REVIEW

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CURRENT OPINION

Public access defibrillation: challenges and new solutions

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Purpose of review
The purpose of this article is to review the current status of public access defibrillation and the various utility modalities of early defibrillation.

Recent findings
Defibrillation with on-site automated external defibrillators (AEDs) has been the conventional approach for public access defibrillation. This strategy is highly effective in cardiac arrests occurring in close proximity to on-site AEDs; however, only a few cardiac arrests will be covered by this strategy. During the last decades, additional strategies for public access defibrillation have developed, including volunteer responder programmes and drone assisted AED-delivery. These programs have increased chances of early defibrillation within a greater radius, which remains an important factor for survival after out-of-hospital cardiac arrest.

Summary
Recent advances in the use of public access defibrillation show great potential for optimizing early defibrillation. With new technological solutions, AEDs can be transported to the cardiac arrest location reaching OHCAs in both public and private locations. Furthermore, new technological innovations could potentially identify and automatically alert the emergency medical services in nonwitnessed OHCA previously left untreated.

Keywords
drone-assisted automated external defibrillator delivery, mobile automated external defibrillators, public access defibrillation, volunteer responder programmes, wearables for detecting out-of-hospital cardiac arrests

INTRODUCTION

Out-of-hospital cardiac arrest (OHCA) remains a substantial cause of death with more than 350 000 cases annually in the United States with a survival rate of only 8–10% [1]. Cardio-pulmonary resuscitation (CPR) and early defibrillation before arrival of the Emergency Medical Services (EMS) have the greatest impact on OHCA survival [2–4]. Recommendations for public access defibrillation (PAD) were first published by the American Heart Association in 1992 and later by the European Resuscitation Council in 1998 [5,6]. Since then, substantial efforts have been made worldwide to deploy automated external defibrillators (AEDs) in areas with a high incidence of OHCA and train community members to use them. However, although the chance of survival with immediate defibrillation by an on-site AED is reported as high as 50–74% [7,8,9▪], the proportion of OHCAs occurring in high-risk locations such as airports are very limited, as the majority of arrests occur in private homes where access to early defibrillation is very low or nonexistent [10–12]. Now, almost three decades from the first guideline recommendations of implementing static PAD programmes, it seems timely to move

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KEY POINTS

- Traditional public access defibrillation programmes with static, on-site AEDs cover very few cardiac arrests and are rarely used in private home where the majority of arrests occur.
- AED delivery by volunteer responder programmes holds a great potential to increase bystander defibrillation in both public and residential locations, but randomized clinical trials documenting survival benefit is lacking.
- Mobile AEDs used by professional first responders (e.g. police and firefighters), by AED equipped volunteer responders or delivered by drone could potentially lead to earlier defibrillation compared with standard EMS response.
- Innovative technological applications such as wearables capable of transmitting vital signs directly to the local EMS present a unique opportunity to identify unwitnessed cardiac arrest previously left untreated.
- Authorities and policy makers need to prioritize funding and implementation of the basic infrastructure for successful resuscitation.

towards a more multifaceted approach for early defibrillation using mobile AEDs and new technologies for AED delivery to the cardiac arrest scene before EMS arrival, covering OHCAs in both public and private locations [13,14▪▪]. This study reviews and summarizes different approaches for early defibrillation and gives a perspective of future possibilities for detection and treatment of OHCA.

Public access defibrillation with on-site automated external defibrillator

The traditional PAD approach has been deployment of publicly available AEDs in areas with a historical high incidence of OHCA, to be used on-site by random bystanders. Within the last decades, many countries have implemented national programmes for the use and dissemination of publicly available AEDs [15–19] with a dramatic increase in the number of accessible AEDs. The use of on-site AEDs in public locations (e.g. casinos, airports or similar facilities) has been associated with survival from 74 to 100% in patients presenting with a shockable rhythm [7,9▪], most likely due to a combination of positive predictors such as a high proportion of witnessed arrests, bystander CPR and a short time from collapse to defibrillation [20,21]. Studies have found that the probability of bystander defibrillation is tripled, and survival doubled if the OHCA occurs near an accessible AED, with a rapid fall in bystander defibrillation with increased distance to nearest AED [22,23]. However, only few arrests occur in high-incidence areas, and even fewer in close proximity of an accessible AED [23,24]. Furthermore, in residential areas where most OHCAs occur, the probability of bystander defibrillation is low even when an AED is on-site [22]. In conclusion, traditional PAD with on-site AEDS offers high survival rates, but cover very few patients and are rarely used in private home arrests (Fig. 1).

