

ORIGINAL RESEARCH

Impact of dual dispatch system implementation on response times and survival outcomes in out-of-hospital cardiac arrest in rural areas

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Abstract

Objectives: Dual dispatch early defibrillation in out-of-hospital cardiac arrest (OHCA) victims provided by firefighters in addition to Emergency medical services (EMS) has proven to increase rate of return of spontaneous circulation (ROSC) and thus survival in the metropolitan or suburban areas whereas the data in rural areas are scarce.

Methods: This was a retrospective observational cohort study of EMS resuscitated OHCA victims in regions with dual dispatch of volunteer firefighters as first responders (intervention group). Historical group was based on all OHCA occurring in these regions before the implementation of first responders (EMS response only). Multivariate logistic regression with following variables: intervention, age, gender, witnessed status, bystander cardiopulmonary resuscitation (CPR), first rhythm and etiology were used to control for confounding factors affecting ROSC.

Results: A total of 312 OHCA were included in the study (historical group, $n = 115$ and intervention group, $n = 197$). Median time to arrival of first help shortened significantly for all patients, patients with ROSC and patients with Cerebral Performance Category 1/2 (CPC 1/2) in intervention vs historical group (8 vs 12 min, $p < 0.001$; 7.5 vs 11 min, $p = 0.002$; 7 vs 10 min, $p = 0.011$; respectively). The proportion of patients with ROSC, 30-day survival and CPC 1/2 at hospital discharge remained unchanged in intervention vs historical group (21% vs 23%, $p = 0.808$; 7% vs 6%, $p = 0.914$; 6% vs 3%, $p = 0.442$; respectively). The logistic regression model of adjustment confirms the absence of improvement in the ROSC rate after the implementation of first responders.

Conclusions: Introduction of a dual dispatch of local first responders in addition to EMS in cases of OHCA significantly shortened response times. However, reduced response times were not associated with better survival outcomes.

Keywords

Out-of-hospital cardiac arrest; First responder; Survival rate; Sudden cardiac death; Automated external defibrillator; Cardiopulmonary resuscitation; Firefighters

1. Introduction

Out-of-hospital cardiac arrest (OHCA) is one of the leading causes of death and annually affects ~275,000 people in Europe [1, 2]. Bystander cardiopulmonary resuscitation (CPR) [3] and early defibrillation with automated external defibrillator (AED) are essential in improving survival of OHCA victims [4, 5]. Different strategies were implemented to support Emergency medical services (EMS) reduce the time interval to first shock. Public access defibrillation programs place AEDs in densely populated areas and in locations with many visitors, where AEDs can be used by bystanders [5–7]. Other programs include first responders with AEDs like police officers [8–10], firefighters [11–14], local lay rescuers [15, 16] or any combination thereof [4, 17, 18] dispatched to a suspected OHCA victim as a part of organized EMS response. Dual dispatch

early defibrillation in OHCA provided by firefighters increases survival and was studied predominantly in the metropolitan or suburban areas [11, 14, 17, 19], whereas in rural areas the data are scarce [12, 13]. OHCA victims in rural areas benefit from local first responders due to shorter driving distance thus reducing the time interval to first shock and minimizing the risk that an initial shockable rhythm deteriorates to a non-shockable rhythm, which decreases the chance of survival [20–22]. A time difference of as little as 1 minute appears to significantly influence survival [17].

The aim of the present observational study was to determine the impact of volunteer firefighter interventions as local first responders on response times and survival outcomes in OHCA victims in rural areas.

2. Methods

The regional ethics committee of University Medical Center Maribor approved the study and waived the requirement to obtain any informed consent (No. UKC-MB-KME-24/20, 02/010/03-003/01/20).

2.1 Setting

This study took place in the northeastern part of Slovenia. The study region included surrounding catchment rural areas with several smaller and bigger villages of the following EMS: Maribor, Ptuj, Velenje and Koroška region with the population of 138,281 covering 1504.6 km² and average population density of 91.9 people/km². In this area, 63 local fire stations are equipped with AEDs.

