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Clinical paper

Factors associated with the arrival of smartphone-activated first responders before the emergency medical services in Out-of-Hospital cardiac arrest dispatch

Lorenzo Gamberini[a], *Donatella Del Giudice*[b], *Stefano Saltalamacchia*[a], *Benjamin Taylor*[c], *Isabella Sala*[d,e], *Davide Allegri*[f], *Antonio Pastori*[g], *Carlo Coniglio*[a,*], *Giovanni Gordini*[a], *Federico Semeraro*[a], *Collaborators*[1]

Abstract

Background: First responder programs were developed to speed up access to cardiopulmonary resuscitation and defibrillation for out-of-hospital cardiac arrest (OHCA) victims. Little is known about the factors influencing the efficiency of the first responders arriving before the EMS and, therefore, effectively contributing to the chain of survival.

Objectives: The primary objective of this retrospective observational study was to identify the factors associated with first responders' arrival before EMS in the context of a regional first responder program arranged to deliver automated external defibrillators on suspected OHCA scenes.

Methods: Eight hundred ninety-six dispatches where FRs intervened were collected from 2018 to 2022. A robust Poisson regression was performed to estimate the role of the time of day, the immediate availability of a defibrillator, the type of first responder, distances between the responder, the event and the dispatched vehicle, and the nearest available defibrillator on the probability of responder arriving before EMS.
Moreover, a geospatial logistic regression model was built.

Results: Responders arrived before EMS in 13.4% of dispatches and delivered a shock in 0.9%.
The immediate availability of a defibrillator for the responder (OR = 3.24) and special categories such as taxi drivers and police (OR = 1.74) were factors significantly associated with the responder arriving before EMS. Moreover, a geospatial effect suggested that first responder programs may have a greater impact in rural areas.

Conclusions: When dispatched to OHCA scenes, responders already carrying defibrillators could more probably reach the scene before EMS. Special first responder categories are more competitive and should be further investigated.

Keywords: Cardiopulmonary Resuscitation, Cardiac Arrest, Heart Arrest, Emergency Medical Services, First Responder, AED

Introduction

Out-of-hospital cardiac arrest (OHCA) is still a leading cause of mortality and disability worldwide, with an estimated incidence of 89 per 100,000 inhabitants per year.[1–2]

Bystander cardiopulmonary resuscitation (CPR) and early defibrillation play a key role in determining OHCA outcomes and were recently demonstrated to have a major impact on ROSC probability and long-term disability.[3]

Bystander CPR rate varies across countries,[2,4–5] and different strategies to increase the propensity of bystanders to initiate CPR

Abbreviations: OHCA, out of hospital cardiac arrest, FR, first responder, EMS, emergency medical services, AED, automated external defibrillator, CPR, cardiopulmonary resuscitation, OR, odds ratio

* Corresponding author at: Department of Anesthesia, Intensive Care and Prehospital Emergency, Ospedale Maggiore Carlo Alberto Pizzardi, Bologna, Italy.
E-mail address: car.coniglio@gmail.com (C. Coniglio).

[1] Collaborators Listed in Appendix A.

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and bring external automatic defibrillators (AEDs) to the scene are being developed, ranging from drones to artificial intelligence.[6–9]

First responder (FR) programs substantially involve volunteer citizens who can be contacted based on their geo-localization and distance to the OHCA event via a smartphone app or an SMS system and sent to the OHCA scene to bring an AED and provide high-quality CPR.[10–15]

The FRs are citizens of either healthcare or non-healthcare professionals who can have direct access to an AED (e.g., at work or in their vehicle) or need first reach a publicly available AED before heading to the scene.

It is still unclear which factors influence the probability of the FRs arriving on the scene before the EMS.

Knowing these factors could help better define when FRs should be effectively activated, which locations would benefit from a reinforcement of FR programs, and which kinds of responders have a higher probability of getting to the scene before EMS and giving an effective contribution to resuscitation.

Moreover, frequent futile activations may discourage the FRs from intervening in further calls and even increase the risk to their safety, as recently reported.[12]

The main objective of this retrospective observational cohort study was to evaluate the factors influencing the probability of the FRs reaching the OHCA scene before the EMS.

The study's secondary objective was to describe the FRs' interventions in performing CPR and defibrillation on the scene.

