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Chapter 9
Location Information Services of Automated External Defibrillators (AEDs)

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ABSTRACT

Cardiovascular diseases are a leading death cause in the world. Cardiac arrest is one of the most usual, and very quickly fatal, especially in out-of-hospital environments. Defibrillation, aside with cardiopulmonary resuscitation, is an effective means to restart blood circulation and heart operation, even though even these forms of treatment can help just in sadly few situations. Defibrillation was invented and first demonstrated already year 1899, but first in the 2000s portable defibrillators with good automatic functions started to penetrate daily environments of people, especially in urban settings. Nowadays the starting point is that every citizen with normal human functionality should be able to use automated defibrillators. The chapter discusses how modern information and communication technology, especially mobiles services, internet, and location services based on them, could help citizens in the first crucial step in implementing their safety competence in emergency situations by using automatic defibrillators if they could only find them.

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INTRODUCTION

Cardiovascular diseases are a leading death cause in the world. Of them, cardiac arrest is one of the most usual, and very fast fatal, especially in out-of-hospital environments, where most cardiac arrests happen. World Health Organization (WHO) gives following facts about cardiovascular diseases (CVDs) (World Health Organisation, 2020):

- CVDs are the number 1 cause of death globally: more people die annually from CVDs than from any other cause.
- An estimated 17.9 million people died from CVDs in 2016, representing 31% of all global deaths. Of these deaths, 85% are due to heart attack and stroke.
- Over three quarters of CVD deaths take place in low- and middle-income countries.
- Out of the 17 million premature deaths (under the age of 70) due to non-communicable diseases in 2015, 82% are in low- and middle-income countries, and 37% is caused by CVDs.

Cardiac arrest can hit anyone, even though risk usually grows with age. Alarmingly, the study of Ringh & al (2009) found that there was a decreasing median age (form 68 to 64 years) in their study of out-of-hospital cardiac arrest patients in Sweden. In their Japan-wide study of SCAs in years 2013-2015 (Kobayashi et al., 2020) found 4863 out-of-hospital cardiac arrest patients less than 18 years of age. As SCA hits the core of critical body functions, hearth, fast response is needed.

Defibrillation, aside with cardiopulmonary resuscitation, is an effective means to restart blood circulation and heart operation, even though even these forms of treatment can help just in sadly few situations. Not all blood circulation or heart –related traumas are treatable with automated external defibrillators. Especially, asystole, a state with flat line –pattern, telling that the hearth has no electrical activity, and also causes no blood circulation, is not shockable with an AED.

Defibrillation was invented and first demonstrated already year 1899, but first in the 2000s portable automated external defibrillators (AEDs) with good automatic functions started to penetrate daily environments of people, especially in urban settings. Nowadays the starting point is that everyone with normal human functionality should be able to use automated defibrillators, and is expected to do so. The fast and right response is symbolized in the chain of survival: finding the patient/victim as early as possible, immediately started cardiopulmonary resuscitation (CPR), immediately started defibrillation with AEDs devices, and fast advanced cardiac life support in hospital settings. AED use should start within 5 minutes from the hearth stop, and before that taken cardiopulmonary resuscitation strongly improves the changes of survival.

Despite much activity, automatic external defibrillators are still scarce, and even if they would be available, they very seldom end up to productive use. This article studies the reasons for the rather low effectiveness of the heavy AED investments. The effectiveness of the AED investments has been already widely discussed, as for example in (Ringh et al., 2009) and (Walker, Sirel, Marsden, Cobbe, & Pell, 2003). Especially, this article discusses how modern information and communication technology, especially mobiles services, Internet and location services based on them could help citizens in the first crucial step in use of automatic defibrillators, the finding of them. Even when a defibrillator is found in time, there is sadly ample evidence, that they do not end up to use, or the use cannot help the victim. However, willingness to act, and knowledge and skills to execute needed operations in using AEDs should be a part of citizens' safety competence that could be enhanced by digital mobile applications.