2.2 Emergency medical services (EMS)

The EMS in Slovenia is provided by the Community health-care centers with EMS stations located in the urban areas. The catchment area of a single EMS expands over several surrounding municipalities and thus the EMS provides its service not only in the urban/suburban but also in the rural areas with response times up to 40 min. When a cardiac arrest is suspected, an ambulance with two paramedics and an emergency physician on board is dispatched.

2.3 First responders

From 2014 first responders (local voluntary firefighters) have been organized in the rural areas with the EMS response times of more than 10 min. Median response time of EMS included in the study is 8 min in the urban/suburban areas. According to the Rules on Emergency Medical Service published in Official Journal of the Republic of Slovenia all first responders have to undergo a 10-hour training to gain the following knowledge and skills in basic life support (BLS): adult and children CPR with the use of an AED according to the European Resuscitation Council (ERC) guidelines, foreign body airway obstruction and control of the major isolated traumatic external bleeding. Initially, the ERC guidelines from 2010 were used for the training [23]. In the beginning of 2016, the training was adapted to the 2015 guidelines [24]. The algorithms of the AED were changed accordingly. After the training, the participants have to pass a written and a practical exam to obtain the first responder license. All first responders have to renew their license annually.

2.4 Dual dispatch

In Slovenia, Regional Emergency Notification Center receives all 112-emergency calls. In case of a medical emergency, the emergency call is forwarded to the Medical dispatch center. In cases of suspected cardiac arrests, the Medical dispatch center alerts the nearest available ambulance (EMS) with emergency physician on board first and then, as soon as possible, dispatches the closest available fire brigade with organized local first responders *via* the Regional Emergency Notification Center. The fire brigade dispatch should happen simultaneously with the EMS dispatch. The first responders to arrive at the

scene are responsible for performing medical assessment. If the patient is unresponsive and not breathing, CPR is initiated and the AED is attached. When the EMS crew arrives, they take over the responsibility for the treatment, but the first responders are included in ongoing resuscitation as additional help.

2.5 Study design

This is a retrospective observational cohort study of the prospective gathered data in regions where a dual dispatch of first responders was implemented (intervention group). Enrollment of the patients in the intervention group depended on the time of the first responder implementation in each studied region. In EMS Maribor and EMS Koroška region the first responder system had been stepwise organized since May 2014 and was fully implemented in January 2015. Within the Northeastern Slovenia the system was incrementally rolled out to the other included regions with complete coverage from December 2017. Historical control group was based on all OHCA occurring in these regions before the implementation of first responders (EMS response only). Comparison of all OHCA victims for an equivalent time period in both groups was made (see Appendix Fig. 2).

EMS protocols designed according to the Utstein style reporting for OHCA, first responder intervention reports, dispatch protocols of the Medical dispatch center and hospital medical reports for the study period were analyzed. Calculations of times and intervals were based on the above-mentioned reports.

2.6 Study participants

Eligible patients were all EMS resuscitated OHCA in the rural areas included in the study (independent of witnessed status, cardiac rhythm and previous morbidity). The exclusion criteria were: age ≤ 18 years, EMS crew-witnessed OHCA, in-hospital arrests, patients with obvious signs of death, people with existing Do Not Attempt Resuscitation (DNAR) orders and patients where no CPR was initiated by the EMS.

2.7 Endpoints

The primary endpoints were: (1) number of OHCA with the return of spontaneous circulation (ROSC), (2) 30-day survival and (3) neurological outcome. Secondary endpoints were: (1) first responder response times, (2) proportion of patients admitted alive to hospital and (3) proportion of patients with VF/VT as initial rhythm.

2.8 Statistical analyses

Baseline characteristics of the sample are presented with frequencies (means, standard deviations, number, and percentages). Comparisons between intervention and historical groups were analyzed with *t*-tests for age and Chi squared test for categorical data. Median time intervals and survival between groups were compared with Mann-Whitney *U* test due to non-normal distribution. Multivariate logistic regression was used to control for confounding factors affecting ROSC between the intervention and the historical

