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ORIGINAL RESEARCH

Out-of-Hospital Cardiac Arrest in the Eye of the Beholder and Emergency Medical Service

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Purpose: Out-of-hospital cardiac arrest (OHCA) remains a global healthcare problem, with low survival and bystander cardiopulmonary resuscitation (CPR) rates. This study aimed to identify event-related factors in OHCA and their impact on return of spontaneous circulation (ROSC) achievement and maintenance until hospital admission.

Patients and Methods: All data were collected from Utstein Resuscitation Registry Template for OHCA from The Institute of Emergency Medicine of Zagreb from January 2012 to August 2022. This cross-sectional research analyzed 2839 Utstein reports, including 2001 male, 836 female, and 8 subjects of unknown gender. The average age was 65.4 ± 16.2 years.

Results: The most frequent place of collapse was private residence, and 27% of collapses were unwitnessed. Dispatcher-provided CPR instructions were provided in 39.7% of cases until the arrival of the emergency service team, which showed a very strong effect on bystander-provided CPR, and were followed in 68.4% of cases, while non-instructed bystander CPR was provided in only 7.9% of cases. Bystander CPR is more likely to be provided in public places than in private residences, often with both compression and ventilation. Bystander CPR was also more likely to be provided to men. Cases with bystander CPR, and compressions with ventilation compared to compression only CPR, showed a significantly greater success in maintaining ROSC later in CPR, both with moderate effects.

Conclusion: Bystander CPR has been shown to have a significant role in achieving and maintaining ROSC until hospital admission. However, our results showed a location-dependent nature of bystanders' willingness to perform CPR as well as sex disparities in patients receiving CPR. With deficient education in basic life support in Croatia, dispatchers need to insist on and instruct bystander CPR performance.

Keywords: out-of-hospital cardiac arrest, cardiopulmonary resuscitation, emergency medical service

Introduction

Out-of-hospital cardiac arrest (OHCA) incidence in Europe is 37–55 per 100,000 per year,[1–3] with coronary artery disease as the leading cause of OHCA.[4] Unfortunately, OHCA with attempted emergency medical service (EMS) cardiopulmonary resuscitation (CPR) result in only 5–19% of patients with a favorable neurological outcome even in high-performing resuscitation centers, and it is estimated that only 1 in 10 patients who experience OHCA will survive.[1,5] The outcome and survival rate of OHCA is influenced by a multitude of factors, including the location of the arrest, the timelines of EMS, and notably, the bystanders' proficiency in performing CPR.[6] Despite improvements and changes regarding the resuscitation algorithm, the survival rates of the OHCA remain low. Frequent interruptions within the first three links of the Chain of Survival, presented by the American Heart Association- recognition and activation of the emergency response system, high quality (bystander) CPR, are the result of a lack of proper reaction by the layman.[7] The bystander CPR rate is still low, and education on basic life support is lacking in Croatia as well as worldwide.

The only mandatory basic life support course in Croatia is implemented as a prerequisite for obtaining a driver's license; however, not all individuals undergo driver's license education, resulting in a certain percentage of the

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population never receiving first aid training. Recognizing this, it is imperative to adopt alternative strategic approaches to ensure that people receive proper training on basic life support.

Since 2014, the foundation, "Croatian Heart House" in cooperation with the Student First Air Organization (StEEP) has been conducting public actions under the name, "Revive Me" that informs and educates the public about the importance of basic life support, as well as the Red Cross Organization which raises awareness of the importance of first aid skills and enables citizens to be educated on basic life support.

Remarkably, few studies on this subject have been conducted in Croatia, with none specifically addressing the situation in Zagreb from an EMS perspective.

Materials and Methods

This study included 2839 cases with out-of-hospital cardiac arrests, including 2001 males, 836 females, and 8 subjects of unknown sex. All OHCA data were collected from the Utstein Resuscitation Registry Template for OHCA at the Institute of Emergency Medicine of Zagreb between January 2012 and August 2022. This is a retrospective cohort with certain limitations. Due to the unavailability of hospital survival rates to the EMS, the outcomes will be defined as the pronunciation of death or hospital admission. The bystander reaction interval was defined as the period from the estimated time of collapse to the first call to the EMS. EMS response interval was defined as the period from the received emergency call to the arrival of the emergency medical team (EMT) by the patient's side.

Exclusion Criteria

Cases with asystole as the initial rhythm and bystander reaction time (period from the estimated time of collapse to the first call to the EMS) over 20 min without provided bystander CPR were excluded, with a total of 38 cases.

Statistical Analysis

The distribution of variables was analyzed using the Shapiro–Wilk test. Continuous variables are presented as means and standard deviations. Differences in quantities between groups were analyzed using the Mann–Whitney test for parametric variables and the Kruskal–Wallis test for nonparametric variables. The chi-square test was used to analyze differences in categorical variables between the groups. Binomial logistic regression was used to test the probability of the return of spontaneous circulation (ROSC) maintenance. Values of P less than 0.05 were considered to be statistically significant. The program used for statistical analysis was JAMOVI ver. 2.3.21.

This study was approved by the Ethics Committee of the Institute of Emergency Medicine of Zagreb on July 30th, 2022, and the study was conducted in accordance with the Helsinki Declaration. The data accessed complied with relevant data protection and privacy regulations.

Results

General

A total of 2839 UTSTEIN reports were analyzed, including 2001 male (70.3%), 836 female (29.4%), and 8 subjects of unknown sex (0.3%). The average age was 65.4 ± 16.2 years (CI 95% 64.8–66, men: 64.0 ± 15.6 years, CI 95% 63.3–64.7 years, women: 68.6 ± 17 years, CI 95% 67.4–69.7 years).

