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Mathias Ströhle MD, Peter Paal MD, MBA, DESA, EDIC, Giacomo Strapazzon MD, Giovanni Avancini MD, Emily Procter MSc, Hermann Brugger MD

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DEFIBRILLATION IN RURAL AREAS

Mathias Ströhle\textsuperscript{a,*}, MD, Peter Paal MD, MBA, DESA, EDIC\textsuperscript{b,c}, Giacomo Strapazzon MD\textsuperscript{c,d}, Giovanni Avancini MD\textsuperscript{e}, Emily Procter MSc\textsuperscript{f}, Hermann Brugger MD\textsuperscript{c,g}

\textsuperscript{a}Department of Anesthesiology and Critical Care Medicine, Innsbruck Medical University, Anichstrasse 35, A-6020 Innsbruck, Austria; mathias.stroehle@uki.at
\textsuperscript{b}Department of Anesthesiology and Critical Care Medicine, Innsbruck Medical University, Anichstrasse 35, A-6020 Innsbruck, Austria; peter.paal@uki.at
\textsuperscript{c}International Commission for Mountain Emergency Medicine, ICAR MEDCOM
\textsuperscript{d}EURAC Institute of Mountain Emergency Medicine, Viale Druso 1, I-39100 Bozen/Bolzano, Italy; E-mail: giacomo.strapazzon@eurac.edu
\textsuperscript{e}EURAC Institute of Mountain Emergency Medicine, Viale Druso 1, I-39100 Bozen/Bolzano, Italy; E-mail: giovanni.avancini@gmail.com
\textsuperscript{f}EURAC Institute of Mountain Emergency Medicine, Viale Druso 1, I-39100 Bozen/Bolzano, Italy; E-mail: emily.procter@eurac.edu
\textsuperscript{g}EURAC Institute of Mountain Emergency Medicine, Viale Druso 1, I-39100 Bozen/Bolzano, Italy; E-mail: hermann.brugger@eurac.edu

*Corresponding author: Mathias Ströhle, MD; Department of Anesthesiology and Critical Care Medicine, Innsbruck Medical University, Anichstrasse 35, 6020 Innsbruck, Austria; Phone +43-512-504-80496; Fax: +43-512-504-22450; E-mail: mathias.stroehle@uki.at

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Abstract

Aim of the study: Automated external defibrillation (AED) and public access defibrillation (PAD) have become cornerstones in the chain of survival in modern cardiopulmonary resuscitation. Most studies of AED and PAD have been performed in urban areas and evidence is scarce for sparsely populated rural areas. The aim of this review was to review the literature and discuss treatment strategies of out-of-hospital cardiac arrest in rural areas.

Methods: A Medline search was performed with the keywords “automated external defibrillation” (617 hits), “public access defibrillation” (256), “automated external defibrillator public” (542). Of these 1415 abstracts and additional articles found by manual searching references, 92 articles were included in this non-systematic review.

Results: Early defibrillation is crucial for survival with good neurological outcome after cardiac arrest. Rapid defibrillation can be a challenge in sparsely populated and remote areas, where the incidence of cardiac arrest is low and rescuer response times can be long. The few studies performed in rural areas showed that the introduction of AED programs based on a two-tier emergency medical system (EMS), consisting of a Basic Life Support (BLS) and Advanced Life Support (ALS) team, resulted in a decrease in collapse-to-defibrillation times and better survival of patients with out-of-hospital cardiac arrest.

Conclusions: In rural areas, introducing AED programs and a two-tier EMS may increase survival of out-of-hospital cardiac arrest patients. More studies on AED and PAD in rural areas are required.

Keywords

Automated external defibrillation; Basic Life Support; Cardiopulmonary Resuscitation; Electric Countershock; Public access defibrillation; Rural Health.
1. Introduction

In North America, the incidence of out-of-hospital cardiac arrest (OHCA) is approximately 50-55 per 100,000 inhabitants per year [1,2]. Sudden cardiac arrest is caused by myocardial infarction in more than 60% of cases, with ventricular fibrillation (VF) in 50-80% of collapsed patients [3,4]. In urban areas with rapid bystander cardiopulmonary resuscitation (CPR) and public access defibrillation (PAD) survival rates from cardiac arrest have improved substantially [5]. Most studies on AED and PAD have been performed in urban areas (e.g. Maastricht, Netherlands, with a population density of 1975 inhabitants km\(^{-2}\); in Goteborg, Sweden, with 2562 inhabitants km\(^{-2}\), and Copenhagen, Denmark, with 5985 inhabitants km\(^{-2}\)) [6-8]. Data are scarce in less densely populated rural and mountain areas such as the European Alps, with a population density of ~20-240 inhabitants km\(^{-2}\), or Oregon, USA, with 15 inhabitants km\(^{-2}\). It is unclear how to equip rural areas with AEDs and PAD. The aim of this review was to review the literature and discuss evidence regarding treatment strategies of OHCA-VF in rural areas.
2. Material and methods