In most cases even in heavily urban areas professional emergency staff (EMS) is not able to arrive to the venue of the cardiac arrest fast enough (Kitamura et al., 2010; O'Keeffe, Nicholl, Turner, & Goodacre, 2011; Zakaria et al., 2014). In US, the median time from 911 call to the arrival of professional rescuers often exceeds 6 minutes, even in dense urban environments (Myerburg, Velez, Rosenberg, Fenster, & Castellanos, 2003). This reveals why bystander help is needed crucially. Still, in the US, less than 8 percent of patients with out-of-hospital cardiac arrest in public setting have an automated external defibrillator applied before EMS personnel arrive (S. C. Brooks, Hsu, Tang, Jeyakumar, & Chan, 2013; Weisfeldt et al., 2011).

The article unfolds as follows. After this introduction to the topic we discuss defibrillators, and automatic external defibrillators as a subgroup of them. Then we discuss the medical outcomes of usage of AEDs, and stress the need for fast action. Then we turn to discuss why all citizens, including laymen, should have common safety competence including knowledge, skills and a willingness to use AEDs, and what kind of reasons inhibit them from doing so. Then the concept of chain of survival is introduced, and extended to reflect possibilities and challenges in using information and communication technologies (ICT) support to find and use AEDs. In the next section we focus on the crucial chain of survival component, finding an AED, and the role of ICT-based services in this. Conclusions follow.

DEFIBRILLATORS

A defibrillator is a device that gives a high energy electric shock to the heart through the chest wall to someone who is in cardiac arrest. This high energy shock is called defibrillation, and it is an essential life saving step in the chain of survival (British Heart Foundation, 2020).

Defibrillators help in the cases of cardiac (hearth) arrhythmia. Arrhythmia means that heart beats too quickly, too slowly, or with an irregular pattern. Arrhythmia is not to be confused with hearth attack, which is the death of a segment of heart muscle caused by a loss of blood supply. AEDs are useful in the cases of ventricular fibrillation and pulseless ventricular tachycardia. They are not helping or may be even harmful in many other hearth problems.

Especially AEDs are not usable as electric shock givers in the situations of totally stopped blood circulation called in medical terms asystole. Asystole is the absence of ventricular contractions and connected to cardiac flatline, that is the state of total cessation of electrical activity from the heart, and consequently blood flow to the rest of the body. AEDs can in such cases still be used to analyze and confirm the possible (but often not probable) restart of blood circulation.

"Automated" in the notion of AED means that the device works as independently as possible. Especially it means that the AED itself decides whether an electric shock is appropriate, and gives it. Many models anyway want human to confirm and give the electric shock, already as it might be dangerous to outsiders being (by mistake) connected to the victim.

"External" means that the device is portable and not implemented to a human. Internal defibrillators are surgically implanted to the human body, and they are connected with electrodes to the human body, usually hearth muscle.

Health professionals have their own manually operated or automated defibrillators. The usually allow more decision power to the user, but often also include automatic features, if they are preferred to be used by the professional users.

Defibrillators are places on the human chest so that the two pads of the device are at the other ends of the hearth, one up on the right side and another below the hearth on the left side (as seen from the patient point of view). The pads should be in direct contact with the human skin, clothes and sometimes even hairy skin surface can be obstacles. The modern AEDs typically give two sequential shocks with power of 120-200 joules, the two shocks changing polarity during the activity. In early years of AEDs, changing polarity was not used, and the electronic energy was much higher.

In addition to doing the core defibrillation with electronic shocks, defibrillators are already helpful in analyzing the status of the hearth even if defibrillation cannot be done (non shockable rhythms), and in such way assist also the process of cardiopulmonary resuscitation (Kishimori et al., 2020).

First use of an external defibrillator on a human being was conducted in year 1947 by Claude Beck. The first portable defibrillator was invented by Frank Pantridge in Ireland in year 1965. Current developments in include web-enabled AED, also an AED that is in constant connection with the Internet. These devices offer new possibilities finding them when needed through the web, and they can also for example report themselves of their maintenance needs (Mao & Ong, 2016). Constant connection to Internet of course on the other side consumes battery recourses.