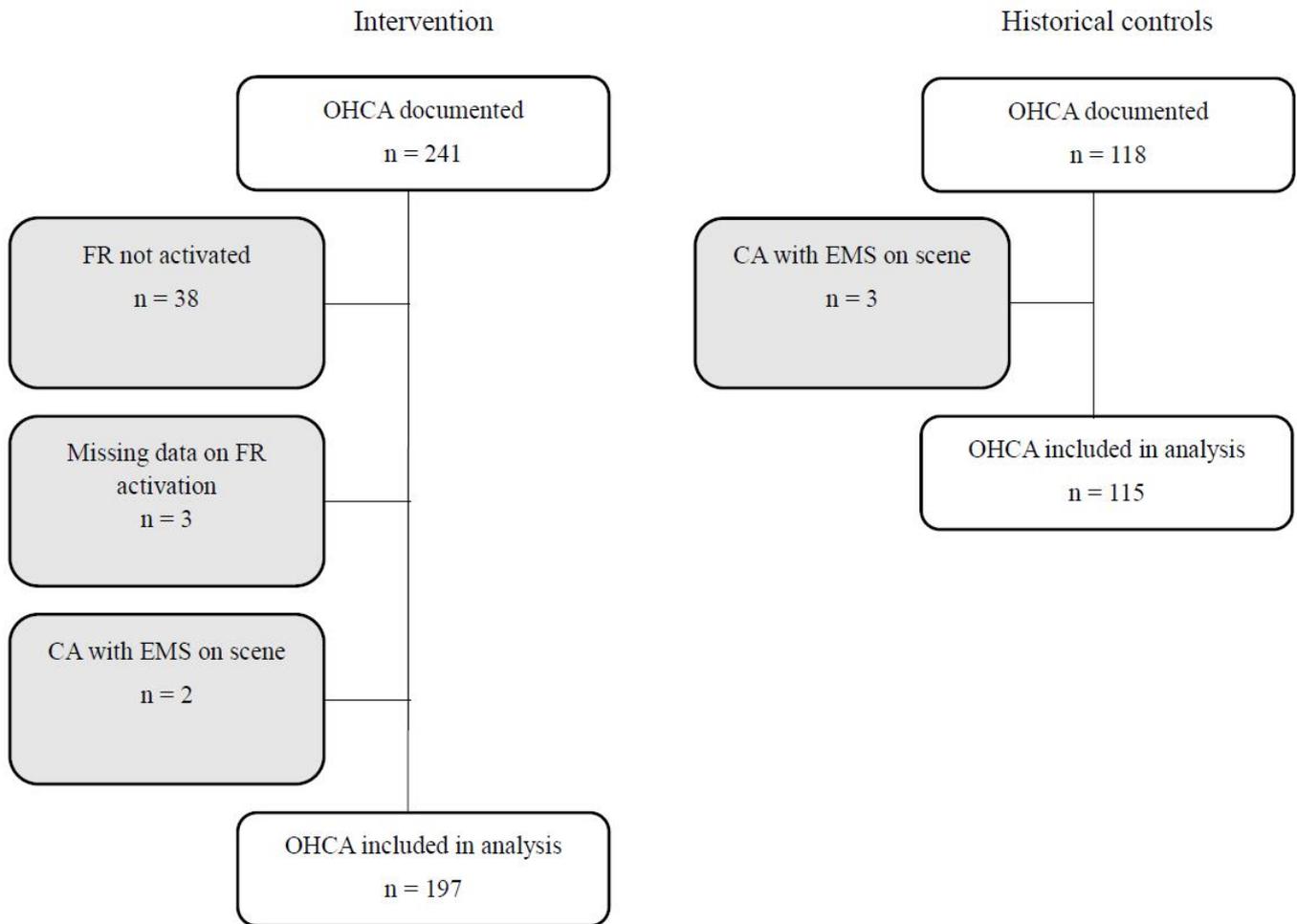


FIGURE 1. Flowchart of patient inclusion.

Note: OHCA, out-of-hospital cardiac arrest; CA, cardiac arrest; FR, first responders; EMS, emergency medical services.

group. Following variables suggested by previous studies [11, 12, 14] were added in a multivariable model: intervention (dual dispatch vs historical controls), age: (≤ 67 years (median) vs ≥ 68 years), gender (female vs male), witnessed status (witnessed vs non-witnessed), bystander CPR (yes vs no), first rhythm (shockable vs non-shockable), etiology (cardiac vs other). Correlation matrix was checked for collinearity which was considered significant if correlations were greater than 0.80 (which was not the case with any of the chosen variables). Associations are presented as odds ratios (ORs) with 95% confidence intervals (CIs). Results were regarded significant if a two-tailed test yielded a p -value equal to or less than 0.05. SPSS software (version 25, SPSS Inc., Chicago, IL, USA) was used for statistical analysis.

