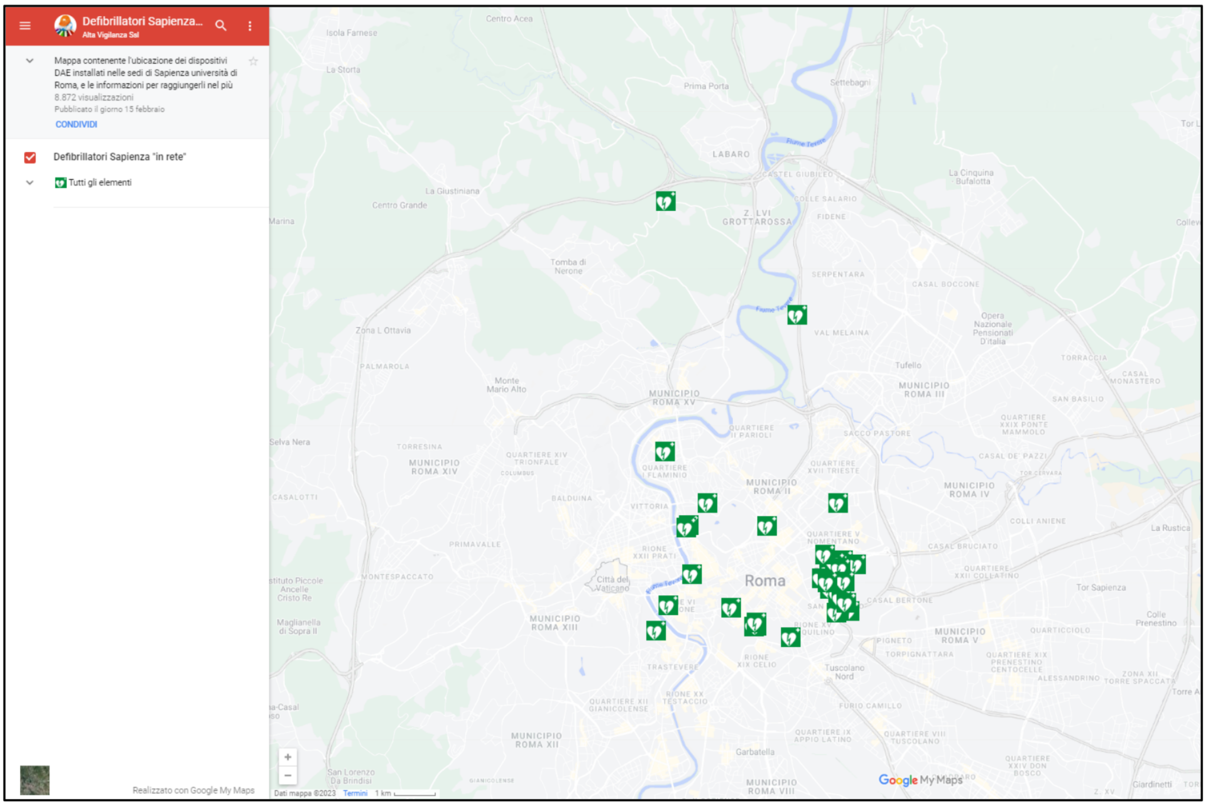

Figure 2. A webMap view of geolocated AEDs, as identified by the green squares with white hearts. Authors' elaboration.

