REUE | Original Article

Fixed versus mobile automatic defibrillators to cover a geographically sparse population: Analysis of "Girona Territori Cardioprotegit" project

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AIMS. Public access defibrillation doubles the survival after an out of hospital cardiac arrest, nevertheless covering sparse populations is a challenge. The aim of this study was to compare the rate of use and the effectiveness between fixed and mobile devices of the "Girona Territori Cardioprotegit" program.

METHODS. Prospective registry of uses of the program's public automatic defibrillators (542 fixed, 241 mobile) and analyses of the tracings recorded by the devices between June 2011 and December 2019. The usage rate, the percentage of shockable rhythms and the effectiveness between the fixed and mobile units were compared.

RESULTS. From 566 registered uses 494 were analysed, of which 108 (21%) were fixed devices. The use rate was 2.4 /100 devices-year for the fixed and 17.7 for mobile devices. Compared to mobile devices, fixed defibrillators found a greater proportion of shockable rhythms (34.2 % vs 20.3% p = 0.01) and presented a greater proportion of rhythm conversion (79% vs 63%, p = 0.02). The proportion of patients with a shockable rhythm transferred to the hospital was 62.1% for fixed and 50% for mobile devices (p = 0,306).

CONCLUSIONS. Fixed automated external defibrillators found more shockable rhythms and were more successful in converting those rhythms than mobile devices which had an eight fold more usage rate.

Key words: Cardiac arrest. Public access defibrillation. Automated external defibrillator. Cardiopulmonary resuscitation.

Desfibriladores automáticos móviles o fijos para cubrir una población geográficamente dispersa: análisis del proyecto "Girona Territori Cardioprotegit"

OBJETIVO. La desfibrilación pública multiplica por dos la probabilidad de sobrevivir indemne a una parada cardiaca extrahospitalaria. Se desconoce la mejor forma de dar cobertura a poblaciones geográficamente dispersas. El objetivo de este estudio fue comparar la tasa de uso y la efectividad entre los desfibriladores móviles y los fijos del programa pionero en desfibrilación pública "Girona Territori Cardioprotegit".

MÉTODOS. Registro prospectivo de usos de los desfibriladores automáticos públicos del programa (542 fijos, 241 móviles) y análisis de los trazados procedentes de los dispositivos entre junio de 2011 y diciembre de 2019. Se comparó la tasa de uso por desfibrilador, el porcentaje de ritmos desfibrilables y la efectividad de la desfibrilación entre dispositivos fijos y móviles.

RESULTADOS. De 566 usos registrados, se dispuso para el análisis de 494 casos, de los cuales 108 (21%) correspondieron a desfibriladores fijos. La tasa de utilización fue 2,4 usos/100 dispositivos/año en el caso de los fijos y 17,7 en el caso de los móviles. Comparados con los móviles, los dispositivos fijos encontraron una mayor proporción de ritmos desfibrilables (34,2 % *vs* 20,3%, p = 0,01) y presentaron una mayor proporción de conversión a ritmo favorable (79% *vs* 63%, p = 0,02). La proporción de pacientes trasladados al hospital en los ritmos desfibrilables fue de 62,1% en fijos y de 50% en móviles (p = 0,306).

CONCLUSIONES. Los desfibriladores fijos registraron más ritmos desfibrilables y consiguieron más conversiones de ritmo. Los desfibriladores móviles fueron ocho veces más utilizados.

Palabras clave: Parada cardiaca. Desfibrilación pública. Desfibrilador automático externo. Reanimación cardiopulmonar.

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Introduction and objectives

Early defibrillation is the most effective measure to counteract the high mortality of out-of-hospital cardiac arrest (OHCA).[1] Unfortunately, emergency medical services often arrive at the scene when the chances of survival are already very low,[2] particularly outside metropolitan areas.[3]

The use of automated external defibrillators (AEDs) by lay bystanders has been shown to double survival in victims of OHCA,[4] which has prompted both public and private institutions to promote widespread availability and use of these devices. To achieve this goal, public-access defibrillation programs have implemented two parallel population-coverage strategies: fixed AEDs and mobile AEDs.[5]

Fixed defibrillators are static devices accessible to the general public, usually placed in areas with high foot traffic, allowing rapid response by bystanders. Although multiple successful experiences support their use,[6-8] covering large geographic areas—even urban ones—remains a challenge, requiring deployment of a large number of AEDs.[9] The strategy based on mobile devices uses first-response vehicles (police, firefighters, civil protection) to transport an AED, achieving faster response times than advanced life support ambulances[10] and providing wider geographic coverage with fewer devices.[11]

While mobile devices are transported to the arrest location and used by trained personnel, fixed devices can potentially reach the victim more quickly but must first be located and are generally used by laypersons. Limited information exists regarding which strategy is superior in terms of frequency of use and defibrillation effectiveness. The objective of the present study was to compare the number of uses, functionality, and effectiveness of mobile AEDs versus fixed devices within the public-access defibrillation program "Girona Territori Cardioprotegit."