Volunteer responder programs using on-site automated external defibrillators

Due to the limitations of on-site AED use in public locations, the concept of dispatching volunteer responders to nearby OHCAs has evolved during the last 10–15 years [25]. A great variation exists between current different programmes with respect to both the number of volunteers to alarm, activation radius, alerting hours (only daytime or around the clock), type of responders alerted (volunteer laypersons, healthcare personnel or off-duty professionals) and mode of alert (text messages or GPS-based app alerts) [25,26]. Common to all systems is that they are interconnected with local or national AED registers making it possible for volunteers to fetch nearby AEDs (often guided directly by the smartphone application). Volunteer responder programmes seek not only to increase CPR rates but also to initiate early defibrillation before EMS arrival (Fig. 2). Although several observational studies have found arrival of volunteer responders associated with increased bystander CPR and early defibrillation [27–29,30▪,31–33], only two randomized controlled trials of volunteer responder programmes exist [34,35]. The first trial investigated the effect of adding volunteer responders to the standard EMS response (without AED retrieval) and found increased bystander CPR rates (primary outcome) but no significant improvements in 30-day survival [34]. The recent SAMBA trial investigated whether AED attachment improved when volunteer responders were guided to fetch a nearby AED on the way compared with responders directed directly to the OHCA location and found no significant difference in AED attachment (primary outcome) as well as bystander defibrillation [35]. It is possible that activation of volunteer responders will have a bigger impact on patient survival in areas with long EMS response times (e.g. more rural areas), as they can reach the patient faster with an AED. However, for a volunteer responder programme to be effective, several issues need to be addressed: the EMS dispatcher needs to recognize the emergency call as a potential OHCA, requiring activation of both the professional EMS system and the volunteer

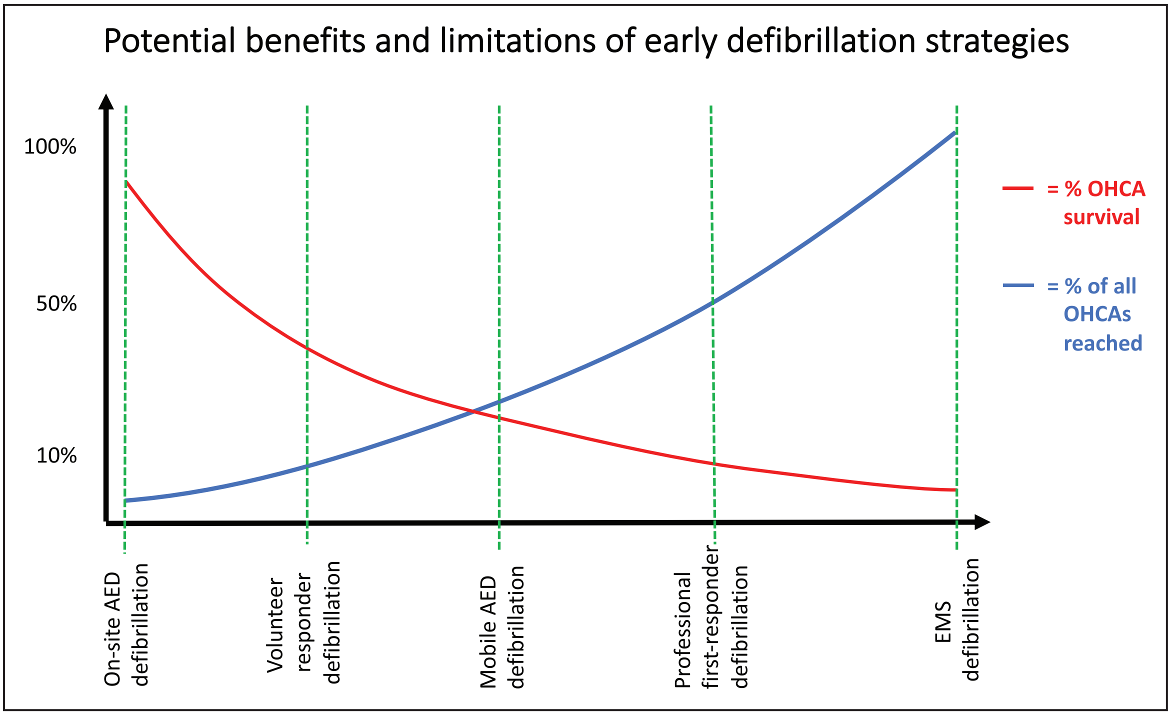

FIGURE 1. A theoretical graph of potential survival and proportion of out-of-hospital cardiac arrest reached according to type of early defibrillation strategy. AED, automated external defibrillator; EMS, emergency medical services; OHCA, Out-of-hospital cardiac arrest.