The official AED sign (Figure 1) was developed by the International Liaison Committee on Resuscitation in year 2008, and it was accepted as ISO standard 7010 E010 in year 2011. Sadly, when taking a look at Google with the keyword "AED sign", one sees hundreds of different versions of this sign. This is not of course in any way alleviating the difficulties of finding an AED in the moment of need.

Figure 1. The official AED sign (ISO standard 7010 E010)

Automated external defibrillators are increasingly installed to public places. Reasons for and methods of installing vary. An usual group of AED installations is haphazard donations, where there typically is not any detailed planning for the location of the AED. Many organizations, such as insurance companies, install AEDs to their premises to show example. Cities are typically actors for planned and systematical AED acquirement and installation. In a study about Stockholm, Sweden, (Ringh et al., 2009) showed that systematic placement of AEDs to city setting are much more effective than unregulated placement.

Sun & al (2019) calculated a new positions of AEDs in Copenhagen based on real OHCA case register. They found that their reallocated AED positions would have increased AED out-of-hospital cardiac arrest (OHCA) coverage by 50 to 100 percent. Legal reasons, such as fear for liability are also a strong motivation installing AEDs (Coris, Miller, & Sahebzamani, 2005).

The current recommendation for the density of defibrillators is that they should be in places where one cardiac arrest is expected to happen every 5 years[1]. To take an example, (Folke, Lippert, & Nielsen, 2009) evaluated that in the rather urban city of Copenhagen with some 600 000 inhabitants following this standard would mean some 1100 AEDs. In the article it was counted that this resulted in the cost of $40 900 per quality-adjusted life year (QALY).

Especially it must be noted that in most cases cardiopulmonary resuscitation and defibrillation activities go hand in hand. Typical scenario is that CPR must be started and maintained, until a defibrillator is found to stabilize the hearth beat.

It is suggested by the American Heart Association (AHA) that an AED should be available within 100 meters so that it can be reached in 1,5 minutes at a brisk pace (Aufderheide et al., 2006). AED application should be started within a maximum of five minutes, and they should be accessed in a timeframe of 1-1,5 minutes (Kishimori et al., 2020). It has been assessed that every minute of delay of defibrillation start causes 9 percent decrease in neurologically intact survival (Kitamura et al., 2010).

The prices of AEDs have gone down, and their usability is good enough for a normally functional layman. Finding the defibrillator fast and effectively in the case of need is of crucial importance and improves the probability to survive out of hospital cardia arrest (Public Access Defibrillation Trial Investigators, 2004). Fortunately, the constantly increasingly more ubiquitous information and communication technology can help in the finding of the defibrillator location (Merchant & Asch, 2012), because of mobile phones and improved location-based services in them.

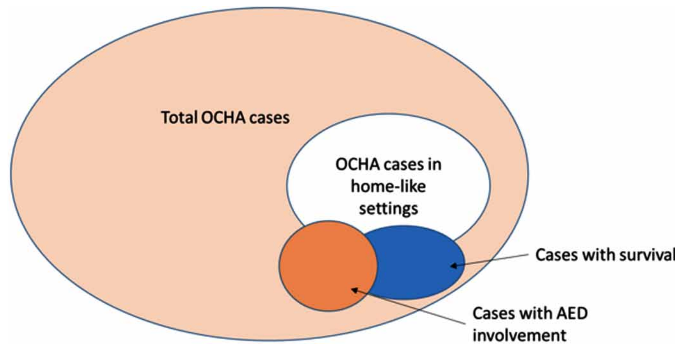
Results of AED Use

Out-of-hospital cardiac arrest (OHCA) Survival rates vary drastically between communities (Nichol et al., 2008). Situations, conditions and figures in different countries, environments and with different populations are different, but Figure 2 gives a broad illustration on the importance of AED use. Some 20 percent of OHCA cases happen outside home-like public inaccessible settings. According to (Becker, Eisenberg, Fahrenbruch, & Cobb, 1998) and (Pell et al., 2002) 79 to 83 percent of out-of-hospital arrests happen at home. In optimal conditions, an AED is used in some 20 percent of those cases. Survival rate is clearly improved because of the AED use, but still remains far below 10 percent. According to (Deakin, Shewry, & Gray, 2014) AEDs are successfully used in less than 2 percent of cases of out-of-hospital cardiac arrests.