Methods

Setting

Emilia Romagna is an Italian region covering 4,432,700 inhabitants, with a 22,510 km^2 surface area, with an EMS composed of three main types of ground vehicles: basic life support (BLS), intermediate life support (ILS) ambulance and advanced life support (ALS) medical cars. Three HEMS and one HEMS-SAR helicopter complete the ground-based EMS.

EMS response is two-tiered. Ambulances can be sent independently from medical cars that carry a physician and a nurse and act as support vehicles.

Three dispatch centres, located in the western (Emilia Ovest), central (Emilia Est) and eastern part (Romagna) of the region, are responsible for the call taker and dispatch function.

The dispatch algorithm has been described elsewhere.[16] When a cardiac arrest is suspected based on the telephonic interview (Code Blue-ALS), the dispatcher calls for FRs' intervention via the regional App. In Emilia Romagna, the Regional Healthcare Service, in collaboration with the Regional EMS, has activated an app named "DAE RespondER", which uses a combined approach based on the AEDs regional registry, the EMS' cartographic system, and data from the dispatch centre.[13]

Because of the different local choices of the dispatch centres, the FRs are always called for events that occur in public places. At the same time, they are activated for events that occur at home only in Emilia Ovest.

DAE RespondER program

The "DAE responder" App (https://www.118er.it/dae) was developed for Android and iOS and released on October 1st, 2017.[13]

The adhesion to the program is voluntary. BLS formal training is not mandatory: if an untrained responder is engaged, he/she can retrieve the nearest AED and receive pre-arrival instructions with a chest compression-only procedure from the dispatch operators (mainly nurses with experience in the field of emergency). The DAE responder app accounts for 14,520 people subscribed by November 2022.

Recently, the Italian government released a system approach law that suggests using apps and legal protection of the occasional rescuer as a bystander in a witnessed CA.[17]

The smartphone app continuously collects information about the FR's position and calls for interventions if a Code Blue-ALS mission for suspected OHCA is dispatched within a 5 km radius of him/her. If the position is unavailable, the FRs are activated for all the calls happening in the municipalities they previously selected among the application options.

Once the mission is accepted, the FR should reach the nearest public AED and bring it to the scene. At the same time, the bystanders are instructed to perform CPR, with an eventual phone contact from the dispatch centre to help the responder take the most appropriate actions based on his/her competencies.

At the end of each accepted mission, an email is sent to the responder that reviews the actions performed, and these data are prospectively stored.

The program was also carried on during the COVID-19 pandemic, ensuring adequate FR protection, as for other FR programs worldwide.[18]

Study design and Ethics approval

We retrospectively collected fully anonymised electronic data from the Emilia Romagna dispatch centres between January 2018 and June 2022.

We calculated the radial distances based on the coordinates of the event, the dispatch vehicle sent to the scene, the nearest AED available at the time and those of the responder who arrived at the scene before the EMS, or the coordinates of the nearest responder who accepted the intervention. Time of the emergency call, time of responder arrival (if arrived before the EMS) and time of EMS arrival were also collected. Finally, the responder's actions (i.e., took an AED, brought to the scene an AED, performed CPR, analysed rhythm, delivered a shock) were also collected.

The study is part of the System Saving Lives study and received approval from the local Ethics Committee (NCT04510480).

Statistical analysis

Continuous variables were expressed as medians and interquartile ranges (IQR) or means and standard deviations based on their distribution evaluated with the Shapiro-Wilk test. Comparisons between continuous variables were performed with the Mann-Whitney U test or the t-test where appropriate. Categorical variables were expressed as numbers and percentages and compared using the Chi-square test.

Since missing data for the variables of interest were over 10%, we compared the missing and non-missing data populations and geographically projected the difference in the density distribution between cases with missing and non-missing data.

A multivariable robust Poisson regression model, to take into account the common outcome, was performed to evaluate the association between the distance of the FR, the nearest available AED and the dispatched vehicles from the event, the number and type

of FR accepting the mission, the condition of already-carrying AED, and the daytime (independent variables) and FR's arrival before or after EMS (dependent variable). In brief, this model considers robust estimators for the variance of regression coefficient named sandwich estimators.[19] Finally, we built a spatial logistic regression model adjusted for the significant covariates in the robust Poisson regression model to assess the eventual geospatial effects on the odds ratios (ORs) for FR arriving before EMS.[20–21]

Spatial regression introduces space or geographical context into a regression's statistical framework. It is used when these variables are thought to play an essential role in the explored process or when space can act as a reasonable proxy for other factors.