responder programme, and the programme needs to have a sufficient density of volunteer responders as well as known location of accessible AEDs, securing enough responders and AEDs in all areas where OHCAs occur (e.g. both in public places and especially residential areas) [36]. Although volunteer responder programmes transporting the AED to the OHCA location before EMS arrival hold a great potential to increase bystander defibrillation rates, not only in public locations but also especially in private homes, high certainty evidence for the effect on short-term and long-term survival is still lacking [37].

Another concept of utilizing on-site AEDs is to activate 'next generation' AEDs installed in chosen locations (e.g. public places or in residential communities) by the EMS dispatch centre if an OHCA is within a reasonable distance from the AED. When activated, the AED could alert random bystanders through lights and acoustic alarms and encourage them to collect the AED. When picked up, bystanders can be guided to the arrest location by a digital screen integrated in the device, in a similar fashion as current volunteer responder apps. Although the AED technology is already invented [38], such activation strategies have not yet been tested or proven efficient in real OHCA scenarios. Furthermore, the AED activation concept requires nearby bystanders that can be alerted and engaged by the AED, which in public places would be limited during evening and nighttime.

Dispatch of mobile automated external defibrillators

Professional first responder systems have been suggested as a solution to increase chances of CPR and defibrillation before EMS arrival. Professional first responders (e.g. police officers, fire fighters, off-duty healthcare personnel) can provide AED coverage in areas not covered by on-site AEDs and are often able to arrive at the OHCA location before traditional EMS (Fig. 1). A systematic review from 2017 found a median survival rate to hospital discharge of 28.6% (range, 9–76%) among OHCAs defibrillated by professional first responders [8]. A recent observational study including 27 European regions found that more than half the regions had implemented first responder programmes. These implementations were associated with higher rates of return of spontaneous circulation (ROSC) and survival [39]. The only clinical trial comparing professional first responders with standard EMS found earlier defibrillation and increased ROSC with police or firefighter involvement, but no effect on 30-day survival [40]. Furthermore, recent studies on cost-effective analysis regarding dispatch of first responders are limited. A study from the Netherlands investigated pre and