3. Results

A total of 358 interventions with resuscitation attempts were documented. Three interventions were excluded due to missing data on first responder dispatchment, 38 were excluded because first responders were not activated due to various reasons. Another 5 were excluded because cardiac arrest happened when the EMS was already on scene. The remaining 312 interventions were analyzed in this study (Fig. 1).

Mean age of patients was 66.7 ± 13.7 years and 230 (73.7%)

were male. Most OHCA cases occurred at home, 275 (88.4%), and most were witnessed, e.g., 233 (76.1%). In 277 (93.9%) documented cases the cause of the arrest was cardiac. Bystander CPR was performed in half of the cases (155). Initial rhythm was shockable in 111 cases (36.2%). Comparisons between historical and intervention groups are reported in Table 1.

There were significant differences in time from call to first shock among groups within intervention group ($p = 0.004$). Patients with ROSC and survivors with CPC 1/2 received the first shock significantly faster compared to all patients together ($p = 0.032$ for both comparisons). In historical group, the time interval to first shock was also significantly shorter in survivors with CPC 1/2 compared to all patients ($p = 0.038$).

The details of the response times (time intervals between call to Medical dispatch center and other time points) are reported and compared separately for all patients, patients with ROSC, and survivors with good neurological outcome (CPC 1 and 2) in both historical and intervention groups in Appendix Table 4.

Characteristics, survival, and neurological outcome of patients with ROSC are presented in Table 2.

In patients with shockable initial rhythm, the number of shocks before the arrival of EMS was significantly higher after first responder implementation (2.2 ± 0.8 in historical group and 2.2 ± 1.6 in intervention group; $p < 0.001$).

TABLE 1. Baseline characteristics of patients with OHCA.

	N documented (Historical/Intervention)	Historical	Intervention	<i>p</i>
Mean age in years (SD)	114/197	64.9 (13.7)	67.8 (13.6)	0.117
Male gender, n (%)	115/197	82 (71)	148 (75)	0.459
Location of collapse	115/196			0.005
At home, n (%)		94 (82)	181 (92)	
Other, n (%)		21 (18)	15 (8)	
Witnessed collapse, n (%)	115/191	95 (83)	138 (72)	0.040
Bystander CPR performed, n (%)	113/193	54 (48)	101 (52)	0.443
Initial rhythm shockable, n (%)	76/117	37 (49)	74 (63)	0.337
Cause, n (%)	107/188			0.074
Cardiac		104 (97)	173 (92)	
Trauma		2 (2)	3 (2)	
Overdose		/	1 (0.5)	
Electrocution		/	1 (0.5)	
Asphyxia		1 (1)	10 (5)	
N of patients shocked before arrival of EMS, n (%)	59/193	7 (12)	69 (36)	<0.001
Time from call to arrival of first help (min)	98/195	12	8	<0.001
Patients with ROSC		11	7.5	0.002
Survivors with CPC 1/2		10	7	0.011
Time from call to 1st shock (min)	24/77	16.5	11	0.013
Patients with ROSC		15	7.5	0.007
Survivors with CPC 1/2		3.5	5	0.032

Note: SD, standard deviation; CPR, cardiopulmonary resuscitation; ROSC, return of spontaneous circulation; EMS, Emergency medical services; CPC, Cerebral Performance Category. Percentages in parentheses refer to numbers of documented cases.

A multivariate logistic regression analysis on ROSC is presented in Table 3. The model adequately fitted the data according to Hosmer and Lemeshow test ($p = 0.551$). None of the variables correlated with each other significantly.

The logistic regression model of adjustment confirms the absence of improvement in the ROSC rate after the intervention. In the multivariable logistic regression analysis, the factors associated with improved ROSC were: bystander CPR (adjusted OR 2.0, confidence interval (CI) 1.1–3.6) and shockable first rhythm (adjusted OR 2.4, CI 1.3–4.5).