In particular, we further explored the geographical variation of the probability of the OR for the FR arriving before the EMS being over 1.5.

Analyses were performed using the R software v. 4.2.2.[22]

Results

Between January 2018 and June 2022, 14,221 high-priority dispatches for suspected OHCA were performed in the Emilia Romagna region. Of these, 5,073 (35.7%) fulfilled the criteria for activation of the FRs.

In 1,077 out of the 5,073 requests sent (21.2%), at least one FR was available for intervention. Finally, 1,074 events were included in the present study after excluding 3 cases for completely missing data (Fig. 1).

In 144 out of 1,074 cases (13.4%), the FR reached the scene before the EMS and performed CPR in 67 cases (6.2%). The FR analysed a rhythm in 43 events (4.0%), and a shock was delivered in 10 cases (0.9%).

Data were complete for all the variables of interest only for 896 out of 1,074 cases (83.4%). Most of the missing data were related to the distances of the ambulances from the events due to missing geolocalisation of the vehicles (Supplement Fig. 1).

The analysis of the differences between the cases with missing and non-missing data demonstrated that data-missing cases had slightly longer FR or EMS arrival times (7.1 vs 6.4 minutes, p = 0.007), higher distances between the FR and the AED (3.5 vs 2.8 km, p = 0.05), and were differently distributed across years, with significantly more missing values in 2018 and 2019 (p = 0.003: Supplement Table 1).

Moreover, the difference in the geographical distribution of missing data suggested a higher density of missing data in areas far from the major cities (Supplement Fig. 2).

All these aspects suggested that data were missing not at random, therefore, we avoided missing data imputation techniques and considered only the complete cases for further analyses.

Table 1 shows the main characteristics of the events included in the analysis.

The FRs arrived more frequently before EMS when more than one FR accepted to be dispatched on the same event and if the FR belonged to particular categories, such as taxi drivers and police. In contrast, they were more likely to arrive after the EMS during nighttime.

We found no differences concerning the place of OHCA events, and, despite the advent of the COVID-19 pandemic, no year-related significant differences were found.

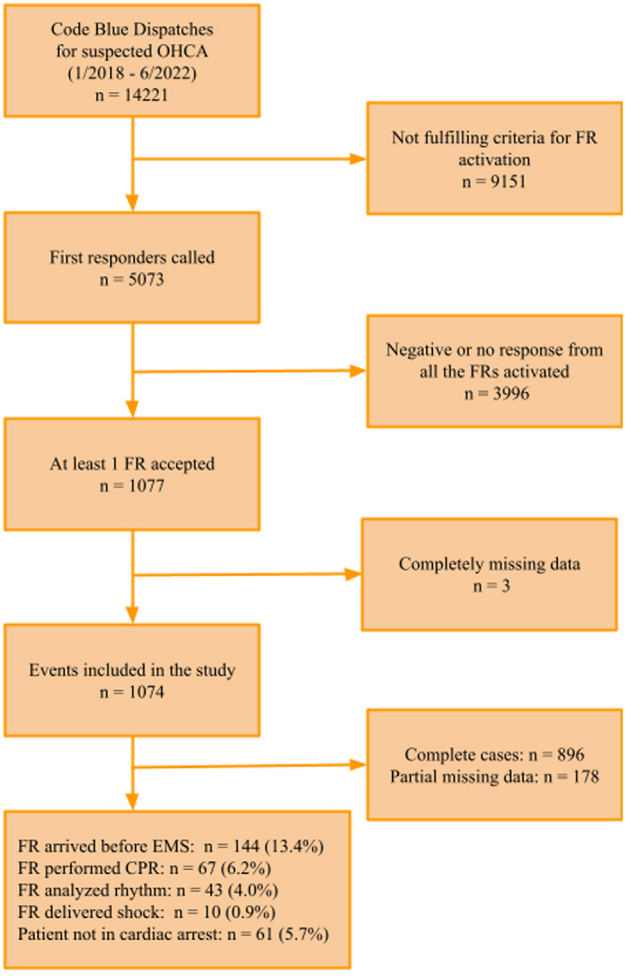

Fig. 1 – Flow of the cases throughout the study Abbreviations: OHCA – out of hospital cardiac arrest; FR – first responder; EMS – emergency medical services; AED – automated external defibrillator; CPR – cardiopulmonary resuscitation.

