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REVIEW ARTICLE

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# Effective deployment of public-access automated external defibrillators to improve out-of-hospital cardiac arrest outcomes

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## Abstract

Out-of-hospital cardiac arrest (OHCA) is a major health concern in Japan and other developed countries with aging populations. Improvements in OHCA outcomes require streamlining the chain of survival. Deployment of public-access automated external defibrillators (PADs) and defibrillation by bystanders is one strategy that may streamline the chain by reducing the time to defibrillation in individuals with shockable rhythms. Although the effectiveness of PAD programs in increasing survival to discharge has been reported, there have been criticisms and concerns about the small population impact, cost-effectiveness, and potential negative impact on those with nonshockable rhythms. This article reviews relevant literature regarding the effectiveness and concerns regarding PAD for OHCA.

**KEYWORDS**
bystander, out-of-hospital cardiac arrest, public-access automated external defibrillators, resuscitation

## 1 | INTRODUCTION

Out-of-hospital cardiac arrest (OHCA) is a major health concern in societies with aging populations. In Japan, OHCA occurrence is gradually increasing: The number of patients with OHCA transported to the hospital by ambulance was 102 738 in 2005 and 125 951 in 2014.[1] The prognosis of OHCA is improving, although it remains quite poor, particularly among the elderly. In 2005, the 1 month neurologically intact survival rate was only 3.3% among those with cardiogenic OHCA, and this increased to 7.8% in 2014. This improvement has been achieved through streamlining the chain of survival, particularly the increase in cardiopulmonary resuscitation (CPR) attempts by bystanders and intensive care during and after resuscitation.[2,3]

Deployment of public-access automated external defibrillators (PADs) in public areas is one of the most important advancements in Japan during the last decade. Early defibrillation of shockable rhythms can improve patient outcomes. The use of automated external defibrillators (AEDs) in pre-hospital settings is a strategy to reduce the time interval until defibrillation.[4] PAD use by bystanders or first responders can more effectively reduce this time interval and improve patient outcomes than the use of AED by emergency medical services (EMS) personnel.[5–8] However, controversy exists regarding the population impact of PAD deployment in communities, as only a small proportion of OHCA patients benefit from defibrillation.[9]

This article reviews the existing scientific literature regarding the use of PADs in programs designed to improve OHCA prognosis. Issues related to the population impact of PADs, such as cost-effectiveness, suboptimal deployment location, and potential negative impacts on patients with nonshockable rhythms, are discussed.

## 2 | PAD PROGRAMS

### 2.1 | Definition of PAD programs

PAD programs consist of PAD deployment and training of non-EMS lay personnel in the community, so that bystanders or first responders

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can provide defibrillation using a PAD before EMS arrival. AEDs are usually deployed in public places so that anybody can use them, whereas some programs assume AED use exclusively by facility staff, first responders, or family members. PADs may be fixed on-site or carried by first responders.[10] Although PADs are not literarily public access in some programs, this review includes programs that try to facilitate AED use by non-EMS personnel.

## 2.2 | PAD programs in Japan

In Japan, a large number of PADs have been deployed, and training of basic life support has been given to lay people, resulting in increased neurologically intact survival rates. AED use by lay persons has been permitted for the defibrillation of patients with OHCA since 2004, and PAD deployment in public places has subsequently increased rapidly. The estimated cumulative number of PADs in Japan exceeded 500 000 in 2014.[11] Fire departments throughout the country give training of basic resuscitation procedures such as chest compression and AED use to more than 1 700 000 community people every year.[1] Consequently, bystander defibrillation of patients with OHCA greatly increased during the past decade: 46 incidents were reported in 2005, and 1030, in 2014. This accounted for 21.6% of patients with bystander-witnessed cardiogenic OHCA with shockable rhythms, although this still represents a small proportion of all bystander-witnessed cardiogenic cases, accounting for only 4.1%.[1]

In agreement with this trend, long-term outcomes have improved in Japan. Among patients with bystander-witnessed cardiogenic OHCA with shockable rhythms, 10.5% survived with intact neurological function in 2005, which increased to 23.0% in 2014.[1] A study analyzing nationwide registry data estimated that 9% of neurologically intact survival was attributable to bystander defibrillation in 2012.[8] Some observational studies based on the same registry showed that bystander defibrillation with a PAD greatly improved 1 month neurologically intact survival rates among those with shockable rhythms.[12–14]