A literature search of the Medline database was performed using the keywords “automated external defibrillation” (617 hits), “public access defibrillation” (256), and “automated external defibrillator public” (542) for articles published on or before July 18th, 2014. A manual search of the references was performed to find additional articles. In total 92 articles related to AED and PAD in rural areas were included in this non-systematic review.
3. **Results and Discussion**

3.1 **Collapse-to-defibrillation time is decisive for survival and neurological outcome**

Time from OHCA-VF to defibrillation is crucial for survival and neurological outcome. The defibrillation success and survival rate of OHCA-VF patients not receiving CPR rapidly decline in the first five to ten minutes after collapse [9]. Other studies also report a steep decline in survival [10,11], which underlines that a response time shorter than five minutes has the biggest impact on positive outcome [11-17]. In a British study, patients with OHCA-VF witnessed by a physician had a survival rate of ~60% when the outpatient clinics where they collapsed were equipped with AEDs [18]. The response time was also decisive for survival: the hospital discharge rate was ~60% with a response time <4min and ~18% with a response time >4min. AED studies with long call-to-defibrillation intervals (e.g. >10min) have not demonstrated a substantial increase in the overall survival rate [19].

Short response times after OHCA-VF are also essential for good neurological outcome. In Amsterdam, survivors of OHCA-VF had less neurological impairment and loss of autonomy when the collapse-to-CPR and collapse-to-defibrillation times were shorter [20,21]. Another study reported that life expectancy and quality of life were similar in patients who had survived OHCA-VF compared to a matched population [22].

While early studies suggested a benefit of CPR before defibrillation [23-27], recent studies do not support these findings [28-33]. Thus, current CPR-guidelines do not recommend a specific CPR interval before defibrillation, but highlight the importance of efficient and continuous chest compressions with as short as possible hands-off time until successful defibrillation [25,34,35].
3.2 Early defibrillation programs in urban areas within emergency medical services

Emergency medical services (EMS) have different structures. A single-tier EMS consists of an ALS team that is called to an emergency; a two-tier system consists of a BLS and an ALS team that are dispatched according to medical information and needs. Other systems have a non-transporting first responder team who are BLS or ALS trained and a transporting unit that is dispatched simultaneously. Two-tier systems may be more cost effective because less-qualified personnel and less equipment is needed to provide a good standard of care [36]. In a review, survival from OHCA-VF ranged from 3 to 33%, but was higher with a two-tier compared to single-tier system [37]. The greatest improvements in survival from OHCA-VF were reported in areas where no preclinical defibrillation was available before these programs were introduced [38-40]. However, the advantage of a two-tier system could not be replicated in areas where the response time of an ALS team had been fast (within minutes) before the program was introduced [41-43]. As a result, both the AHA and ERC recommend that BLS teams should be equipped with AEDs [44]. Studies reporting outcomes after early defibrillation in urban areas within an EMS are listed in table 1.

3.3 Early defibrillation programs in urban areas outside emergency medical services

In some two-tier systems BLS AED is performed by BLS first responders trained in the use of AEDs, for instance fire brigade members and police officers. These first responders perform continuous CPR and apply AED until the arrival of an ALS team. A two-tier system outside the EMS can shorten call-to-defibrillation time and it may improve outcome if the call-to defibrillation time is reduced to a few minutes, especially in areas where an ALS team is not rapidly available [3,15,45-50]. Some studies did not report improved outcomes because call-to defibrillation time could not be sufficiently reduced (e.g. <10min). Studies reporting outcomes after early defibrillation in urban areas outside an EMS are listed in table 2.
3.4 Public access defibrillation

Public access defibrillation (PAD) is defined as the installation of AEDs in public places (e.g. aeroplanes, airports, casinos). Introduction of PAD in densely populated or heavily frequented areas can increase pre-existing survival rates to hospital discharge by up to 50% [54]. The achieved survival rates can be as high as 55% [13,16,51-53]. In a large PAD study, bystanders were trained in either CPR or CPR with defibrillation; survival was 14% in the CPR group and 23% in the CPR with defibrillation group (P=0.03) [55,56].