FRs arriving before the EMS had a median distance from the scene lower than 1 km (IQR: 0.29 – 2.07) and competed with ambulances about 4.2 km (IQR: 1.95 – 7.06) distant. At the same time, those arriving after EMS had a median distance of over 3 km (IQR: 1.09 – 8.80), while the dispatched ambulances were less than 2.2 km (IQR: 1.30 – 4.48) distant.

When the FRs arrived before the EMS, the median time between the call and the first contact with the patient was around 4.8 minutes (IQR: 3.4–7.8) versus 6.6 minutes (IQR: 4.8–9.2) when EMS vehicles arrived first.

The median distance of an available and operative AED with public access and the events was around 370 m, with no significant differences when the FRs arrived before or after the EMS.

Finally, FRs were more likely to arrive at the scene before EMS if they were already carrying an AED at the time of the call or if they took it from their current location (e.g., at work).

Fig. 2 shows the relative frequencies of FRs reaching the scene before the EMS under different conditions of the distance between the FR and the scene and his/her characteristics.

Table 1 – General characteristics of the included events.

	FR arrived after EMS n = 777	FR arrived before EMS n = 119	p
OHCA place			0.717
Home - n (%)	316 (40.7%)	46 (38.7%)	
Public exercise - n (%)	117 (15.1%)	19 (16.0%)	
Street - n (%)	177 (22.8%)	32 (26.9%)	
Other - n (%)	167 (21.5%)	22 (18.5%)	
Year			0.319
2018 - n (%)	184 (23.7%)	36 (30.3%)	
2019 - n (%)	175 (22.5%)	24 (20.2%)	
2020 - n (%)	140 (18.0%)	25 (21.0%)	
2021 - n (%)	160 (20.6%)	17 (14.3%)	
2022 - n (%)	118 (15.2%)	17 (14.3%)	
Night time (20 – 8) - n (%)	142 (18.3%)	10 (8.4%)	0.011
More than 1 FR accepted - n (%)	155 (19.9%)	40 (33.6%)	0.001
Type of FR			<0.001
Police - n (%)	0 (0.0%)	5 (4.2%)	
Other FR - n (%)	764 (98.3%)	98 (82.4%)	
Taxi driver - n (%)	13 (1.7%)	16 (13.4%)	
FR had AED with him/her - n (%)	20 (2.6%)	36 (30.3%)	<0.001
Distance FR - event - m (IQR)	3188 (1023–8490)	769 (288–2067)	<0.001
Distance AED - event - m (IQR)	368 (161–814)	358 (172–751)	0.965
Distance FR - AED - m (IQR)	3317 (1088–8803)	910 (389–2241)	<0.001
Distance ambulance - event - m (IQR)	2267 (1299–4478)	4211 (1952–7060)	<0.001
Time for EMS or FR arrival - min - (IQR)	6.6 (4.8–9.2)	4.8 (3.4–7.8)	<0.001
FR performed CPR - n (%)	9 (1.2%)	49 (41.2%)	<0.001
FR analysed a rhythm - n (%)	2 (0.3%)	31 (26.1%)	<0.001
FR delivered a shock - n (%)	0 (0.0%)	8 (6.7%)	<0.001
Patient not in cardiac arrest - n (%)	10 (1.3%)	39 (32.8%)	<0.001

Abbreviations: FR first responders; OHCA – out of hospital cardiac arrest; AED – automated external defibrillator; CPR – cardiopulmonary resuscitation.

Table 2 shows the results of the multivariable robust Poisson regression model. The lower distance between the FR and the site of the event (OR = 0.98 [95% CI: 0.97–0.99]), the higher distance between the ambulance and the event (OR = 1.01 [95% CI: 1.007–1.014]), and the FRs already carrying an AED at the time of the call (OR = 3.24 [95% CI: 2.28–4.61]) resulted significantly associated to a higher probability of arrival before the EMS.