## 2.3 | PAD programs in other countries

Early successful examples of PAD programs in other countries involved implementation in densely populated public places, such as airports and casinos, or in confined areas with no access to medical care, such as inside aircrafts. As such places are staffed with trained personnel, CPR can be readily administered to a collapsed person using a PAD before EMS arrival. In addition, a PAD can be used to monitor a sick person, which is particularly useful in aircrafts. A program involving 32 casinos over 32 months demonstrated that 38% of the 148 arrest cases survived to hospital discharge (Table 1).[15] In an airport-based program over a 2-year period, 50% of 20 witnessed arrest cases resulted in survival with intact neurological function at 1 year.[16] In an aircraft-based program, the incidence of cardiac arrest was 1 in 21 654 flights, and during the 2-year study period, PADs were applied to 200 people. Of them, shock was recommended to 16 cardiac arrest patients; shock was delivered to 15 patients, with six (38% of the 16) surviving to

**TABLE 1** Observational studies showing the effects of PAD use by bystanders

| Authors | Settings | Population | Intervention | Effects |
|---|---|---|---|---|
| Valenzuela et al., 2000[15] | Casinos in the USA, Mar. 1997-Oct. 1999 | Guests of casinos; 148 cardiac arrests | PAD placement in casinos and training of security officers | 105 of 148 had initial ventricular fibrillation and 56 of 148 (38%) survived to discharge |
| Caffrey et al., 2002[16] | Airports in the USA, Jun. 1999-May 2001 | Airport users; 20 witnessed nontraumatic cardiac arrests | PAD placement in passenger terminals in airports | 18 of 20 had initial ventricular fibrillation and 11 of 20 (55%) survived at hospital and 10 of 20 (50%) survived at 1 yr with intact neurologic function. |
| Page et al., 2000[17] | A commercial airline in the USA, Jun. 1997-Jul. 1999 | Airline passengers; 200 people to whom an PAD is applied | PAD placement in airplanes | 16 of 200 had cardiac arrest with shockable rhythms, 15 of 16 received shock, and 6 of 16 (38%) survived to discharge |
| Weisfeldt et al., 2010[22] | Resuscitation Outcomes Consortium sites, Dec. 2005-May 2007 | Community people; 13 769 EMS-treated nontraumatic OHCAs, excluding EMS-witnessed cases | PAD placement outside the EMS system | 170 of 13 769 (1.2%) received PAD shock before EMS arrival and 64 of 170 (38%) survived to discharge. |
| Culley et al., 2004[23] | Seattle and King County, Jan. 1999-Dec. 2002 | Community people; 3754 EMS-treated OHCAs with cardiac origin | PAD placement outside the EMS system | 50 of 3754 (1.3%) received PAD treatment before EMS arrival and 25 of 50 (50%) survived to discharge. |
| Berdowski et al., 2011[24] | North Holland Province of the Netherlands, Jan. 2006-Mar. 2009 | Community people; 2833 OHCAs with cardiac origin, excluding EMS-witnessed cases | PAD placement outside the EMS system | 97 of 2833 (3.4%) received PAD shock before EMS arrival and 61 of 97 (63%) survived with minimal neurologic impairment. |
| Rea et al., 2010[25] | Seattle and King County, Jan. 1999-Dec. 2006 | Community people; 10 332 EMS-treated OHCAs (2759/10 332 had ventricular fibrillation) | PAD placement outside the EMS system | 157 of 10 332 (1.5%) received PAD application, 122 of 2759 (4.4%) received non-EMS PAD shock, 102 of 122 (84%) attained ROSC, and 64 of 122 (52%) survived to discharge. |

PAD, public-access automated external defibrillator; EMS, emergency medical services; OHCA, out-of-hospital cardiac arrest; ROSC, return of spontaneous circulation.

discharge.[17] PADs were used more frequently to monitor ill passengers in aircrafts than to resuscitate patients following cardiac arrest.