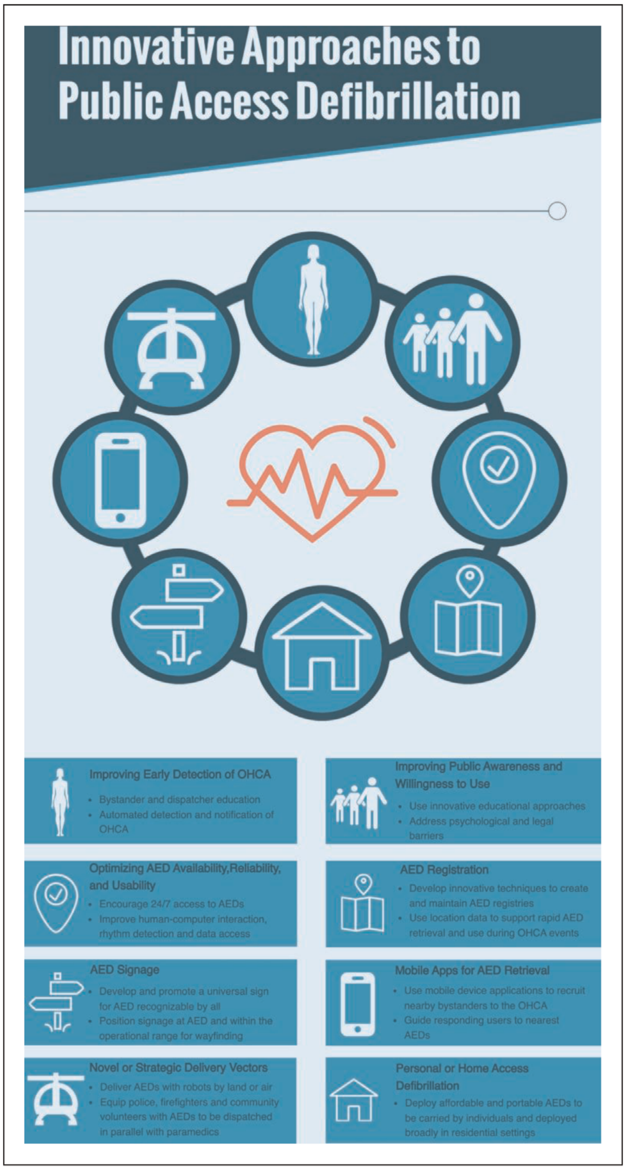

FIGURE 2. Different innovative approaches to public access defibrillation. Reprinted with permission from [14▪▪].

in-hospital healthcare costs for on-site AED used by laypersons and dispatched mobile AEDs used by professional first responders. Defibrillation with on-site AED was associated with lower in-hospital costs compared with dispatched first responders carrying an AED, partially attributed to fewer days in the intensive care unit [41].

Another concept of early defibrillation is the use of mobile AEDs delivered by laypersons. In Singapore, AEDs have been deployed in taxis ('AED-on-wheels') with drivers activated to nearby OHCAs as part of the myResponder volunteer app system [42]. Such mobile AEDs have a markedly larger coverage radius compared with on-site AEDs and with traditional volunteer responder systems (often walking/running with the AED). However, when taxis are occupied by customers, they are likely not to attend to alarms and taxi drivers could also retain from accepting alarms because they cannot continue their taxi business while attending an OHCA alert. Accordingly, experiences from Singapore found a very low acceptance rate of alarms (1.2%) and only 0.4% of alerted taxis arrived at scene before EMS arrival [42]. Despite the low reported numbers, the concept of equipping volunteer responders with mobile AEDs is expanding. In Victoria, Australia, the Victoria Ambulance Service are currently running a randomized controlled trial (The First Responder Shock Trial; FIRST) wherein volunteer responders are equipped with a new, small and cheap mobile AED [43,44]. Such strategies could potentially lead to earlier defibrillation compared with volunteer responder systems using on-site AEDs, as volunteer responders equipped with AEDs could travel directly to the OHCA location without spending time to find and fetch an AED on their way.

First responder programmes are likely to improve survival in OHCA primarily when response times are reduced substantially (Fig. 1); however, more cost-effective analyses are needed to elucidate whether these programmes should be implemented into guideline recommendations.

Drone delivered automated external defibrillators

As most AEDs are generally located in public places with high personnel turnover, it can be difficult to find and retrieve the nearest defibrillator when needed. Although EMS dispatch centres linked to local AED registries can guide bystanders to locate the nearest AED, this strategy has shown very little effect in daily clinical practice [45,46]. Another solution for AED retrieval is to bring the AED to the cardiac arrest location by a drone. Drones can potentially cover a large area including rural areas, not easily reachable regions (islands/mountains), and could be beneficial in selected time periods where many people are gathered (beaches, summer residences, major public events and so on). Several studies using mathematical optimization modelling and simulated drone flights have demonstrated faster AED delivery by drones compared with conventional EMS response times [47]. However, very few studies have implemented and tested drone AED delivery in real OHCA scenarios, and to date, only one case of successful defibrillation and survival with a drone AED has been described [48▪]. Although AED drone delivery could improve access to early defibrillation, drone flights are currently restricted in most countries due to significant regulatory, safety and privacy concerns.

Early detection of out-of-hospital cardiac arrest

All the initiatives (outlined in Table 1 and Fig. 2) for improving early defibrillation require that the arrest is recognized either by the bystander or by the medical dispatcher. However, a large proportion of OHCAs remains unwitnessed and therefore untreated, especially for OHCAs in private homes [10]. In these cases, there will be no bystander CPR, no AED attachment and no EMS alert, and the chance of survival close to zero. Innovative technological applications such as wearables (e.g. glasses, clothing, watches, finger rings) present a unique opportunity to identify unwitnessed cardiac arrest by measuring various biometrics signals, including rhythm detection, respiration rate, blood oxygen saturation and accelerometers (acceleration-deceleration identifying a fall) [49]. In addition, systems capable of 'contactless' early cardiac arrest recognition like mobile phones and smart speakers able to detect agonal breathing, or video surveillance systems identifying OHCAs by movement patterns (persons displaying stereotypical behaviours or transitioning from an upright position to a horizontal position followed by an absence of movement), present a unique opportunity to identify and trigger an automatic alert to the emergency dispatch centre and facilitate timely CPR and early defibrillation [50,51]. Although promising, these innovative technological solutions have not yet proven their effect in daily practice, and both wearables and contactless devices for OHCA recognition are most likely primarily used for selected groups (resourceful settings and high-risk patients) and comes with the risk of many 'false' positive alarms stressing an already busy EMS.