Moreover, police and taxi FRs were significantly associated with arrival before the EMS with respect to the other FRs (OR = 1.74 [95% CI: 1.16 – 2.63]).

Fig. 3 shows the geospatial distribution of the events where FRs arrived before the EMS. In contrast, Fig. 4 depicts the spatial distribution for the probability of the adjusted OR being over 1.5 for FRs arriving before the EMS. We observed a geospatial effect with an increased probability of the adjusted OR being over 1.5 in the mountain areas in the southwestern region.

Discussion

Dispatching citizens as FRs has been demonstrated to be an effective strategy to increase the rate of bystander CPR and defibrillation, thus reducing time-to-CPR and defibrillation and, ultimately, increasing the probability of survival with a good neurological outcome.[23–26]

In this work, we aimed to evaluate which factors were associated with an increased probability of the FRs arriving before the EMS. Our results suggested that: i) FRs carrying AEDs or having full access to AEDs in their workplace have a higher chance to reach the scene before EMS; ii) some categories of FR, such as taxi drivers and police, demonstrated to be more competitive FR; iii) there is a potential geospatial effect on the probability of FR arriving before EMS.

In our experience, at least one FR accepted the invitation in one out of 5 cases; in approximately 13% of events where at least one FR was finally sent, they effectively arrived before EMS, and in about 1 out of every 100 events, a shock was delivered.

Our results are similar to those of Andelius et al.[12] concerning the number of FRs accepting the invitation. Still, we observed a considerably lower number of FRs reaching the scene before EMS (13.4% vs 33.2%). This difference may be related to underlying aspects of the EMS, a slightly higher distance of the FRs, and a potential influence of the COVID-19 era on the organisation and the propensity of the FRs to effectively reach the scene.[18]

The most important result of our study is the evidence that there are some kinds of FRs more efficient in reaching the scene before the EMS. In particular, those who already had an AED with them or had it easily accessible in their workplace had an adjusted OR of reaching the scene before EMS three times higher than those who needed to get an AED near the scene.

It also has to be noted that taxi drivers and police officers were proficient at arriving at the scene quickly and independently from having an AED with them.

This observation could be explained by different factors, including faster access to a vehicle, a deeper knowledge of the local geography, and the possibility of accessing preferential roads and eventually violating the road code. Moreover, most of these jobs have idle periods while waiting for tasks to be assigned, so an eventual intervention for an OHCA dispatch may be less problematic than other jobs.