Based on intervention and observational studies, current guidelines strongly recommend the introduction of community-based PAD programs, with training for nonhealth professionals.[5,18] A cluster randomized controlled study showed that PAD deployment and training of lay volunteers in CPR and AED use significantly increased survival to discharge rates in comparison with volunteer CPR training only (23.4% vs 14.0%; relative risk=2.0) (Table 2).[7] A meta-analysis of three studies (one assessing PAD use by lay volunteers[7] and two assessing PAD use by fire fighters and police officers[19,20]) assessed the effects of PAD use with CPR by nonhealthcare professionals and showed a significantly favorable association with survival to discharge compared with CPR alone (relative risk=1.39).[6] In contrast, home placement of PADs is not a promising strategy. A randomized controlled study showed no effects of home PADs among a high-risk population (survivors of myocardial infarction) in improving long-term survival (hazard ratio=0.97).[21]

Observational studies showed that only a small fraction (1%-5%) of patients with OHCA can benefit from community-based PAD programs, although such programs significantly improve prognosis among those who receive defibrillation with a PAD, with almost 50% surviving to discharge (Table 1).[22–25] Thus, for effective program planning, places with a high OHCA incidence should be selected for PAD deployment. The guidelines recommend that places with at least one OHCA case every 5 years be selected.[26,27]

## 3 | COST-EFFECTIVENESS

Due to the rarity of OHCA occurrence in public places and the high cost of AEDs, controversies exist regarding the cost-effectiveness of PAD programs.[9,28] The cost-effectiveness of PAD deployment can be evaluated using the incremental cost per additional quality-adjusted life year (QALY) gained. As the costs for purchase and maintenance of PADs, and the training of personnel are relatively stable, cost-effectiveness is dependent on the frequency of PAD use for OHCA (ie, the incidence of cardiac arrest in places with PAD deployment). Folke et al.[29] calculated the cost-effectiveness over various deployment strategies. The cost was $33 100/QALY or $40 900/QALY in places with incidence once every 2 or 5 years, respectively. In unguided PAD deployment of one per 100 m$^2$ regardless of incidence, the cost was $108 700/QALY. Nichol et al.[30,31] reported a cost of $56 700/QALY for a casino program, $55 200/QALY for PAD deployment in international airports, and $46 700/QALY for a community PAD program (PAD Trial Study). Groeneveld et al.[32] reported a cost of $40 800/QALY for PAD deployment in aircrafts with more than 100 passengers. Marukawa et al.[33] reported ¥5 945 000/QALY (approximately $50 000/QALY) for the current nationwide PAD deployment in Japan. In contrast, home PAD deployment cost more than $100 000/QALY, depending on the risk of arrest in the population.[34] Generally, the incremental cost of PAD deployment per additional QALY gained in places with an incidence of more than

**TABLE 2** Controlled trials for community-based PAD deployment

| Authors | Design (unit for intervention allocation) | Setting | Intervention vs control treatment | Population | Effects RR/OR/HR, (95% CI); survival rates, intervention vs control groups |
|---|---|---|---|---|---|
| Hallstrom et al., 2004[7] | Cluster RCT (community units) | USA and Canada, Jul. 2000-Sep. 2003 | Training of lay volunteer+PAD vs training alone | EMS-treated OHCAs with cardiac origin aged ≥8 yrs | Survival to discharge: RR=2.0 (1.07-3.77); survival rates, 23.4% vs 14.0% ($P$=.03) |
| Kellermann et al., 1993[19] | Nonrandomized crossover (areas) | Memphis, Tennessee, USA, Mar. 1989-Jun. 1992 | Training of fire fighters+PAD vs training alone | EMS-treated OHCAs with cardiac origin aged ≥18 yrs | Neurologically intact survival: OR=1.5 (0.8-2.6)<br>Survival to discharge: OR=1.6 (1.0-2.6)<br>Survival to admission: OR=1.1 (0.9–1.4)<br>ROSC: OR=1.0 (0.8-1.2) |
| van Allem et al., 2003[20] | Cluster RCT+crossover (areas) | Amsterdam and surroundings, the Netherlands, Jan. 2000-Jan. 2002 | Training of fire fighters and police officers+PAD vs training alone | EMS-treated witnessed nontraumatic OHCAs aged ≥18 yrs | Survival to discharge: OR=1.3 (0.8-2.2)<br>Survival to admission: OR=1.5 (1.1–2.0)<br>ROSC: OR=1.5 (1.0-2.2) |
| Sanna et al., 2008[6] | Meta-analysis (areas) | Three studies described above | Training of first responder or family+PAD vs training alone | Populations described above | Survival to admission: RR=1.22 (1.04-1.43)<br>Survival to discharge: RR=1.39 (1.06-1.83) |
| Bardy et al., 2008[21] | RCT (patients) | International multicenter study (USA, Canada, Australia, UK, New Zealand, the Netherlands, and Germany), Jan. 2003-Oct. 2005 | Training of family+PAD vs training alone | Patients with previous anterior-wall myocardial infarction | Death from any cause: HR=0.97 (0.81-1.17) |

PAD, public-access automated external defibrillator; RR, relative risk; OR, odds ratio; HR, hazard ratio; RCT, randomized controlled trial; OHCA, out-of-hospital cardiac arrest; EMS, emergency medical services; ROSC, return of spontaneous circulation.

once every 5 years does not exceed $50 000, which is an acceptable threshold.