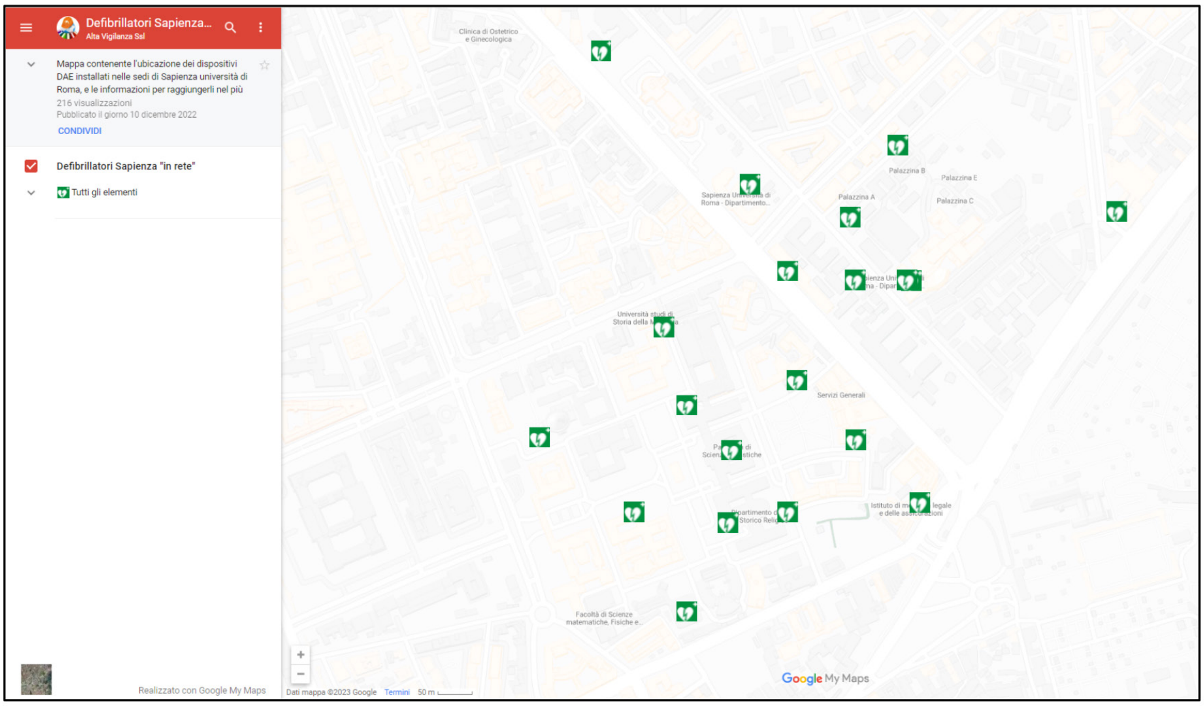

Figure 3. A zoomed-in webMap geolocalized view of AEDs on a digital street map template and with reference to different buildings. Authors' elaboration.

vival as being characterized by four fundamental links in the resuscitation procedure of OHCA patients. The American Heart Association subsequently adopted it and added two more links. The integration of the following six links can improve survival and recovery rates of cardiac arrest patients: i) early cardiac arrest recognition and emergency medical service (EMS) activation; ii) early CPR; iii) early defibrillation; iv) advanced resuscitation by EMS and other healthcare professionals; v) post-cardiac arrest care; and vi) recovery[29]. However, the most significant potential for improved survival is through prompt bystander initiation of the first three links of the chain of survival, including cardiac arrest recognition and EMS activation, CPR, and defibrillation[30].

Regarding cardiac arrest recognition and EMS activation, an Australian study found that witnesses of OHCA struggled to describe the incident and did not know who to call[31]. Education and training programs have been used to increase community awareness of and response to OHCA[32]. After EMS activation, the EMS dispatch center coordinates OHCA response through resource deployment. However, even the best EMS systems may find it challenging to reduce ambulance response times[33]. As a result, increased attention has focused on increasing bystander CPR and defibrillation[6-7,34].