4. Discussion

This observational study showed that the introduction of dual dispatch of voluntary firefighters as local first responders was not associated with increased survival. In our study, reduced response times for patients with OHCA in rural areas as well as a substantial number of OHCA patients resuscitated by first responders were observed.

4.1 Survival

Percentage of OHCA patients with initial shockable rhythm did not differ significantly between compared groups in the present study and was similar in other studies [13, 14, 26]. Shorter first responder response times lead to reduced time interval from call to first shock, especially in the group of

patients with ROSC. Shorter time intervals to first shock in the two patients that survived without neurological sequelae in the historical controls were resuscitated by bystanders, who were incidentally a health worker and a local firefighter, who was not involved in an organized first responder system and hence stand out from the rest of the population in this study group. Furthermore, a higher number of shocks was delivered by first responders before arrival of EMS. These findings are supported by observations from several studies which also reported that shorter time interval from collapse to initial rhythm analysis more likely resulted in shockable initial rhythm thus increasing chances of ROSC [20, 22, 27]. Unfortunately, we did not observe a statistically significant increase in ROSC, admission to hospital and 30-day survival between compared groups although the hospital admission and 30-day survival rate were similar to other studies [12, 14, 18]. Increased survival to hospital admission and 30-day survival were described in metropolitan/suburban areas with dual dispatch system [11, 14, 19]. On the other hand, a twofold increase in favourable neurological outcome in patients with OHCA was found in our study but it did not reach statistical significance. Saner *et al.* [13] reported about 18 patients with favourable neurological outcome in OHCA patients resuscitated by first responders. These observations could be due to the fact that only patients with shockable rhythm were included in that study, longer time period of

TABLE 2. Survival of patients after ROSC.

	N of responses (Historical/Intervention)	Historical	Intervention	<i>p</i>
ROSC, n (%)	115/196	26 (23)	42 (21)	0.808
VF/VT, n (%)	37/74	13 (35)	21 (28)	1.000
Survival to HA, n (%)	115/196	25 (22)	34 (17)	0.341
30-day survival, n (%)	108/191	7 (6)	13 (7)	0.914
Survival CPC 1/2, n (%)	6/12	3 (50)	11 (92)	0.442

Note: ROSC, return of spontaneous circulation; VF/VT, ventricular fibrillation/pulseless ventricular tachycardia; HA, hospital admission; CPC, Cerebral Performance Category.

TABLE 3. Multivariate logistic regression analysis on factors associated with ROSC.

		No. of cases	ROSC (%)	Adjusted ^a OR	95% CI
Intervention	Dual dispatch	197	21.3	0.8	0.5–1.6
	Historical control	115	22.6		
Age	≥68 years	160	23.1	1.2	0.6–2.1
	≤67 years	151	20.4		
Gender	Female	82	24.4	1.4	0.7–2.8
	Male	230	20.9		
Witnessed status	Witnessed	233	24.0	2.5	1.0–6.0
	Non-witnessed	73	13.7		
Bystander CPR	Bystander CPR	155	27.7	2.0	1.1–3.6
	No-bystander CPR	151	15.9		
First rhythm	Shockable	111	30.6	2.4	1.3–4.5
	Non-shockable	201	16.9		
Etiology	Cardiac	277	33.3	0.3	0.1–0.9
	Other	18	17.6		

Note: OR, odds ratio; CI, confidence interval. ^aAdjusted for intervention, age, gender, witnessed status, bystander CPR, first rhythm, etiology.

the study and shorter response times of the firefighters which could contribute to better survival outcome. Despite shorter response times and the fact, that dual dispatch of firefighters provides more skilled people at the scene, we failed to observe increase in ROSC after first responder implementation. This finding is similar to conclusions from Nordberg *et al.* [12] who also have not found increased survival rates of the OHCA victims after implementation of the dual dispatch with first responders in the rural area of the greater Stockholm area with the population density of <250/km². Observations from our study could be due to several factors. One might be that there were more resuscitation attempts in unwitnessed OHCAs as well as in patients of advanced age, both having poorer prognosis [25, 28]. Delayed advanced life support performed by EMS crew in rural areas also contributes to unfavourable outcome. Nordberg *et al.* [12] also suggest there could be a breakpoint, after which further reduction in the time interval is of less importance. This observation is supported by survival models where each minute of delay to defibrillate shockable rhythm reduces the probability of survival by 10% [5, 17, 20].