## 4 | ISSUES CONCERNING PAD THAT NEEDS TO BE ADDRESSED

There are several issues that need to be considered to improve the effectiveness of PAD programs. Firstly, there are mismatches between places of OHCA occurrence and PAD deployment: The great majority of OHCA incidents occur in places with poor or no access to a PAD.[9,35] Secondly, a small and declining proportion of patients experiencing OHCA have shockable rhythms. These two issues result in PAD programs achieving a small population impact because only a small fraction of patients with OHCA benefit from PADs. In addition, applying a PAD to those with nonshockable rhythms, who do not require defibrillation, may pose potential negative effects.[22,36] Thirdly, there are some cases in which PADs are readily available but not used.[9]

### 4.1 | Location mismatches

PAD location mismatches mainly result from the great majority of OHCA incidents occurring in private areas.[9,37] PADs in public places cannot confer benefits to OHCA cases at home. In addition, even among OHCA incidents in public places, mismatches are a commonly observed problem, as many OHCAs occur in places with no access to a PAD.[9] Only a small fraction of deployed PADs have been actually used.[23–25] An extreme example was reported in Denmark where PAD deployment took place based on unguided initiatives, and none of the PADs were used during the study period.[29] Mismatches in cities in North America, though differing in degree, have also been reported (Table 3).[37–39] Information regarding the incidence of OHCA relative to the types of deployment locations is crucial to effectively deploy PADs in places with a high OHCA incidence.

Several Japanese studies have explored OHCA occurrence by location type and mismatches with PAD deployment (Table 3). Like other countries, approximately 80% of cases occur at home or in residential facilities.[40,41] Murakami et al.[40] indicated that healthcare facilities (nonhospital) accounted for 34% of nonprivate places, followed by streets (20%), workplaces (9%), railway stations (4%), and sports facilities (3%). However, incidents in airports were quite rare (0.1%). Muraoka et al.[41] estimated the incidence per site per year and showed that railway stations had the highest incidence (0.30/site/year). PAD use to deliver shock to Japanese patients with OHCA takes place most frequently in railway stations and sports facilities, whereas PADs have been mainly deployed in public facilities and schools.[42,43]

OHCA incidence patterns differ by area, depending on people's daily transport behaviors and activities. Railway stations and bus terminals have a high incidence in societies with highly developed and utilized public transportation system, whereas roads and parking areas have the highest incidence in societies dependent on road transportation (Table 3).[29,38,44,45] Race tracks and casinos have a high incidence in societies where such recreations are popular, whereas casinos do not exist in some countries.[39] Although early experiences indicated success of PAD deployment in airports, OHCA incidence in airports differs greatly between countries, with some having a very low incidence: A study in the UK showed a high incidence in airports, but studies in Australia, Canada, and Japan did not.[39,40,44,45]

### 4.2 | PAD effects on nonshockable rhythms

The proportion of individuals with shockable rhythms is low: It is currently less than half in Western countries, even lower (10%-20%) in Japan, and is declining yearly.[1,9,22,46,47] Thus, the majority of patients with OHCA do not directly benefit from PADs. Rather, there is concern about potential harmful effects of PAD application to those with nonshockable rhythms in the unfavorable influence on CPR quality and process.[22,36] PAD use interrupts chest compression, delays ambulance calls, and lowers compliance with telephone instructions due to rhythm analysis (longer delay in shockable than nonshockable rhythms), lengthy audio instruction by the AED, and the incorrect order of actions (PAD use before ambulance call).[36,47–49]

On the contrary, there are potential benefits of PAD application to those with nonshockable rhythms. AEDs have an audiovisual prompt, which provides instructions, and have timing systems, which guide chest compression rate. These factors may improve CPR quality and benefit all patients with OHCA regardless of the initial rhythm type.[4,49] Few studies have investigated the effects of such prompt and real-time feedback functions on the actual CPR. Two randomized studies compared AED use by EMS personnel with and without prompt/feedback functions and showed no effects on long-term or short-term survival outcomes.[50,51] The effects of the prompt/feedback functions on CPR quality are also limited. One of the randomized studies and other observational studies have shown that the prompt/feedback function can reduce the variability of compression rates, but has little or no effect on other aspects of CPR quality, such as compression depth and compression fraction.[5,50,52] It is also of importance to note that the AED users in these studies were trained personnel. Among untrained lay persons, the use of a prompt/feedback device can considerably improve CPR quality, as reported in a simulation study.[49] However, little is known about the effects of such functions on actual CPR quality by untrained lay persons.