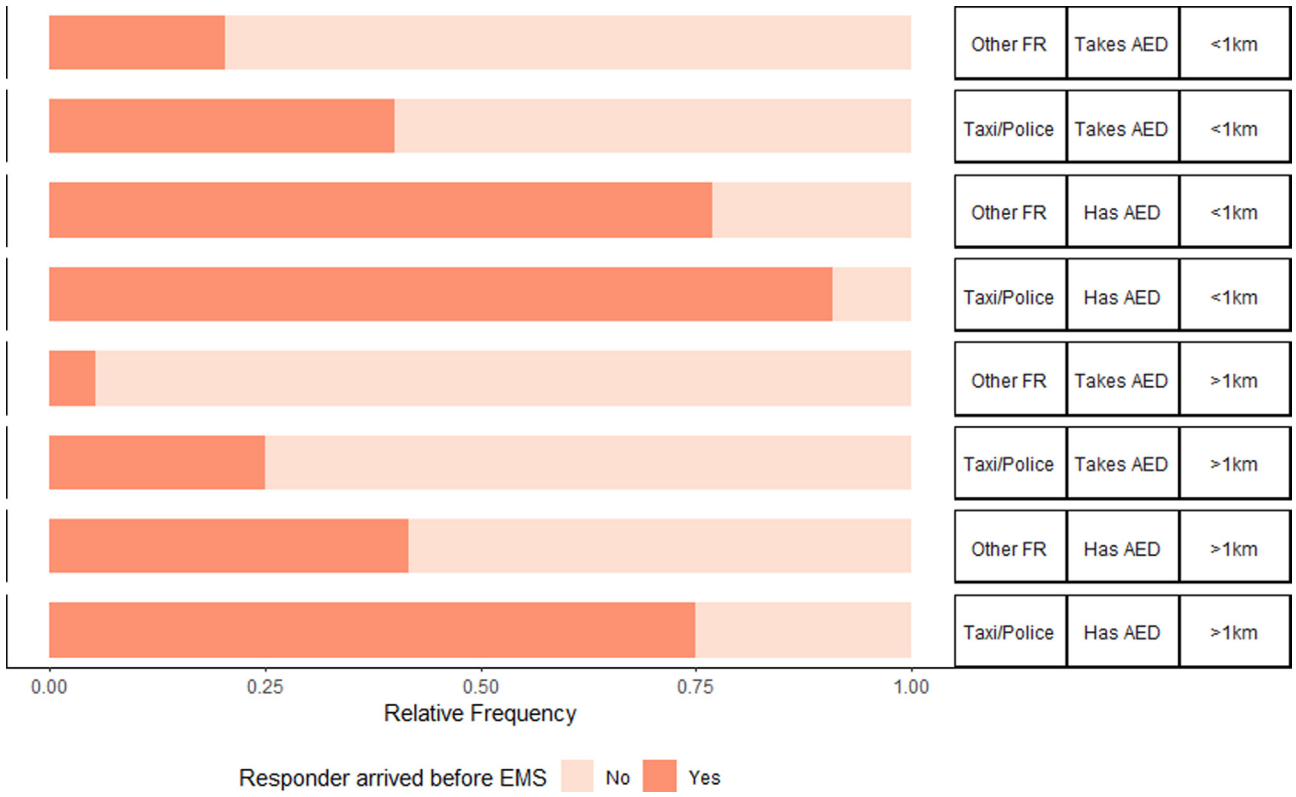

Fig. 2 – Relative frequencies of first responder arrivals before EMS Abbreviations: FR – first responder; EMS – emergency medical services; AED – automated external defibrillator.

Table 2 – Multivariable robust Poisson regression model.

	OR	95%CI	p
Daytime (Night)	0.598	0.330–1.085	0.091
Distance FR - event (100 m increase)	0.978	0.968–0.988	< 0.001*
FR has already AED with her/him (Ref – FR has not AED with her/him)	3.243	2.281–4.610	< 0.001*
Distance Ambulance - Event (100 m increase)	1.010	1.007–1.014	< 0.001*
Distance available AED – Event (100 m increase)	1.003	0.983–1.023	0.760
Taxi/Police FR (Ref – All other types of FR)	1.742	1.156–2.626	0.008*
More than 1 FR accepted (Ref – only 1 FR accepted)	1.285	0.911–1.814	0.153

Abbreviations: OR – odds ratio, CI – confidence interval, AED – automated external defibrillator.

Similar results were reported by Berglund et al.,[26] who evidenced that CPR-performing FRs directly dispatched to the scene were the most likely to arrive before EMS. With the advent of more portable AEDs, the role of these types of FRs may become more crucial. Other FRs whose jobs share the characteristics of fast access to vehicles and idle periods, such as firefighters,[27] delivery riders and private security guards, should be investigated as subjects on whom to invest in FR trials.

The efficiency of the different kinds of responders could also have influenced the negative results of the recently published results of the SAMBA trial,[28] which failed to demonstrate the role of FRs sent taking AEDs in increasing the rate of overall bystander AED attachment, thus underlying the need to refine the knowledge about who are the best competitors of the EMS and bystanders and which strategy should be adopted (public access AEDs taking versus portable AEDs) to maximise their effectiveness.

Compared to events in cities located at the same distance, the geospatial analysis showed that FRs could play a more decisive role in areas farther from the big cities and in mountain areas that are more difficult to reach by EMS. Thus, while the global number of OHCA events is lower in rural areas, the potential role of FR in providing access to early CPR and defibrillation may be greater in these areas.

Limitations

The main limitations of this study rely on its observational nature and the impossibility of deeply tracing the FRs' paths, the vehicles they used to reach the scene, and which AED was effectively taken. For the latter, we considered the nearest AED to the scene, but the FR's choices could have been different.

Moreover, the reliability of smartphone-recorded FRs' GPS coordinates is not verifiable. When multiple FRs accepted the mission, but none arrived before EMS, we included data from the first FR accepting, and this may not have been the most proficient competitor of the EMS.