Disparities in public access defibrillation implementation

Although the above-mentioned models for rapid defibrillation hold great potential to increase survival, they all require substantial funding and organization. For instance, implementing a volunteer responder programme requires establishing an AED registry integrated with the emergency

Table 1. An oversight of the different defibrillation strategies with their advantages and challenges

	Advantages	Challenges
Public access defibrillation with on-site AEDs	Rapid defibrillation with reported high survival rates	Little effect on survival in private homes Difficult to predict high-risk areas for optimal AED placement Requires a large number of AEDs, preferably registered
Volunteer responders using on-site AEDs	Potential to increase defibrillation when volunteer responders arrive before EMS May increase defibrillation rates in private homes Increase the use of static on-site AEDs as they are now transported to the arrest location by volunteer responders	Requires a large density of volunteer responders and registered AEDs Requires an established AED register linked to the volunteer responder system Requires continuous recruitment of volunteer responders
Professional first-responders (e.g. firefighters or police officers)	Fire and police stations are spread evenly throughout the community Firefighters and police officers are trained in CPR and AED usage Able to enter private homes for resuscitation	Firefighters and police officers can be occupied by other jobs and may leave the scene if dispatched to another incident Only effective if arrival before the traditional EMS
Mobile AEDs delivered by lay persons (e.g. in taxis)	Taxies are mobile and can cover a larger area compared to on-site AEDs AEDs could also be installed in mail vans, security cars or distributed to selected volunteer responders	Few taxis in rural areas If a taxi is occupied by customers, the driver cannot attend an OHCA Risk of lay persons breaking traffic laws for rapid AED delivery
Drone-delivered AEDs	One AED drone can cover a large area for AED delivery Can complement a volunteer responder programme (volunteers can move directly to the OHCA location while the drone delivers the AED) Potential fast AED delivery before EMS arrival, especially in rural/semiurban areas	Legislation prohibits drones to fly outside predefined airspaces Drones must be operated by a drone pilot Expensive setup Not able to fly in bad weather (strong winds or heavy rain)

AED, automated external defibrillator; CPR, cardiopulmonary resuscitation; EMS, emergency medical services.

dispatch centre as well as software to activate volunteer responders. Implementing a drone delivery system requires not only purchasing drones and funding drone pilots, but also high functioning EMS systems with advanced software integration. Further, before any of these programmes are meaningful, key community initiatives need to be in place, such as training the community in recognition of cardiac arrest, calling the emergency medical services, and performing CPR, training emergency dispatchers in recognition of arrest, dispatch-assisted CPR, providing fast, high-quality EMS response with sufficiently trained staff and high-quality advanced in-hospital treatment. Concomitantly, high-quality data need to be collected for quality assurance and research. Many communities have not yet established such initiatives. As described here, due to technological advances, rapid defibrillation with AEDs is much more feasible today than 30 years ago, but health authorities and decision makers need to prioritize funding and implementing the basic infrastructure for successful resuscitation. We still need to follow the Utstein formula of survival: Medical Science x Educational Efficiency x Local Implementation = Survival.

CONCLUSION

During the last decades, various strategies for PAD have been developed. Implementation of mobile AEDs carried by volunteer responders, professional first responders and drones enables more OHCAs to be reached and potentially defibrillated compared to traditional on-site AED strategies. Novel technological solutions such as wearables and contactless devices for OHCA recognition present a unique opportunity to identify nonwitnessed OHCAs previously left untreated and with dismal survival chances. Although these models for cardiac arrest detection and rapid defibrillation hold great potential to increase survival, authorities and policy makers need to prioritize funding and implementation of basic infrastructure for successful resuscitation such as community CPR-training and high-quality EMS delivery.

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Conflicts of interest

There are no conflicts of interest.

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