4.2 Time intervals

Response times of local first responders are significantly shorter compared to EMS response times (8 min vs 12 min, respectively). Similar first responder response times were also reported by other studies [12, 15, 18, 25]. Voluntary firefighters trained as first responders mostly reside in close proximity to the local fire station in the centre of the rural village. After activation, first responders on the way to the OHCA victim usually make a quick stop at the fire station to collect the first aid equipment and an AED. On rare occasions, when a first responder lives closer to the location of the OHCA victim than to the fire station, he or she goes directly to the OHCA victim providing first aid and starts with BLS if necessary, waiting for other first responders to bring the first aid equipment. Such logistics results in shorter response times, which could be further reduced with more optimal dispatch activation. Voluntary firefighters in Slovenia are a part of protection, rescue and relief forces governed by the Administration of the Republic of Slovenia for Civil Protection and Disaster Relief. The request for first responder activation is transferred telephonically from Medical dispatch center *via* the Regional Emergency Notification Center, which then alerts first responders using a rescue mobile application.

Consequently, prolonged activation time for first responders was observed in our study compared to Saner *et al.* [13] (3 min vs 30 sec, respectively). Dispatch delay eliminates much of the benefit of the shorter travel time of the first responder [19].

On the other hand, EMS response times were significantly prolonged with the median delay of 8 min after first responder arrival. Similarly, an increase in EMS response times in rural areas during the first responder project was observed by Moore *et al.* [25]. This could be due to the fact that more resuscitations were attempted in the remote rural areas with prolonged EMS response times and thus included in the study. Voluntary firefighters as local first responders are trained to perform BLS and AED protocol until arrival of the EMS team, which then takes over the resuscitation effort. Due to different professional backgrounds and limited training as first responders, they are not capable of making crucial decisions. Therefore, they attempt resuscitation of every victim with OHCA regardless of the victim's underlying conditions or whether the collapse was witnessed. Thus, higher numbers of all as well as unwitnessed resuscitations in the intervention group were observed similar to Nordberg *et al.* [12]. In very few cases, first responders withheld resuscitation attempts due to obvious signs of death (rigor mortis) or in cases where the patient's DNAR order was well known. All these decisions were made after telephone consultation with the on-coming emergency physician. In the study period before the implementation of first responders, EMS arrival times in remote rural areas were prolonged and thus an emergency physician may have recognized resuscitation attempts as futile on arrival. The other reason for prolonged EMS response times could also be less extreme and safer ambulance driving, because when the EMS team is informed that the first responders are activated and on scene, they rely on them to provide BLS and use an AED.

4.3 Suggestions

Based on observations from our study the following adjustments to further reduce time from call to arrival of first help and thus improve the survival of OHCA victims are suggested: implementation of a systematic telephone assistance for witnesses to perform chest compressions; immediate activation of the firefighters first responders (not after the EMS); consider an alarm to citizens as lay first responders on a large scale (e.g., via a phone application).

4.4 Limitations of the study

Our study has several limitations. First, it is a retrospective study of prospective gathered data which could lead to some bias. When using registry data, results have limitations arising from missing or incorrectly reported variables. Second, the study design makes drawing true conclusions about causality difficult. Third, due to the narrow inclusion criteria the study population is small. Fourth, during the study period the changes in pre- and in-hospital treatment guidelines may have influenced the outcome. Fifth, we did not examine the cost effectiveness of the intervention.

5. Conclusions

Introduction of dual dispatch of voluntary firefighters as local first responders in addition to EMS in cases of OHCA significantly shortened response times. However, reduced response times were not associated with better survival outcomes. Nevertheless, based on the results of this study, that is reduced time intervals to first shock and trends towards better neurological outcome in OHCA patients, we encourage implementation of local first responders in rural areas to improve pre-hospital management.