The AED attachment by the FRs would probably have been a better indicator of FRs' effectiveness. However, we considered the

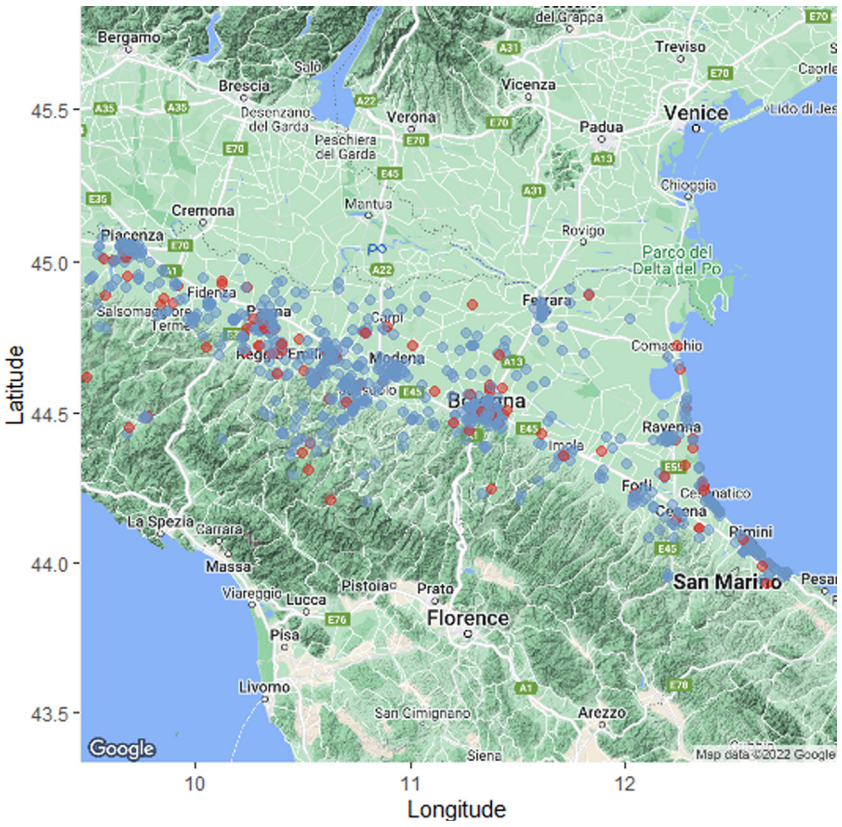

Fig. 3 – Geospatial distribution of the events and spatial logistic regression model Notes: red dots refer to events where the FR arrived before the EMS, blue dots refer to events where the FR arrived after the EMS.

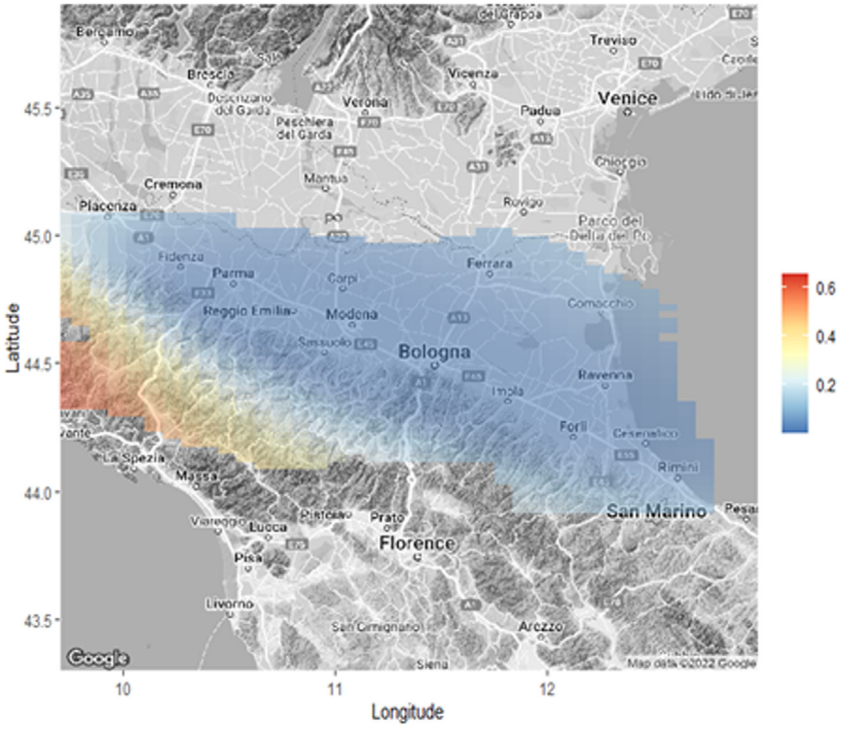

Fig. 4 – Spatial logistic regression model Notes: the legend shows the distribution of the probability of the adjusted OR for FR arriving before EMS being over 1.5.