One study using data from Copenhagen, Oslo, Stockholm, and Amsterdam found that nearly 60% of OHCA collapses occurring in a public place were characterized by a shockable rhythm, a rate that remained stable from 2006-2015[9]. In the presence of a shockable rhythm, bystander CPR may double or triple 1-month survival from OHCA at any interval until defibrillation is applied[35]. Bystander CPR also increases the probability that a defibrillator shock will end the ventricular fibrillation and the heart will resume a viable rhythm[36]. Conventional approaches to increase bystander CPR have included CPR training courses. CPR training is typically resource-intensive and requires training a sufficient proportion of the population and a long-term strategy to produce desirable results[37]. However, despite widespread community training initiatives, increasing bystander CPR rates remains a challenge[15], with some potential reasons including bystanders' lack of confidence in their ability to perform CPR correctly[38] and a reluctance to do mouth-to-mouth resuscitation[39]. In response, simplified training programs have been developed with promising results. For example, a large campaign in Arizona, USA, that emphasized compression-only CPR was able to increase bystander CPR and survival rates[40]. Another option to improve CPR rates and survival is through dispatcher-assisted CPR[41].

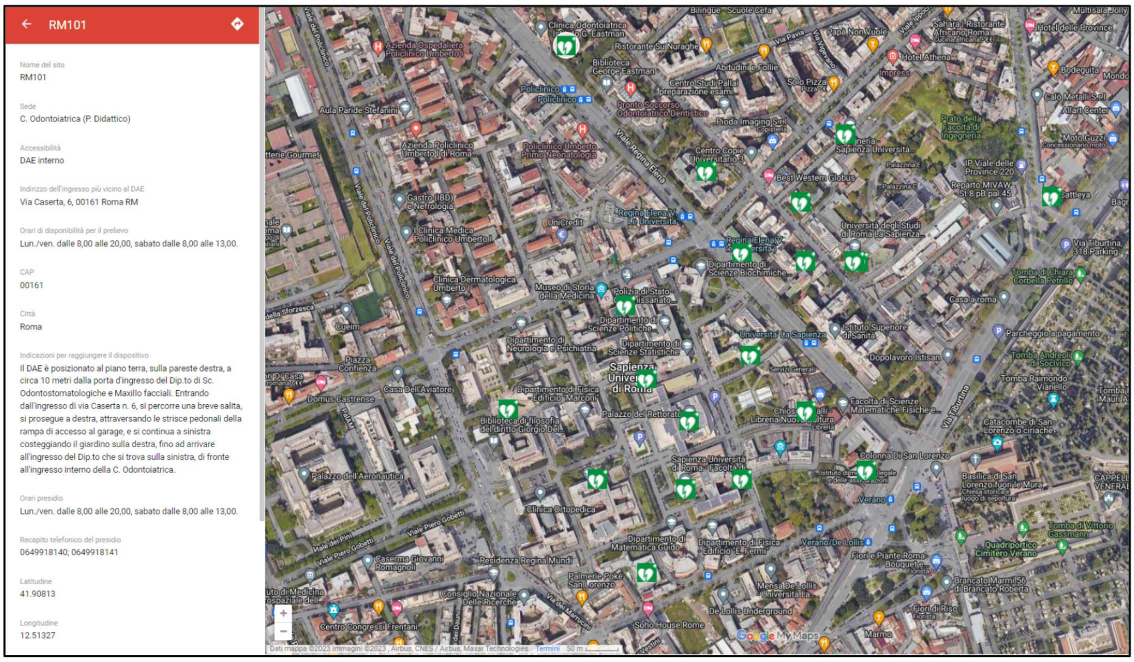

Figure 4. A zoomed-in webMap view of AEDs using satellite imagery, with the pop-up on the left containing information available for the specific AED selected (top of the page, circled in white). Authors' elaboration.