Method

We conducted a prospective observational study that included all public-access defibrillator activations within the "Girona Territori Cardioprotegit" program from its launch in 2011 through December 2019. All OHCA cases without an AED electrocardiographic tracing were excluded from analysis.

The "Girona Territori Cardioprotegit" program is a public defibrillation initiative promoted by the Diputació de Girona (Dipsalut), comprising 787 AEDs distributed throughout the province of Girona (area 5910 km^2, population 755,000; density 128 inhabitants/km^2).

Of these 783 devices, 542 are fixed AEDs distributed according to municipal and population criteria (all municipalities have at least 1 AED, and towns with > 1,000 inhabitants have 1 device per 1,500 inhabitants). Additionally, 241 mobile AEDs are carried in first-response vehicles (police, fire services, civil protection), and 40 "free" devices serve as fixed AEDs during high-attendance events (concerts, sporting events, etc.). Free devices were analyzed as fixed AEDs.

The locations of the fixed devices can be consulted at the project website: http://www.gironaterritoricardioprotegit.cat/.

In addition to AED distribution, Dipsalut conducts various training activities (secondary school courses, public campaigns, media outreach) and provides a mobile application (DEACAT) that identifies AED locations and allows callers to notify emergency medical services with GPS coordinates.

Data sources

The methodology of the present study has been previously published.[12] Data were obtained from the usage registry maintained by Dipsalut for the "Girona Territori Cardioprotegit" project. The registry is populated through reports completed by program technicians, who are automatically notified whenever an AED is used and subsequently travel to the arrest location for device maintenance. The information collected includes circumstances of use (true OHCA, time, location), basic demographic data, and whether the patient died or was transported.

In addition to replacing batteries and electrodes and verifying AED integrity, technicians download the device's memory, which includes ambient audio recordings (not used in this study) and an electrocardiographic tracing showing key events during resuscitation (device opening, electrode placement, rhythm analysis, shocks). ECG review allows precise assessment of the cardiac rhythm during arrest, AED interpretation, and delivered therapy. Chest-compression artifacts on the tracing also allow indirect assessment of cardiopulmonary resuscitation (CPR) performance.

To assess the first recorded rhythm in OHCA, 3 cardiologists independently evaluated AED tracings. Shockable and non-shockable rhythms were classified according to the American Heart Association consensus document.[13] Shock effectiveness was defined as conversion to sinus rhythm. As in previous studies, CPR quality was considered adequate when compressions followed device prompts and maintained a rate > 50 per minute.[14]

Ethical considerations and vital status assessment

The Girona Vital Project is the scientific research initiative derived from the "Girona Territori Cardioprotegit" program and includes the present study. It was approved by Hospital Universitari Josep Trueta (Girona, Catalonia, Spain) Ethics Committee in July 2012.

All registry data from Dipsalut and AED downloads are anonymous, with no identifying information. Vital status after CPR was obtained from resuscitation reports or witness statements collected by Dipsalut technicians during AED maintenance; all information was fully anonymized.

Statistical analysis

Continuous variables are expressed as mean ± standard deviation or median ± interquartile range; categorical variables as absolute values and percentages. Comparisons of categorical variables were performed using the chi-square test, and quantitative variables using the Student t test or Mann–Whitney U test when normality assumptions were not met. A 2-sided $P < .05$ was considered statistical-

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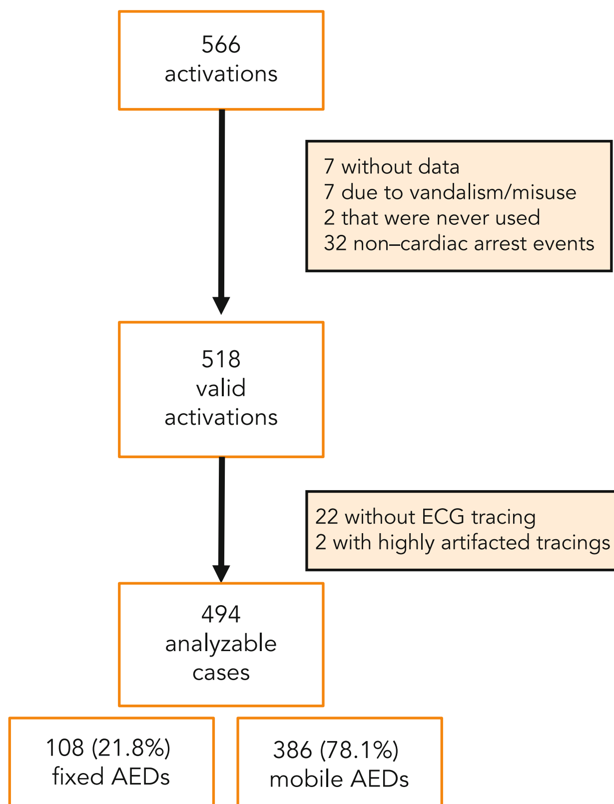