Exact measurement of the improvement of survival rates is next to impossible. First, at the very moment of the hearth problems, and as much afterwards based on documentation, it is in many cases difficult if not impossible to exactly tell whether the encountered (heart-related) health problem witnessed was such one that AED could even theoretically be of use. The term shockable and non-shockable heart rhythm problems well illustrate this (Grunau et al., 2016). Fine-tuned measurement on time needed to start AED use that affects the outcome is also not easy, as exact measurement of time passing is typically not possible in the acute trauma situation.

A question of importance is also the outcome. Thresholds are many: Can the heart and blood-circulation of the victim be restarted and established? Will the patient then make it alive to the ambulance? Will

Figure 2. A broad illustration on the occurrences of out-of-hospital cardiac arrests (OHCA) and their outcomes



the patient arrive in life to the hospital? A typical measurement point is that of discharge from hospital, or the survival rate after 1 month (or some other period) after the discharge from the hospital. Even at those time points, the condition of the patient can vary. Typical measures are depicted in the cerebral performance categories (CPC) of (1) good cerebral performant, (2) moderate cerebral disability, (3) severe cerebral disability, (4) coma or vegetative state, and (5) death or brain death (Kishimori et al., 2020). In total, the discussion shows that saying and assessing what was a “successful” AED use case is hard to define.

AED use neither happens in isolation. As already depicted in the chain of survival, early cardiopulmonary resuscitation (CPR) is of key importance aside AED use. Rapid defibrillation performed together with CPR can improve chances of survival to more than 50% (Merchant & Asch, 2012; Public Access Defibrillation Trial Investigators, 2004; Rea et al., 2010; Weisfeldt et al., 2010). Other conditions that affect the outcome are for example the performed airway management to the patient, as well as the use of adrenaline administration to the patient (Kishimori et al., 2020). The time spent in the ambulance before arriving to the hospital surely has a deep effect on the outcomes (Dicker et al., 2019).

In Japan it was found that even in cases where there was a bystander in the case of an out-of-hospital cardiac arrest, the survival rate was 10 percent (Ambulance Service Planning Office of Fire and Disaster Management Agency of Japan, 2016). Nichol & al (2008) report better but still not good outcomes: 8,4 percent of patients of sudden cardiac arrest survive to hospital discharge. S. C. Brooks & al (2013) report that also only 8,4 percent of out-of-hospital cardiac arrest patients in North America survive to hospital discharge.

A very convincing documentation from Japan was delivered by (Kitamura et al., 2010): “Among all patients who had a bystander-witnessed arrest of cardiac origin and who had ventricular fibrillation, 14.4 percent were alive at 1 month with minimal neurologic impairment; among patients who received shocks from public-access AEDs, 31.6 percent were alive at 1 month with minimal neurologic impairment”. In UK, in one sample collected by (Whitfield et al., 2005) from years 2000 to 2002, 25 percent of ventricular fibrillation patients survived to hospital discharge. The article is also a good example on what kind of data can be collected from the internal digital memories of the AEDs after use.

Readiness to Use an AED

Automated external defibrillator nonuse at a cardiac arrest emergency is a multifactorial problem with potential barriers at many points along the process pathway (S. C. Brooks et al., 2013). The trend has gone towards the conclusion and guidance that any bystander should use the AEDs in the case of cardiac arrest. In their study on Chicago airports (Caffrey, Willoughby, Pepe, & Becker, 2002) found that in 11 successfully resuscitated patients the rescuers had no training or experience in the use of automate defibrillators (albeit 3 of them had medical degrees). In their study, (Whitfield et al., 2005) conclude that the speed of response by the lay first responders in relation to AED use was similar to that reported for healthcare professionals.

Before widely recommending everyone to use AEDs, it was typical to conclude that *trained* laypersons should use them (for example see (Mao & Ong, 2016; Public Access Defibrillation Trial Investigators, 2004). The next step of increased user group would be that persons with duty (and given training) to answer to emergencies would use the devices, persons such as firemen and police officers. Medical professionals without a special education to emergency services are often also counted to this group. The best case of course is that professional emergency medical service (EMS) staff is available to do defibrillation or other tasks they assess as needed.