Few studies have investigated the effects of PAD application on the outcomes of those with nonshockable rhythms, although no harmful effects have been reported to date. It is particularly an important issue to be investigated in Japan, where nonshockable rhythms are quite prevalent among patients with OHCA. An international cohort study in North America[22] showed a favorable association between PAD application and survival to discharge among EMS-treated patients with OHCA as a whole regardless of the initial rhythm type. Nishi et al.,[47] using data from Ishikawa, Japan, reported no apparent association between PAD application and the neurologically intact 1-year survival rate among those with nonshockable rhythms.

**TABLE 3** Locations of out-of-hospital cardiac arrest occurrence, PAD deployment, and PAD use

| Authors | Setting | Population | Locations of arrest occurrence, n (%) or incidence | Locations of PAD deployment or shock delivered n (%)/ frequency of PAD use |
|---|---|---|---|---|
| Levy et al., 2013[37] | Howard County, Maryland (EMS data, Jan. 2001-Dec. 2006) | EMS-treated nontraumatic OHCAs (n=712) | Home, 393 (55%); skilled nursing facilities, 113 (16%); assisted living, 56 (8%); street/highway, 50 (7%) | PAD deployment (n=141)<br>Community pool, 24 (17%); public building (nongovernment), 23 (16%); school/educational facility, 20 (14%); industrial place/premise, 18 (13%) |
| Moon et al., 2015[38] | Metropolitan Phoenix, Arizona (OHCA registry data, Jan. 2010-Dec. 2012) | EMS-treated nontraumatic OHCAs in public places excluding medical/long-term care facilities (n=654) | Car/road/parking lot, 190 (29%); public business/office/workplace, 65 (10%); public street/sidewalk/bus stop/alley, 60 (9%); park/outdoor recreation, 43 (7%); store/mall, 39 (6%) | PAD deployment (n=1704)<br>Public business/office, 663 (39%); school, 558 (33%); government building, 108 (6%); place of worship, 71 (4%) |
| Brooks et al., 2013[39] | Toronto, Canada (Resuscitation Outcomes Consortium Epistry data from Toronto, PAD deployment (n=1587) Jan. 2006-Jun. 2010) | EMS-treated nontraumatic OHCAs in public places excluding clinic, nursing home, and outdoor (n=608) | Number<br>Retail store, 112 (18%); office, 96 (16%); hotel/motel, 80 (13%); shopping plaza, 51 (8%); airport, 0 (0%)<br>Annual incidence (/yr/site)<br>Race track/casino, 0.67; jail, 0.62; hotel/motel, 0.15; hostel/shelter, 0.14; convention center, 0.11; rail station, 0.09 | PAD deployment (n=1587)<br>Elementary/secondary school, 913 (58%); postsecondary school, 238 (15%); office, 126 (8%); community/recreation center, 66 (4%); industrial, 52 (3%) |
| Murakami et al., 2014[40] | Osaka, Japan (survey in EMS system, Jan. 2005-Dec. 2011) | EMS-treated witnessed OHCAs with cardiac origin (n=9453) | Home, 6190 (65%); healthcare facilities (nonhospital), 1108 (12%); street, 652 (7%); workplace, 306 (3%); railway station, 118 (1%); sports facility, 93 (1%); public building, 86 (1%); school, 31 (0.3%); airport, 4 (0.04%) | |
| Muraoka et al., 2006[41] | Takatsuki, Japan (data from fire department, Jan. 1999-Dec. 2004) | EMS-treated OHCAs (n=1112) | Number<br>Home, 870 (78%); street, 68 (6%); home for the aged/welfare, 66 (6%)<br>Annual incidence (/yr/site)<br>Railway station, 0.30; hospital, 0.18; home for the aged/welfare facility, 0.11; playground, 0.08; golf course, 0.07 | |
| Sasaki et al., 2011[42] | Osaka, Japan (survey in EMS system, Jul. 2004-Dec. 2008) | EMS-treated OHCAs receiving PAD shock by bystander (n=53) | | PAD shock delivered by location<br>Railway station, 18 (34%); nursing home for the elderly, 6 (11%); medical facility, 5 (9%); fitness facility, 4 (7%); street, 4 (7%); workplace, 4 (7%) |