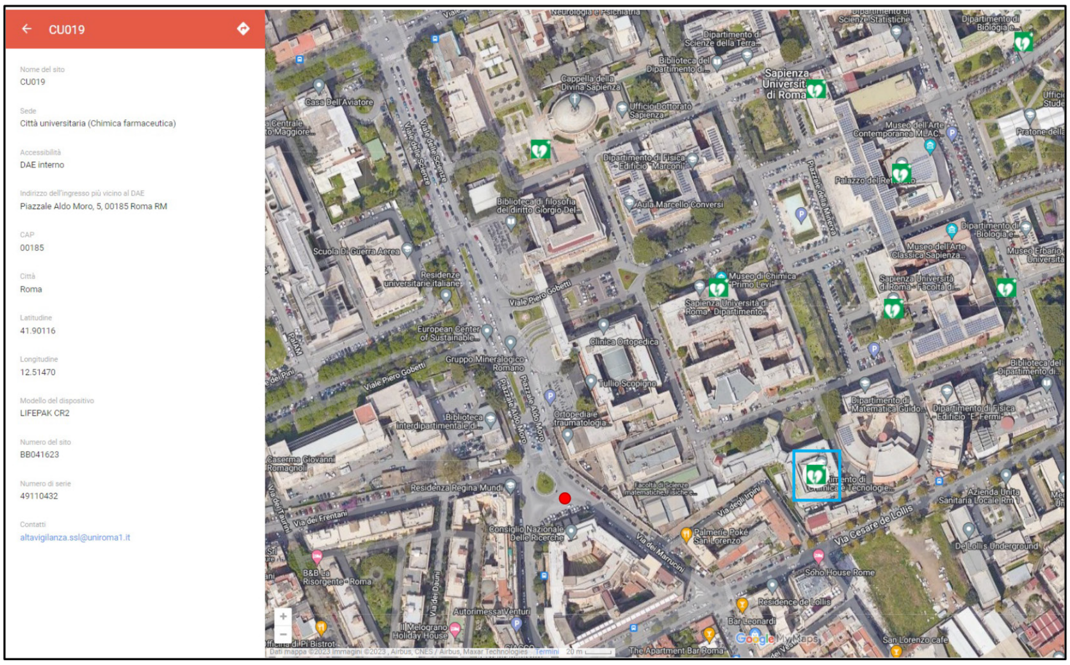

Figure 5. A webMap visualization of nearby AEDs if a bystander is near Piazzale Aldo Moro 7 (red) and wishes to reach the AED in the Department of Chemistry and Technologies (light blue square). Authors' elaboration.

Dispatchers can play a crucial role in the early detection of cardiac arrest and the beginning of bystander CPR. However, this strategy requires that dispatchers be trained to provide clear instructions over the phone, handle the caller's emotions, and ask the necessary questions[15]. In one Canadian study[42], a program for dispatcher-assisted CPR was shown to significantly increase the rate of bystander CPR by nearly 10 percentage points.

However, CPR is only able to maintain blood flow to the heart and brain, but in the presence of a shockable rhythm, defibrillation is necessary to restore a viable rhythm and prevent brain damage[8]. If a shockable rhythm is present, expert consensus recommends performing CPR until an AED is available[15]. Meta-analyses[43] have shown that combining CPR with AED use significantly improves the likelihood of both survival to hospital admission and hospital discharge as compared with CPR alone. Increased survival has also been demonstrated if bystanders deliver a first AED shock prior to EMS arrival[44]. However, defibrillation with a public access AED is only done prior to EMS arrival in 2-5% of cases[6,45,46], making defibrillation one of the largest gaps in the chain of survival. Community-wide initiatives that combine CPR instruction and AED access for the general population, such as those in Japan, have enhanced the likelihood of neurologically intact survival[47,48]. These results suggest that instead of universally simplifying the quality of basic life support instruction, the goal should be to reach more people in the population to create a pyramid of responders[15].

In order to benefit from this strategy, there needs to be a way to connect willing lay responders to nearby AEDs[14]. Unfortunately, prompt AED access may be hampered by cost and a lack of strategic placement. In a study in Copenhagen, Folke et al[49] calculated that to cover 67% of cardiac arrests, 1,104 AEDs would be needed, with a cost per quality-adjusted life year (QALY) gained of US $40,900. This cost might be decreased by using smartphone technologies to connect existing AEDs with lay responders, though this strategy depends on an updated national public registry of AEDs[14]. Some studies[50,51] in Denmark and Sweden have used mobile phone placement to alert volunteer responders to the location of AEDs, with the study by Andelius et al[50] reporting a three-fold increased odds of bystander defibrillation if responders arrived prior to EMS. In Italy, the App DAE Responder software alerts registered users to a cardiac arrest occurring nearby after it has been recorded by the Emilia Romagna EMS. The mobile app informs citizens about: i) the geographical distribution of AEDs; ii) the location of public access AEDs closest to their position; iii) the actions to take in the event of cardiac arrest; and iv) the appropriate rhythm support tool for performing external heart massage[52]. Other countries have developed similar applications. GoodSam (https://www.goodsamapp.org) and PulsePoint (https://www.pulsepoint.org) are well-known smartphone apps that connect trained lay responders with regional EMS dispatch systems. In both apps, users nearby receive a map showing the position of the sudden cardiac arrest and the closest AEDs[53,54].