A key issue in AED use is the citizens' ability and willingness to use them. We refer to citizens' safety competence (Lindfors, Somerkoski, Kärki, & Kokki, 2017; Puolitaival & Lindfors, 2019), which is considered a combination of a) integrated set of attitudes b) knowledge c) skills and d) willingness to act to perform a certain task. The competence is applied in emergency situations where there is need for preparedness, and prevention and/or recognition of needs of actions in to perform a needed task in an authentic situation, e.g. the use of AED.

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The AED automatically analyses the hearth situation (the word Automatic in the acronym AED), and does not recognize giving shocks if they would be dangerous or not usable, often even does not give the shock even if the user would like to do that. In principle no harm can be done with them. However, As stated earlier, "automated" in the notion of AED means the device works independently and further on, the device decides whether an electric shock is appropriate. Yet before this automated mission is accomplished, a layperson or professional who received practical AED training, is needed. The person who uses the device needs to know that AED can be used in the emergency in question. She or he has to have motivation and willingness to act (Figure 3) - to find the device and prepare it for the use. Finally, AED skills are needed. These include: to put power on AED device, to attach the pads correctly, to clear for analysis, to clear safely to deliver the shock and finally to deliver the shock. (American Hearth Association, 2016). It is documented that bystanders that have helped with AEDs in cardiac attack cases often suffer from some level of transient psychological trauma (Public Access Defibrillation Trial Investigators, 2004). It might be however that the level of trauma has nothing or very little to do with the use of the AED.

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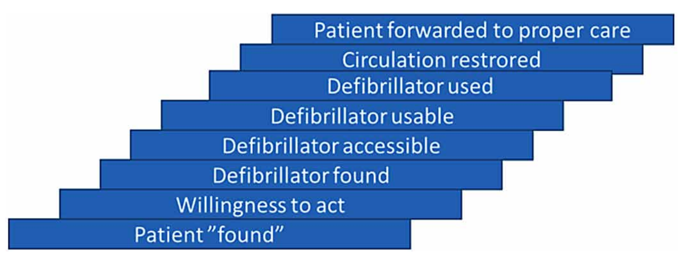
An issue in itself is the possible legal liability for laymen operators of AED (or for any user if so comes). Fear of liability and legal processes is a strong demotivator to use an AED, even when it would be available (Fischer et al., 2011). Many countries and jurisdictions have implemented so-called "Good Samaritan Laws" (Pardun, 1997) to mitigate legal liability of helping bystanders (Hung, Leung, Siu, & Graham, 2019). Unfortunately, these laws vary between different countries (Mao & Ong, 2016), and for example between different states in the US, and so the helpers can never be totally assured of their legal protection. However, on most countries, leaving an emergency-situation without any actions can be considered as a negligence in the legal system.

The Extended Chain of Survival

Securing the function of the chain of survival needs a lot of supporting actions, and steps in between. Figure 3 presents one extended value chain that might lead to successful defibrillation use and restoring of vital activities for the patient. Even more detailed value chain descriptions could be easily done, but then we might lose on keeping the total picture within limits of giving a reasonable overview.

Figure 3. An extended chain of survival for out-of-hospital cardiac arrest



First step is to find the patient. Unfortunately, lot of cardiac arrests take place in isolated environments: home or other private property and distant and non-populated outdoor areas. No-one is to witness or get information about the cardiac arrest – the only thing that is often left is the finding of the dead person. Bardy & al (2008) found no evidence that availability of an AED would significantly improve overall survival of the victims.

The second if a cardiac attack person is found is to decide to help. For the layman who is not healthcare professional, in most countries it is not a crime not to help. Indeed, fear of harming the patient through use of defibrillators, or other means, often keeps by passers from helping. Still worse, in many environments – for example strongly in the US – the by-passers often fear legal consequences if they undertake helping actions, including use of defibrillators.

Even if will to help is there, the next crucial step is the finding of the defibrillator. As this is the key topic in this paper, this is discussed in more detail in the next section.