It has been suggested that automated external defibrillators should be positioned in any area where an ALS team can not arrive in less than five minutes and where at least one OHCA-VF is expected to occur over a period of five years [55,57]. Suitable locations for AED include airports, factories, nursing homes, marinas, schools, shopping malls, sport arenas and train stations [55,57,58]. AEDs have also been recommended for places where >250 persons older than 50 years gather [59]. In Japan, a national PAD program decreased mean collapse-to-defibrillation time from 3.7 to 2.2 minutes (P<0.001), increased the number of defibrillations administered by laypersons and increased the number of patients surviving with minimal neurologic impairment from 2.4 to 8.9 per 10 million inhabitants (P=0.01) [60]. As a result from these retrospective studies some authors proposed locations deemed suitable for installing an AED [7,61-65] and stated that cost effectiveness should be assessed before starting a PAD program [66,67] and first responders should be regularly trained. Studies on PAD are listed in table 3.

3.5 Early defibrillation in rural and mountain areas

The chance of surviving OHCA-VF is higher in dense urban areas than in rural areas [68]. The 2000 ERC guidelines state that early defibrillation should be standard for EMS “except in sparsely populated and remote settings, where the frequency of cardiac arrest is low and rescuer response times are excessively long” [69]. However, some studies have found data opposing this advice (table 4); on San Juan Island, USA, survival of OHCA-VF was 43% with a two-tier system, which is comparable to similar studies in urban areas [70]. In Ketchikan, AK, USA, survival increased from 15 to 38% (P=0.03) using AEDs [71]. In two further studies performed in rural US communities with BLS and AED trained paramedics, survival increased from ~3 to 18% [39,72]. In Galicia, Spain, the survival rate from VF was 12%, but overall survival from OHCA was only 2.3% due to the low incidence of shockable rhythms upon arrival of an EMS team. In this setting, time of activation and response of the
EMS was slow (15 min median collapse-to-crew arrival time), negatively affecting the incidence of VF and survival [19]. In a Swedish retrospective analysis of over 14,000 cardiac arrests, OHCA survival in rural areas was not significantly different from survival in urban areas (4.8 vs. 5.5%). The conclusion was to place AEDs closer to patients of small communities, allowing fire brigades and other first responders to shorten the time to defibrillation [73]. Similarly, the Italian government issued a regulation which obliges organisers of sporting events to have AEDs and trained personnel available on site [74].

Mountain regions have strong seasonal fluctuations in population with resulting fluctuations in the incidence of OHCA-VF. In small communities, the response time of a BLS or ALS team to OHCA-VF is usually more than five minutes. The Medical Commission of Mountain Emergency Medicine (ICAR MEDCOM) suggests that AEDs should primarily be installed in ski areas in the winter and in mountain huts near cable cars or popular hiking trails. The location is determined by the sport type, risk factors of the general participant and environmental conditions [75,76]. In some remote American and European mountainous regions, first responders (e.g. mountain rescuers, fire brigade members, ski lift officers) have been trained in BLS and AED to reduce call-to-defibrillation time. A survey reported that AEDs have been widely implemented by mountain rescue services worldwide [77] and some mountain rescue backpacks are now equipped with AEDs [78].

The literature on AED use in mountain and remote areas is limited and only few case reports of patients with favourable outcomes have been published [79,80]. In these settings, the probability to rescue a hypothermic patient in OHCA is high and the chance of survival at hospital discharge is higher compared to normothermic patients (27% vs. 50%) [81,82]. Administration of up to three shocks is recommended with further dosing guided by the clinical response, when core temperature is <30°C [83]. High-altitude base camps such as Mt. Everest or Aconcagua also have seasonal fluctuations in the population, easy tourist access, and a daily population up to >1,000 [84]. Visitors to these areas should be assessed for risk of coronary heart disease and seek individual pre-travel advice to reduce the incidence of sudden cardiac arrest. An effective chain of survival in such base camps would include AEDs [76,85]. Mechanical CPR could be helpful if no helicopter rescue is available and terrestrial rescue is technically difficult or rescue time is >30min [86].
4. **Conclusions**

Only few studies exist on out-of-hospital defibrillation in rural areas, but most show a better outcome from OHCA after implementation of AED and PAD. Automated external defibrillation and PAD programs can only be successful if implemented into the chain of survival of a two-tiered EMS. An ALS team should be available within a reasonable time. PAD and first responders trained in AED could represent a cost-effective alternative to additional ALS teams. More studies on AED and PAD in rural areas are required.