Figure 1. Inclusion diagram.
ECG: electrocardiogram; AED: automated external defibrillator.

ly significant. Statistical analysis was performed using R software, version 3.6.2 (R Core Team, 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: https://www.R-project.org/).

Results

A total of 566 activations were recorded, of which 518 OHCA cases were confirmed. Ultimately, 494 cases with confirmed OHCA and an interpretable AED tracing were available for analysis (Figure 1), of which 108 involved fixed devices (21.8%) and 386 involved mobile devices (78.1%). The utilization rate was 2.4 uses per 100 AED-years for fixed devices (108 uses among 542 fixed AEDs over 8 years) and 17.7 for mobile devices ($P < .001$). The comparison between fixed and mobile devices is shown in Table 1.

Rhythms encountered in cardiac arrests

The arrhythmia-detection algorithms of the devices identified a shockable rhythm in 115 cases (23.3%), 78 detected by mobile devices and 37 by fixed devices. When comparing the proportion of shockable rhythms identified by AEDs between fixed and mobile devices, the percentage was significantly higher in fixed devices (34.2% vs 20.3%, $P = .002$).

After expert review of the tracings, a total of 26 (5.2%) false negatives were identified, all corresponding to fine ventricular fibrillation, which the AED algorithms failed to recognize as shockable. Among these false negatives, 5 (11.9%) corresponded to fixed devices and 21 (21.2%) to mobile devices ($P = .282$).[3]

Including these cases, the total number of shockable rhythms was 141 (29%), again significantly higher in fixed than mobile devices (39% vs 26%, $P = .011$).[4]

Use of the AED

The median time from lid opening to patch placement across all cases was 52 seconds (IQR, 37–66). No differences were found between fixed devices (53 s; IQR, 38–71) and mobile devices (51 s; IQR, 37–66, $P = .511$).

For rhythms deemed shockable by AEDs, the median time from lid opening to delivery of the first shock was 76 seconds (IQR, 66–93). For fixed devices, this time was 76 s (IQR, 70–100) and for mobile devices 75 s (IQR, 64–91) ($P = .813$). The total mean time of AED use (from lid opening to closing) was 13 minutes (median, 10.7 minutes; IQR, 7–17), with no significant differences between mobile and fixed AEDs (12 vs 13 minutes; $P = .262$).

Devices delivered 259 shocks: an average of 1.7 shocks per patient for fixed AEDs and 2.3 shocks per patient for mobile AEDs ($P = .076$). The efficacy of the therapy in reverting the defibrillable rhythm was 67% overall, 79% in fixed devices, and 63% in mobile devices ($P = .022$) (Table 1).

CPR performance and return of spontaneous circulation (ROSC)

Based on the chest-compression artifacts on the tracings, chest compressions were performed in 77.5% of cases, but only 35.7% met predefined quality criteria. Comparing fixed vs mobile devices, there were no significant differences in CPR performance (71.9% vs 78.4%, $P = .201$) or in CPR quality (36.5% vs 35.5%, $P = .942$).

Among the analyzed activations, 129 patients (26.1%) were transported to the hospital after AED use. Among the 115 cases with AED-identified shockable rhythms, 62 patients (53.9%) were transported: 62.1% for fixed devices vs 50% for mobile devices ($P = .306$).

Discussion

This study analyzed AED use, proportion of shockable rhythms, and defibrillation effectiveness of fixed and mobile AEDs within a pioneering public-access defibrillation program in Spain: "Girona Territori Cardioprotegit." The most significant finding was that fixed devices detected more shockable rhythms and were more effective in treating them.

Colquhoun *et al.*, in 2008, examined 1,530 resuscitation attempts from the England and Wales public defibrillation program—including fixed and mobile devices—and their conclusions were consistent with ours.[15] They found that fixed devices identified more shockable rhythms (79% vs 35.5%) and achieved higher ROSC rates for shockable rhythms (47% vs 22.5%). As these authors suggested, and as we believe, the differences likely arise from the earlier response achieved with fixed devices.