Even a found defibrillator might be inaccessible. It might be behind locks, or controlled by a vending machine that is out of order or too complicated to use. Defibrillators might also be protected by different strong warning signage and different kinds of alarm signals that are activated when the device is touched. All these might make the found defibrillator inaccessible, in real terms or mentally. Many studies have discussed and criticized the practice of allocating AEDs to public premises, which often are accessible only during regular office hours (Hansen et al., 2013). In their study Hansen & al found that in Copenhagen in years 1994-2011, access to AEDs in real public cardiac arrest cases was limited in 53,4 percent of cases during evening, nighttime and weekends. In some, hopefully rare, cases it might also be that public AEDS are being stolen (Public Access Defibrillation Trial Investigators, 2004), most probably for home use or to be sold on some gray market. AEDs might also fall to be victims of pure senseless vandalism.

In the next step, the AED might be in the hands of the helper. As these devices are dependent on working batteries and are complicated electrical devices needing maintenance, the next sad finding by the helper might be that the device is not usable. This condition surely gets more usual as the total amount of AEDs installed increases, and the age of the devices gets higher.

Typically, AEDs are medical devices that cannot be sold without prior acceptance of authorities. They have an expiry date and a maintenance program specified by the manufacturer. In many settings, a battery check and basic check of the devices integrity and cleanliness in expected to take place on a monthly basis (Haskell, Post, Cram, & Atkins, 2009).

A whole big issue of course is whether the device is so user-friendly that the user can operate it, even to begin. For the user, wrong language instructions of even finding the on/off button might be critical steps. Having the basic understanding on how to set the AED pads to the victim body is of course of crucial importance. Often this is clearly guided in picture form in the AED short user instructions.

The use phase is the critical. Even when the original willingness to help is there, it might be that the device never gets used because of user-related reasons. In a study about Copenhagen (Agerskov et al., 2015) found that in a period from 2011 to 2013 just in 3,8 percent of out-of-hospital cardiac arrest cases an AED was used prior to the arrival of the ambulance, even when an AED would have been reachable within 100 meters in 15,1 percent of all cases.

Doing the physical contact with the patient might just be too much for many users. One thing the “automated” refers to in the wording automated defibrillator is that the device analyzes the condition of the patient, and concludes that delivering electric shocks is not beneficial. This is of course good if and as usually the analysis is right, and is not dependent on the user. Some other kind of help should then be delivered, typically cardiopulmonary resuscitation. Other forms of help might be difficult or impossible for the non-professional helper.

Finally, it might be that the defibrillation activity is unsuccessful. Even if it is a success, might be that the further steps in the care taking chain are not successful or fast enough. These are anyway medical considerations beyond the scope of this article.

Finding a Defibrillator

At least three different roads to find an AED are usually available. If no communication-able devices like mobile phones are available, the only option is to start looking for the device in the "real" physical world. A crucial first step is a crucial initial assessment whether there is any change of finding an AED within a reasonable distance exists or not. This assessment might easily lead to totally wrong conclusions. As (Merchant & Asch, 2012) state, "perhaps the only thing worse than not knowing an AED is nearby is wasting time searching for and AED that is there not at all".

If the search is started, in successful cases there are most likely other people, even those knowing the environment well, who can be contacted for help. However, (B. Brooks et al., 2015) found that only 5 percent of people living even in high-risk cardiac arrest areas knew the location of their nearest public AED. Doing a random search without any human help might be a very frustrating exercise.

As a second road, if a mobile phone is available, calling emergency services is a natural, standard and often officially recommended way to proceed. When available, the emergency service can help in many ways: tell whether there is an AED in the near environment, send to place local helpers with AED operating skills, and if needed help orally or maybe even through visual interface in the use of the AED.

The third road might be to try to find the AED through Internet-based location services, often used through a mobile phone –based app. This might sound like a rather difficult and complicated task, but at the mobile app stores we have a lot of apps helping in finding defibrillators. Several challenges might anyway come along even with this option in the case of emergency. The first is through what service the search for the defibrillator should be conducted. Different language boundaries might inhibit the finding of the right site for locating the device. The information on the site might be outdated or otherwise false. Finally, even when the device is located, route to it might be difficult to define and/or find.