5. **Acknowledgements**

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6. References


84. Strapazzon G. Mountaineers at high altitude peaks. 2014.


Table 1. Influence of emergency medical technician defibrillation programs within EMS on survival from OHCA

<table>
<thead>
<tr>
<th>Studies (n=1713)</th>
<th>Design</th>
<th>Survival to hospital discharge before and after implementation of AED</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>Eisenberg et al., 1980 [38] (n=154)</td>
<td>Prospective, historical controls</td>
<td>4%</td>
<td>19%</td>
</tr>
<tr>
<td>Stults et al., 1984 [39] (n=95)</td>
<td>Prospective controlled</td>
<td>3%</td>
<td>19%</td>
</tr>
<tr>
<td>Olson et al., 1989 [40] (n=566)</td>
<td>Prospective controlled</td>
<td>4%</td>
<td>6%</td>
</tr>
<tr>
<td>Sweeney et al., 1998 [41] *(n=627)</td>
<td>Prospective controlled, cross-over</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>Gottschalk et al., 2002 [42] *(n=103)</td>
<td>Prospective controlled</td>
<td>32%</td>
<td>22%</td>
</tr>
<tr>
<td>Stotz et al., 2003 [43] *(n=168)</td>
<td>Retrospective</td>
<td>24%</td>
<td>14%</td>
</tr>
</tbody>
</table>

Studies on early defibrillation within the emergency medicine system. *Studies in areas where the response time of the Advanced Life Support team before introduction of the AED program was a few minutes. ED denotes early defibrillation; EMS emergency medical system; OHCA out-of-hospital cardiac arrest.
Table 2. Influence of AED programs outside the EMS on survival from OHCA

<table>
<thead>
<tr>
<th>Studies (n=7942)</th>
<th>Design</th>
<th>Responders</th>
<th>Controls</th>
<th>Survival to hospital discharge before and after implementation of AED</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Before</td>
<td>After</td>
<td></td>
</tr>
<tr>
<td>van Alem et al., 2003 [3] (n=469)</td>
<td>Prospective controlled, randomized, cross-over</td>
<td>Police, firefighters</td>
<td>EMS</td>
<td>15%</td>
<td>18%</td>
</tr>
<tr>
<td>Stiell et al., 1999 [15] (n=6331)</td>
<td>Prospective controlled, interventional</td>
<td>Firefighters, EMT-D</td>
<td>EMS</td>
<td>4%</td>
<td>5%</td>
</tr>
<tr>
<td>Myerburg et al., 2002 [45] (n=420)</td>
<td>Prospective controlled</td>
<td>Police</td>
<td>EMS</td>
<td>9%</td>
<td>17%</td>
</tr>
<tr>
<td>Kellermann et al., 1993 [46] (n=431)</td>
<td>Prospective controlled, cross-over</td>
<td>Firefighters</td>
<td>EMS</td>
<td>10%</td>
<td>14%</td>
</tr>
<tr>
<td>White et al., 1996 [47] (n=84)</td>
<td>Retrospective</td>
<td>Police, EMT-D</td>
<td>EMS</td>
<td>43%</td>
<td>58%</td>
</tr>
<tr>
<td>Mosesso et al., 1998 [48] (n=207)</td>
<td>Prospective interventional, historical controls</td>
<td>Police</td>
<td>EMS</td>
<td>6%</td>
<td>14%</td>
</tr>
</tbody>
</table>

ED denotes early defibrillation; EMT-D emergency medical technician with AED skills; EMS emergency medical service; OHCA out-of-hospital cardiac arrest; n.s. non significant.
Table 3. Public access defibrillation programmes outside the EMS and survival from OHCA-VF