Despite being on a smaller scale than the aforementioned apps, the Sapienza University of Rome AED webMap has the potential to make a public health impact due to the particular nature of OHCA collapses at educational institutions. Previous studies[48,55,56] that analyzed the location of OHCA events found that collapses at educational institutions often had a higher probability of survival, potentially due to more of these patients being healthier and having a shockable rhythm. Educational institutions may also be characterized by a larger portion of bystanders trained and willing to perform CPR and defibrillation. The AED webMap can help these bystanders quickly identify, locate, and reach AEDs present on the campus, a measure that could help speed defibrillation and maximize the life-saving potential of AEDs. The added value of the webMap includes: 1) detailed AED geolocalization with interactive pop-up information for each AED, including information on whether the AED is located internally or externally, which could be useful for OHCA collapses outside of normal office hours; 2) the option to use different base maps (digital street map, satellite imagery); 3) calculation and display of the route to reach the chosen AED (by walking or driving); and 4) the possibility to migrate towards multiple platforms (Figure 8). Future perspectives include potentially broadening this application to include all public access AEDs located in the community. Furthermore, an ad hoc webApp in an ArcGIS environment, derived from the webMap here presented, is in progress to calculate the search and identification of the AED closest to a starting point and the geovisualization of AEDs in ascending order of distance from a given point.

Conclusions

Most OHCA events in a public setting are characterized by a shockable rhythm that requires prompt defibrillation in order to increase the probability of neurologically intact survival. The Sapienza AED webMap targets early links in the chain of survival for OHCA by facilitating quick public access to AEDs located on the campus of the largest university in Europe, a measure that could help speed defibrillation and maximize the life-saving