As it comes to the physical location of an AED, it must be remembered that two-dimensional coordinates of the device are often no more sufficient. In complicated built (city) environments the vertical position of the AED is of critical importance, for example if it is underground (say at a metro station) or high up (say at a sightseeing floor of a high building). Complicated multi-level street arrangements also necessitate three-dimensional information about the AED location.

A key prerequisite for finding a position of an AED is that it is registered to a publicly available register (Rucigaj, Podobnik, Gradisek, & Sostaric, 2019). It is next to impossible to assess how much AEDs are not taken to any registers. Usually AEDs that have got public financial support are registered to some registers, and the regulations in many countries demand registering for AEDs that are intended for public use. Sometimes the registers have limited access. They might just for professional use, or they might be approachable just through certain software products (for example mobile apps). In total, there is an agreement that AEDs are not properly registered in most of the countries. A new innovation to build registers of AEDs could be crowdsourcing, where citizen would be challenged to register AEDs, for example to a game-like (scavenger hunt) mobile application (Merchant & Asch, 2012).

Drone delivery of AEDs is a fresh initiative taken up. Challenges of course face even this option. Weather conditions might hinder delivery of the AED. Delivery can of course take place only to locations outdoor, and even there, complicated urban structures with multiple levels might pose a serious challenge. It is rather safe to conclude that drone delivery of AEDs could be an add-on service, but that it should not be seen as a technology to substitute AEDs permanently located to public premises

A fresh trend is that now as AEDs have become cheaper, people – especially in older age groups – buy them to their homes. AEDs are on the way to become consumer electronics – at least as basic versions.

This trend of course has its benefits and risks. A fresh innovation taken in many countries is to locate AEDs to taxis or buses (Hajari et al., 2019; Mitamura, 2008).

The general opinion is that AEDs cannot be used as weapons to kill any person (at least one in rather normal condition). The energy amount delivered by AEDs is too slow to kill anyone, and the device should not deliver any shock unless it analyses this as appropriate. Anyway, there is discussion that AED shock can deliver danger and heavy pain in the case of metal objects on the human body, such as metal jewellery or metal wires on textiles such as bras.

Mobile application stores offer possibilities for downloading apps to find the nearest defibrillator. As of 10th of April 2020 the Apple store found 11 applications with the search "defib". Most of them were AED location services, but contained also apps guiding and training in AED use. In Google Play store, department applications, the keyword "defib" returned hundreds of applications. The analysis of these applications, and trying all possible search terms in these stores is out of the scope of this article. The results anyway tell that there are plenty of applications to assist in finding and AED, but their usability and geographical coverage remains an issue to be studied later.

A very beneficial solution to the finding of AEDs could be that they would be integrated to other popular applications or location services. A kind of "silver bullet" solution would for example be that Google Maps would contain AED location information, and citizen would be aware of this and could and would like to use this information at the moment of need.

DISCUSSION

Cardiac arrest is a key cause of death in the world. It can hit anyone anywhere, even though elderly population is in the most danger. Several steps have to be mastered in order to provide successful help with defibrillators to patients. In medicine it is typical to speak of the chain of survival. It is a short version of the total truth consisting of four crucial tasks: finding the patient/victim as early as possible, immediately started cardiopulmonary resuscitation, immediately started defibrillation with AEDs or other – more professional - devices, and fast advanced cardiac life support in hospital settings.

Because of financial and other constrains, AEDs cannot be everywhere within 100 meters of 1 minute reach, as would be the recommendation. Often AEDs are typically allocated based on haphazard voluntary actions, but several cities have also taken coordinated actions to allocate AEDs to optimal locations. Studies have clearly shown that coordinated AED placement leads to better results in life saving. A key success factor is that all AEDs are registered to central, typically nation-wide, databases that are easily accessible.