arrival before EMS as the primary outcome for this study since this is at the root of FRs' function and it could be less influenced by their experience.[27]

Another limitation of our study is using the Euclidean metric to measure distances between the event and potential responders. An alternative here would be to use distance along the road network; however, doing this properly introduces further challenges. Roads are directional networks, one would require details of any one-way systems and diversions in place at the time of the incident and, ideally, the distance should be adjusted to account for traffic conditions and speed restrictions. These are clearly very interesting avenues to pursue in further research.

On the other hand, this study collected more than 800 complete episodes from a region-wide area. It used advanced statistical models to overcome potential biases in estimating the effects of the different determinants taken into account.

Conclusions

Our results suggest that AED-equipped FRs or those with easy access to AED, as well as certain types of worker FRs, such as taxi drivers and police officers, may be subjects in whom to invest, to improve the effectiveness of FR programs. Finally, rural areas may benefit more from the diffusion of FR programs.

CRediT authorship contribution statement

Lorenzo Gamberini: Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Visualization. **Donatella Del Giudice:** Validation, Data curation. **Stefano Saltalamacchia:** Investigation, Data curation, Writing – original draft. **Benjamin Taylor:** Methodology, Formal analysis. **Isabella Sala:** Methodology, Writing – review & editing. **Davide Allegri:** Formal analysis. **Antonio Pastori:** Supervision. **Carlo Coniglio:** Conceptualization, Writing – review & editing. **Giovanni Gordini:** Writing – review & editing, Supervision. **Federico Semeraro:** Conceptualization, Writing – review & editing, Visualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

Collaborators (to be indexed in Pubmed and citable):

Giulio Bernardini – Centrale Operativa 118 Emilia Ovest, Azienda Ospedaliera Universitaria di Parma, Parma, Italy.

Giulio Desiderio – Department of Anesthesia, Intensive Care and Prehospital Emergency, Ospedale Maggiore Carlo Alberto Pizzardi, Bologna, Italy.

Adriano Furlan – Centrale Operativa Emilia Ovest, Azienda Ospedaliera Universitaria di Parma, Parma, Italy.

Andrea Fransceschini - Centrale Operativa 118 Emilia Est, Maggiore Hospital Carlo Alberto Pizzardi, Bologna, Italy.

Fabio Mora – 118 Modena, Azienda Ospedaliero-Universitaria di Modena, Modena, Italy.

Marco Vitali – Centrale Operativa 118 Romagna, Ospedale Santa Maria delle Croci, Ravenna, Italy.

Antonella Zambon - Department of Statistics and Quantitative Methods, University of Milano-Bicocca, Milan, Italy; Biostatistic unit, Istituto Auxologico Italiano, IRCCS, Milan, Italy.

Collaborators: the collaborators were involved in the project management for the regional dispatch centres or supervised the data analysis.

Appendix B. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resuscitation.2023.109746.

Author details

Collaborators[1] [a]*Department of Anesthesia, Intensive Care and Prehospital Emergency, Ospedale Maggiore Carlo Alberto Pizzardi, Bologna, Italy* [b]*EMS 118 Regional Programme, Maggiore Hospital, Bologna, Italy* [c]*University College Cork, Department School of Mathematical Sciences, Ireland* [d]*Department of Statistics and Quantitative Methods, University of Milan-Bicocca, Milan, Italy* [e]*Department of Medicine and Surgery, University of Milan-Bicocca, Milan, Italy* [f]*Department of Clinical Governance and Quality, Bologna Local Healthcare Authority, Bologna, Italy* [g]*Settore Assistenza Ospedaliera, Direzione Generale Cura della Persona, Salute e Welfare, Assessorato Politiche per la Salute, Regione Emilia, Bologna, Italy*

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