<table>
<thead>
<tr>
<th>Studies (n=16580)</th>
<th>PAD Locations</th>
<th>Responders</th>
<th>Survival to hospital discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Folke et al., 2009 [8] (n=1274)</td>
<td>Copenhagen, Denmark</td>
<td>Volunteers</td>
<td>13.9%</td>
</tr>
<tr>
<td>O'Rourke et al., 1997 [13] (n=46)</td>
<td>Qantas Aircrafts</td>
<td>Air crew members</td>
<td>26%</td>
</tr>
<tr>
<td>Valenzuela et al., 2000 [16] (n=105)</td>
<td>Casinos, USA</td>
<td>Casino officers</td>
<td>53%</td>
</tr>
<tr>
<td>Caffrey et al., 2002 [51] (n=26)</td>
<td>Chicago Airports, USA</td>
<td>Volunteers</td>
<td>56%</td>
</tr>
<tr>
<td>MacDonald et al., 2002 [52] (n=53)</td>
<td>Boston Airport, USA</td>
<td>Firefighters, EMS</td>
<td>21%</td>
</tr>
<tr>
<td>Page et al., 2000 [53] (n=200)</td>
<td>US Airline</td>
<td>Flight attendants</td>
<td>40%</td>
</tr>
<tr>
<td>Culley et al., 2004 [54] (n=50)</td>
<td>Seattle, King county, USA</td>
<td>Volunteers</td>
<td>50%</td>
</tr>
<tr>
<td>Hallstrom et al., 2004 [56] (n=235)</td>
<td>USA</td>
<td>Volunteers</td>
<td>23% vs. 14% CPR only (P=0.03)</td>
</tr>
<tr>
<td>Kitamura et al., 2010 [60] (n=12831)</td>
<td>Japan</td>
<td>Volunteers, EMS</td>
<td>37.2% PAD (survival at 1 month)</td>
</tr>
<tr>
<td>Wassertheil et al., 2000 [87] (n=28)</td>
<td>Stadium, ANZAC Parade, Australia</td>
<td>Volunteers, EMS</td>
<td>71%</td>
</tr>
<tr>
<td>Capucci et al., 2002 [88] (n=354)</td>
<td>Piacenza, Italy</td>
<td>Volunteers</td>
<td>44% vs. 21% EMS (P=0.046)</td>
</tr>
<tr>
<td>Davies et al., 2005 [89] (n=172)</td>
<td>UK airports, railway stations</td>
<td>Volunteers</td>
<td>28%</td>
</tr>
<tr>
<td>Cappato et al., 2006 [90] (n=1394)</td>
<td>Brescia, Italy</td>
<td>Volunteers, EMS</td>
<td>1.4% vs. 4.4% after PAD (P=0.04)</td>
</tr>
<tr>
<td>Hanefeld, 2010 [91] (n=12)</td>
<td>Bochum, Germany</td>
<td>Volunteers</td>
<td>50%</td>
</tr>
</tbody>
</table>

EMS denotes emergency medical service; OHCA-VF out-of-hospital cardiac arrest with ventricular fibrillation; PAD public access defibrillation.
Table 4. Influence of automated external defibrillation programs on survival from OHCA in rural areas

<table>
<thead>
<tr>
<th>Studies (n=1121)</th>
<th>Design</th>
<th>Location</th>
<th>Responders</th>
<th>Controls</th>
<th>Survival to hospital discharge before and after introduction of AED programs</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colquhoun, 2002 [18] (n=259)</td>
<td>Retrospective</td>
<td>GP office; Cardiff, UK</td>
<td>GP with AED</td>
<td>GP</td>
<td>Before 12.5% unwitnessed by GP After 63% witnessed by GP</td>
<td>n.r.</td>
</tr>
<tr>
<td>Stults et al., 1984 [39] (n=95)</td>
<td>Prospective controlled</td>
<td>Rural communities; Iowa, USA</td>
<td>EMT-D</td>
<td>EMT</td>
<td>Before 3% After 19%</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Killien et al., 1996 [70] (n=78)</td>
<td>Retrospective</td>
<td>Island community; San Juan Island, USA</td>
<td>EMT-D/ paramedic</td>
<td>EMT</td>
<td>Before n.a. After 43%</td>
<td>n.r.</td>
</tr>
<tr>
<td>Kriegsman et al., 1998 [71] (n=71)</td>
<td>Retrospective</td>
<td>Rural community; Alaska, USA</td>
<td>EMT/ paramedic</td>
<td>EMT</td>
<td>Before 9% After 20%</td>
<td>n.r.</td>
</tr>
<tr>
<td>Vukov et al., 1988 [72] (n=63)</td>
<td>Prospective controlled cross-over</td>
<td>Rural communities; Minnesota, USA</td>
<td>EMT-D</td>
<td>EMT</td>
<td>Before 4% After 17%</td>
<td>n.r.</td>
</tr>
<tr>
<td>Colquhoun, 2006 [92] (n=555)</td>
<td>Retrospective</td>
<td>GP office; Cardiff, UK</td>
<td>GP with AED</td>
<td>GP</td>
<td>Before n.a. After 27%</td>
<td>n.r.</td>
</tr>
</tbody>
</table>

ED denotes early defibrillation; EMT emergency medical technician; EMT-D emergency medical technician with AED skills; EMS emergency medical service; GP general practitioner; n.a. not applicable; n.r. not reported; OHCA out-of-hospital cardiac arrest; OHCA-VF out-of-hospital cardiac arrest with ventricular fibrillation.