(Continues)

**TABLE 3** (Continued)

| Authors | Setting | Population | Locations of arrest occurrence, n (%) or incidence | Locations of PAD deployment or shock delivered n (%)/ frequency of PAD use |
|---|---|---|---|---|
| Sakamoto 2010[43] | Tokyo, Japan (EMS data, Jan. 2006-May 2008) | EMS-treated OHCAs receiving PAD shock by bystander (n=145) | | PAD deployment (n=4376)<br>Public facility, 1428 (33%); school, 1361 (31%); work place/ office, 388 (9%); sport facility, 290 (7%)<br>PAD shock delivered by location (n=145)<br>Railway station, 46 (32%); sports facility, 19 (13%); workplace/ office, 16 (11%); street, 16 (11%)<br>Frequency of PAD use (/5 yr/1 PAD)<br>Railway station, 0.34; nursing home, 0.17; hotel, 0.16; sports facility, 0.14 |
| Davies et al., 2005[44] | Densely populated public areas in UK (Apr 2000-Mar. 2004) | EMS-treated OHCAs receiving PAD application in the study sites (n=172) | | PAD applied by location (n=172)<br>Airport, 96 (56%); railway station, 58 (34%); bus station, 6 (3%); underground station, 5 (3%) *shock was delivered in 134 of 172<br>PAD deployment (n=681)<br>Airport, 300 (44%); railway station, 267 (39%); underground station, 85 (12%); bus station, 12 (2%) |
| Lijovic et al., 2014[45] | Victoria, Australia (Victorian Ambulance Cardiac Arrest Registry data, Jul. 2002-Jun. 2013) | EMS-treated nontraumatic cardiac arrest in public places with shockable rhythms (shocked by EMS vs by bystander: 2117 vs 153) | Shocked by EMS (n=2117)<br>Street/car park/public road/public transport, 1167 (55%); recreation/sporting complex, 386 (18%); workplace, 296 (14%); airport, 0 (0%) | Shocked by bystander with PAD (n=153)<br>Recreation/sporting complex, 76 (50%); street/car park/public road/public transport, 33 (22%); airport, 18 (12%); workplace, 13 (8%) |

PAD, public-access automated external defibrillator; EMS, emergency medical services; OHCA, out-of-hospital cardiac arrest.

### 4.3 | Nonuse of available PADs

PADs are often not applied to patients with OHCA in places where a PAD is readily available.[9] A study on PAD use at schools cited difficulties in identifying cardiac arrest as the main reason for nonuse.[53] Seizure or agonal respiration may mislead untrained lay people. Although dispatcher instructions by phone may help to facilitate bystander CPR, dispatcher recognition of cardiac arrest by phone communication is neither easy nor accurate.[5] Studies in Japan and Seattle have shown that the great majority of citizens who used PADs were off-duty health care providers or trained personnel, such as train station staff and police officers.[23,43,47] This implies that untrained lay citizens are reluctant to apply a PAD to a collapsed person, although the reasons for this are poorly understood. Therefore, there is much room for improvement in the facilitation of PAD use among untrained lay people. When arrest is suspected, dispatchers may instruct PAD use if available by emphasizing the diagnostic function, which can attenuate difficulties in identifying cardiac arrest.[18] However, if facilitating PAD use by untrained lay people does not work, an additional planned response strategy may be considered in Japan, whereby volunteers are systematically trained.[7] Further studies are needed to find effective measures to facilitate bystander CPR using PADs and to improve the accuracy of dispatcher recognition and instructions.

## 5 | CONCLUSIONS AND FUTURE RESEARCH AGENDA

As the number of deployed PADs has increased in Japan, their contribution to improvements in OHCA prognosis has become measurable. The incremental cost per additional QALY is within an acceptable threshold. However, there are several issues that should be attenuated or resolved to ensure effective PAD use. The following information should be acquired in future research to plan improved PAD programs:

1. Determination of places with high OHCA incidence, particularly those with shockable rhythms.
2. Utilization of already deployed PADs (application of a PAD to nonshockable rhythms in addition to defibrillation).
3. Determination of the reasons and situations of nonuse where a PAD is available.
4. Assessment of the effects of prompt/feedback PAD functions on outcomes and quality of CPR by lay rescuers.

### CONFLICT OF INTEREST

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

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