There are several modes of using AEDs. On the contrary to widely spread beliefs, in most countries even laymen without any education and earlier experience are encouraged to use AEDs if need arises. An ability to use AED should be considered a part of citizen's safety competence. Laymen AED use can be improved through connections to emergency response centers, that can give guidance to the use for example through telephone connection during emergency. Better option of course would be that even the laymen have gone through some kind of related education and training, such as courses on basic life support, first aid, certified first responder, or cardiopulmonary resuscitation. The use of AED could be included in safety education as a part of safety competence development in comprehensive, vocational, higher and adult education. Additionally, voluntary courses, workshops and campaigns as part of conferences, exhibitions, trade shows and especially in social media, could be organized for citizens to enhance their ability to use AED. The next step in professionalism is that AEDs are used by special trained helpers, who anyway are not health professionals, such as guards, taxi-drivers or personnel of close-by businesses. Next step increasing professionalism is the use of AEDs by security guards, policemen and firemen (the first responder concept (Ringh et al., 2009)), if possible through the on-line support of emergency centers. The best case of course is that specialized Emergency Service Response teams use the devices, but they usually also bring their own devices with them and are not dependent on public AEDs.

Maintenance of AEDs is a big challenge. They need monthly check and maintenance, have a limited lifecycle, and are useless without a working battery delivering power.

Finding an AED is also critical. The first and decisive decision that has to be taken is whether to start to look for and AED in the case of emergency, or try to do without one. Alone this is a heavy decision, in the case of two or more helpers both activities can be undertaken simultaneously. Typical possibilities are haphazard search of the AED in real world, if possible additionally asking for guidance from local by-passers. Emergency centers can most likely tell the location of the nearest AED, if contact can be established. Then there is a possibility to try to search for an AED through different electronic services. Finding of an AED is helped if it has been fitted with international standard sign telling of its location.

CONCLUSION

Defibrillators have been around us some 50-70 years. They have surely saved millions of lives and given hundreds of millions of life-years for mankind. Yet they seem not to be an innovation that would have penetrated our life very deeply. Very few are aware of their existence, even fewer know hot to use them, still fewer would use them in real situations, and extremely few have used them. Still, over long time, many owe their lives to defibrillators and their skilled users. Studying and better understanding the user acceptance and innovation diffusion of AEDs surely remains an important research topic for many decades to come.

As any human artefact, defibrillators are not just technical or medical innovations. Their efficient usage needs a complex ecosystem, which can be erected just though commitment of key stakeholders, constant social and systemic innovation, not forgetting the core technical and medical innovations, and even some luck and favourable environmental factors.

Three central topics have come up in this analysis based on contemporary literature. First, selecting locations for AEDs is a key task, that needs careful planning in an environment where resources are not endless. Even when the installation of the AEDs in great masses could be afforded, maintaining and keeping track of the total reserve needs tremendous resources. Where to locate AEDs is a key issue now and in the future.

Second, willingness to use an AED in the case of emergency is a crucial issue. Any fear of legal consequences of (not successful) application of AED keep people from using them. It should be made universally clear that using an AED is in the case of need not just a possibility, but a duty for anyone. The automatic functions of AEDs next to totally eliminate the possibility to use them in a harmful way.

Third issue is the finding of the devices. Both real and virtual environments cause challenges. Signage of AEDs varies a lot in different places, and despite a universal standard it is not done everywhere in a standard way. Virtual world also has its challenges. There is no standard way of finding a defibrillator through digital services. Given the endless spectrum of digital devices, platforms and applications a world-wide standard search system in digital space still remains a distant dream. The fast development of various digital location services gives hope and even real developments, but variety of different installations can still cost lives in the situation of a real need.

Academic research on AEDs is rich, but mostly done by medical researchers starting from medical starting points. Computer and IS research community has allocated next to none resources to study the development and assessment of AED finding services. More research is needed to work out the fastest and most efficient strategies to find AEDs, and to understand the role of computerized, typically mobile, applications to find the AED. Additionally, further research is needed in education in considering how to educate citizens and train their ability to use digital applications in advancing their safety competence. In this case to find AEDs in time and to act in emergency where the use of AED is needed. Effective delivery and maintenance of AEDs, usability of them as well as digital applications, citizens' possibilities and ability to find and use them in emergency is a multi-scientific and multi-dimensional research and development challenge where research based innovations are needed.

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ENDNOTE

1 The guidelines are available at https://www.ilcor.org/home/