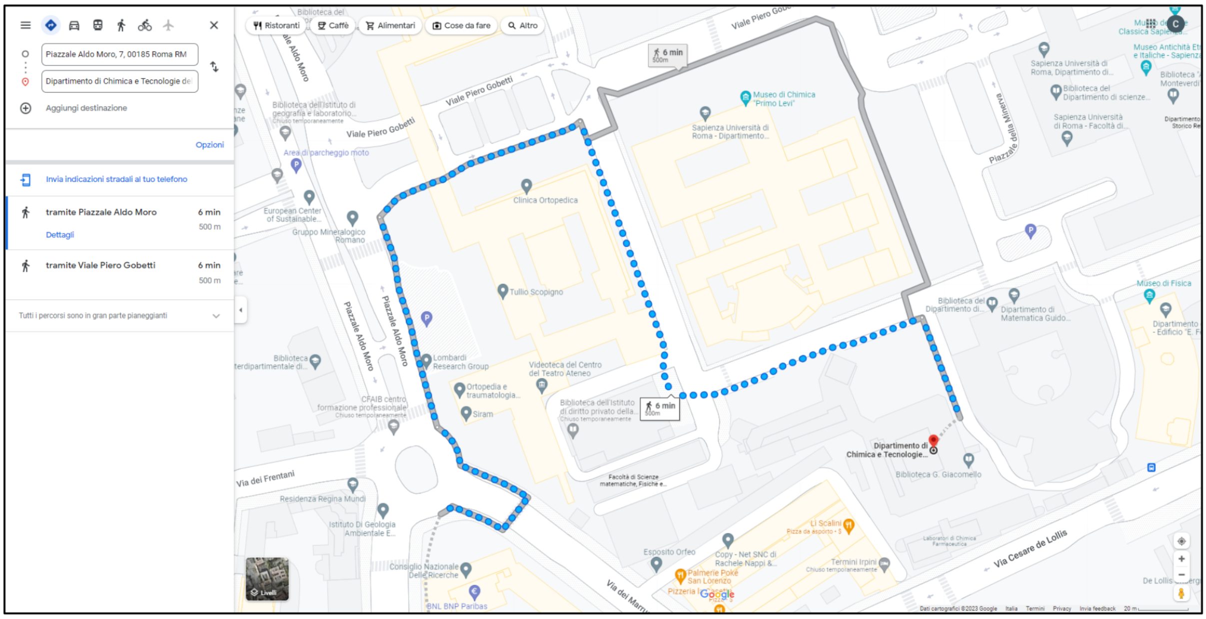

Figure 6. The suggested route to reach the chosen AED as displayed on a digital street map template, with travel time and distance. Authors' elaboration.

Figure 7. The suggested route to reach the chosen AED as displayed using satellite imagery, with travel time and distance. Authors' elaboration.

potential of AEDs. The webMap helps bystanders quickly identify, locate, and reach AEDs and provides information on whether the AED is located internally or externally, which could be useful for OHCA collapses outside of normal office hours. For maximum public health impact, the Sapienza AED webMap should be combined with other early link strategies to increase OHCA survival,

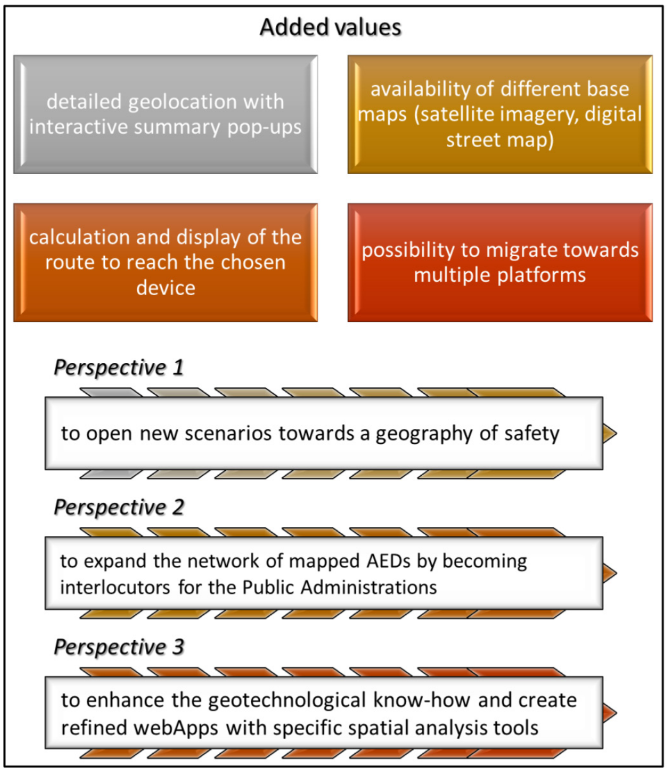

Figure 8. Added values provided by the AED Sapienza webMap and other perspectives. Authors' elaboration.

including widespread training on cardiac arrest recognition and bystander CPR and AED use and measures to increase interaction between bystander responders and EMS dispatchers.

Conflict of Interest

The Authors declare that they have no conflict of interests.

Informed Consent

Not applicable.

Ethics Approval

Not applicable.

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Authors' Contributions

CP, DP, ER, LC, and CDV contributed to the conception and design of the study. LC and ER performed data collection. CP and DP developed the webMap. CP, DP, and CDV wrote the first draft of the manuscript. GF, MK, and ER wrote sections of the manuscript. LC and PV critically revised the manuscript. All authors contributed to the manuscript revision and read and approved the submitted version.

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Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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