AUTHOR CONTRIBUTIONS

MS has contributed in the conception and design of the work, acquisition, analysis and interpretation of the data and has substantively revised the drafted work. PJ has contributed substantially to the conception and design of the work, the acquisition and interpretation of the data. VBL contributed to the design of the work, analysis and interpretation of the data and has substantively revised the drafted work. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The regional ethics committee of University Medical Center Maribor approved the study and waived the requirement to obtain any informed consent (No. UKC-MB-KME-24/20, 02/010/03-003/01/20). Clinical Trial Registration—URL: <http://www.clinicaltrials.gov>. Unique identifier: NCT04485390.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY

The data used to support the findings of this study are available from the corresponding author upon request.

APPENDIX

See Fig. 2, Table 4.

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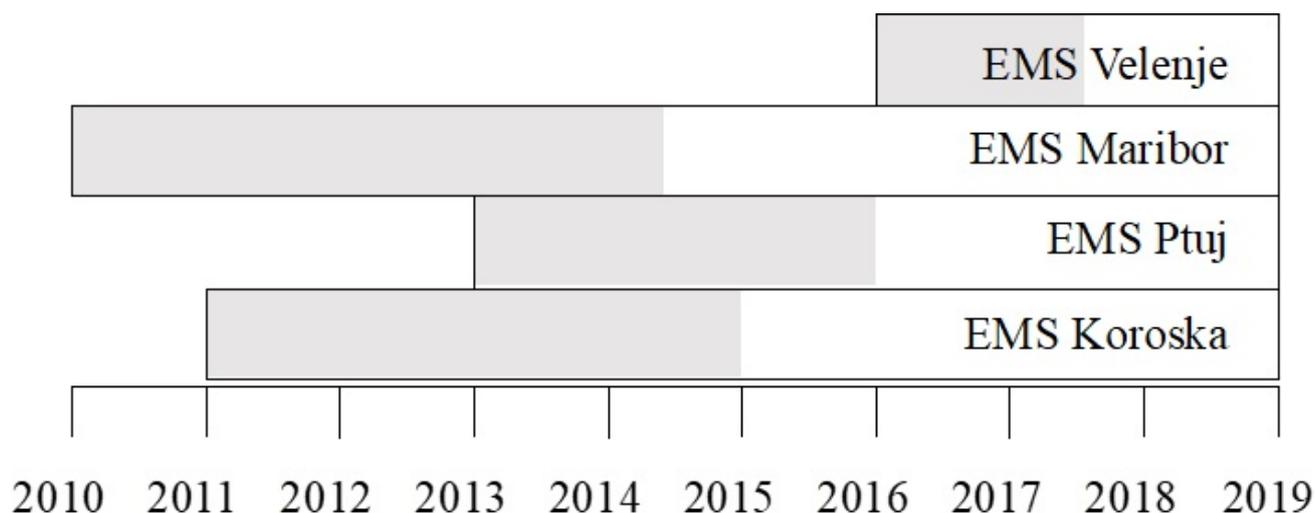


FIGURE 2. Time frames of OHCA cases' inclusion from different EMS.

Note: EMS, Emergency medical services. Time frames of OHCA cases' inclusion in the historical control group (grey) and intervention group (white) according to implementation of first responders in different catchment areas.

TABLE 4. Time intervals (median) before and after first responder implementation.

		N of responses (His- torical/Intervention)	Historical	Intervention	Historical and Intervention groups comparison, <i>p</i> value
Time from call to arrival of EMS (min)	All patients	111/196	13	17	<0.001
	Patients with ROSC		11	16	0.283
	Survivors with CPC 1/2		10	14	0.022
Time from arrival of FR to arrival of EMS (min)	All patients	195	/	8	/
	Patients with ROSC		/	8	/
	Survivors with CPC 1/2		/	8	/
Time from call to ROSC (min)	All patients	24/35	26.5	28	0.713
	Patients with ROSC		26.5	28	0.932
	Survivors with CPC 1/2		16	17	0.731
Time from call to activa- tion of FR (min)	All patients	195	/	3	/
	Patients with ROSC		/	2	
	Survivors with CPC 1/2		/	4	
Time from activation to arrival of FR (min)	All patients	194	/	5	/
	Patients with ROSC		/	4.5	
	Survivors with CPC 1/2		/	2	

Note: ROSC, return of spontaneous circulation; CPC, Cerebral Performance Category; FR, first responders.