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Table 1. Comparison between fixed and mobile automated external defibrillator

Total	Fixed (n = 108)	Mobile (n = 386)	*P* value
Uses per AED-year	0.024	0.177	< .001
Shockable rhythms (%)	37 (34.2)	78 (20.2)	.002
Time from lid opening to electrode placement (s)	53 (38-71)*	52 (37-66)*	.511
CPR performed (%)	71	78	.201
Total time of use (min)	12 (7-16)*	13 (8-17)*	.323
Shockable rhythms	**Fixed (n = 37)**	**Mobile (n = 78)**	***P* value**
Shock effectiveness (%)	79.7	63	.022
False negatives (%)[a]	5 (11.9)	21 (21.2)	.286
Time from lid opening to shock (s)	76 (70-100)*	75 (64-91)*	.813
Shockable rhythms transported (%)	23 (62)	39 (50)	.306

*Interquartile range (IQR).
[a]Percentage over the total number of shockable rhythms identified by expert review.
AED: automated external defibrillator; s: seconds; CPR: cardiopulmonary resuscitation; min: minutes.

The proportion of shockable rhythms in cardiac arrest declines exponentially as untreated arrest time increases, as documented in public defibrillation series. For example, the classic Nevada casino study found 71% shockable rhythms with a mean collapse-to-pad time of 3.5 minutes;[16] the Danish public-access program documented 55% with a mean of 5.7 minutes;[17] and a Swiss first-responder trial reported 30% with a mean response time of 6 minutes.[18]

Additional indirect evidence supports the hypothesis of earlier intervention by fixed devices. Most notably, first-shock efficacy was higher. Defibrillation success is inversely related to arrest duration, dropping sharply after approximately 4 minutes.[19,20] From an electrophysiological perspective, ventricular fibrillation becomes progressively more disorganized, finer, and more resistant to defibrillation, eventually progressing to asystole.[21] This time-dependent reduction in VF amplitude may also explain the (non-significant but notable) trend toward more false negatives in mobile devices, since fine VF is the most common cause of false negatives.[12,22] Because early defibrillation is the strongest determinant of OHCA survival—and closely linked to long-term prognosis[8]—the 12% higher rate of transported patients with shockable rhythms in the fixed-device group is noteworthy, even if it did not reach statistical significance.

In our study, this earlier access with fixed devices was not offset by poorer layperson performance; AED use times and CPR performance were similar to those in trained first responders. This finding underscores the ease of AED use, widely documented in the literature.[23] Of note, both groups showed low rates of high-quality CPR, highlighting the need for improved CPR training for both the general population and first responders.

In our series, mobile defibrillators were used 8 times more frequently than fixed ones. Nelson et al. found that the likelihood of use of a mobile device compared with a fixed device was 172 times higher in Stokes County (North Carolina, United States), a rural area with a population density of 30 inhabitants/km^2.[24] We believe that utilization frequency should not be the main objective, but rather early defibrillation, and mobile defibrillators allow broad defibrillation coverage in geographically dispersed populations and in locations without a fixed public-access infrastructure. Multiple experiences have shown that mobile devices improve emergency medical service response times.[15,18,25]

Public-access defibrillation strategies that combine all possible resources to reach cardiac arrests early are those associated with the best outcomes.[26] In our view, the present study indicates that the two approaches are complementary: equipping first-response vehicles with AEDs should be standard in geographically dispersed areas, alongside the progressive incorporation of additional fixed devices in more densely populated zones.

Limitations

The main limitation of this study is that it relies on electrocardiographic tracings obtained from AEDs, and important variables remain unknown, such as the time elapsed between OHCA and AED use or patients' relevant clinical histories. Second, no medical confirmation of cardiac arrest was available, making it possible that patients with spontaneous circulation were included in the registry. Nevertheless, we consider that this limitation does not apply to shockable rhythms. Additionally, the assessment of survival after cardiac arrest was limited to determining whether patients were transported, based on information provided by bystanders; however, the number of patients who survived transport, survived to hospital discharge, or their neurological status remains unknown due to the anonymous nature of the registry.

Another limitation is the lack of information regarding other public-access AEDs outside the "Girona Territori Cardioprotegit" network, and the differences found between fixed and mobile devices may be inherent to the logistics of our public defibrillation program. Finally, CPR performance assessment was based on an indirect but validated-procedure and should therefore be interpreted with caution.

Conclusions

Fixed AEDs detected more shockable rhythms and were more effective at reversing them compared with mobile AEDs, whereas mobile AEDs were used far more frequently. Although potential confounders influencing effectiveness must be considered, AED use times and CPR performance were similar between device types. Nevertheless, there remains substantial room for improvement in high-quality CPR, both among the general population and among trained first responders.

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ARTICLE INFORMATION

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