CPR

The most frequent place of collapse (Table 1) was a private residence (65.2%), and 27% of collapses were unwitnessed. In cases where cardiac arrest occurred before the initial call to the EMS (n = 2183), cardiac arrest (CA) was recognized by the dispatcher in 51% of cases. CPR instructions were given in 39.7% of cases via emergency calls until the EMT arrival. A total of 413 arrests (14.5%) occurred in front of an EMT, and it was noted that a healthcare worker performed CPR in 97 cases of bystander CPR. An automated external defibrillator (AED) was used in 1.8% (n = 50) of cases, and shock was delivered in 28% (n = 14). Bystander CPR was provided in 36% of cases (n = 874), with statistically more cases including only compressions without ventilation in 478 cases (63.4%, $P < 0.001$).

Table 1 Descriptive Statistics for Collapse Witnesses, Places of Collapse, Recognition of Cardiac Arrest and CPR Instructions via Emergency Call. All Values are Expressed as Counts with (Percentages)

		Total
Collapse witness	Layman	1563 (55.1%)
	Emergency team	413 (14.5%)
	No witness	766 (27.0%)
	Doctor/Nurse	97 (3.4%)
Place of collapse	Private residence	1850 (65.2%)
	Public place	668 (23.5%)
	Emergency vehicle	134 (4.7%)
	Care home	49 (1.7%)
	Primary healthcare	43 (1.5%)
	Health institution	83 (2.9%)
	Other	11 (0.4%)
Cardiac arrest recognition	Recognised	1114 (51.0%)
	Unrecognised	733 (33.6%)
	Unknown	336 (15.4%)
CPR instructions	Yes	866 (39.7%)
	No	745 (34.1%)
	Unknown	571 (26.2%)

Dispatcher-assisted CPR (DA-CPR) was provided in 36.6% of the cases of cardiac arrest that occurred before the initial call to EMS (Table 2). DA-CPR had a very strong effect on bystander-provided CPR, followed in 68.4% of the cases, whereas non-instructed bystander CPR was provided in only 7.9% of the cases (χ^2 (2, 2426) = 721, $P < 0.001$, φc = 0.545).

There was no significant difference in bystander-provided CPR (Table 2) if the collapse was witnessed or not, but CPR was more often performed in cases with witnessed CA (36.99% vs 33.94%, $P = 0.146$). In contrast, bystander CPR was more likely to be provided in public places (Table 2) than in private residences (47.93% vs 30.20%, χ^2 (1, 2426) = 7.30, $P < 0.001$, Cramer's V = 0.173, OR = 2.13, 95% CI 1.79–2.53). Bystander CPR including only compressions was more likely to be provided; however, CPR including compressions and ventilation was more likely to be provided in public places (Table 2) than in private residences (45.94% vs 30.85%, χ^2 (1, 753) = 17.30, $P < 0.001$, φc = 0.152, OR = 1.90, 95% CI 1.40–2.58)

The most frequent initial rhythm was asystole (n = 1315, 46.3%); however, in public places, the most common rhythm was ventricular fibrillation (VF) (39.2%, Table 2). The initial rhythm was shockable in 701 (24.7%) patients, VF in 670 (23.6%), and ventricular tachycardia (VT) without pulse in 31 patients (1.1%).

Women were significantly more likely to have an initial non-shockable rhythm than men (81.87% vs 71.95%, χ^2 (1) = 30.3, $P < 0.001$). A significant difference was also found between men and women in cases where layman bystanders provided CPR; men were more likely to be resuscitated by bystanders (37.74% vs 31.45%, χ^2 (1, 2425) = 8.35, $P = 0.004$, φc = 0.0587, OR = 1.32, 95% CI 1.09–1.60). There was no significant difference in compression or compression with ventilation between sexes (χ^2 (1, 753) = 1.01, $P = 0.316$, c = 0.0365). In some cases, healthcare workers provided bystander CPR (11.2%), and asystole was the initial rhythm in 41.8% of those cases, whereas in layman CPR, asystole made up 45.3% of the initial rhythms at the time of EMT arrival.

ROSC OR DEATH

Overall, return of spontaneous circulation (ROSC) was achieved in 30% of cases (n = 852), with spontaneous breathing in 17.9% (n = 509). At the hospital admission, ROSC was maintained in 25.6% of the cases (85.3% of achieved ROSC, Table 2).

Table 2 Bystander CPR, and Type of CPR – According to the Place of Collapse, Dispatcher Instructions for CPR (for Cases Where Cardiac Arrest Occurred Before the Initial Call to the Emergency Medical Service), ROSC Status and Outcome. All Values are Expressed as Counts

		BYSTANDER CPR			TYPE OF CPR		
		YES	NO	Total	C/V-CPR[a]	CO-CPR[b]	Total
Place of collapse	Private residence	492	1137	1629	145	325	470
	Public place	274	359	633	122	145	267
	Care home	9	27	36	3	6	9
	Primary healthcare	30	7	37	2	1	3
	Health institution	68	13	81	2	1	3
	Other	1	9	10	1	0	1
DA-CPR[c]	Yes	603	291	894	227	358	585
	No	51	678	729	10	35	45
ROSC achieved	Yes	303	375	678	115	150	265
	No	571	1177	1748	160	328	488
ROSC at the hospital admission	Yes	264	308	572	105	130	235
	No	610	1244	1854	170	348	518
Outcome (death or hospital admission)	Death at the place of collapse	550	1128	1678	148	318	466
	Death in the emergency vehicle	2	17	19	0	2	2
	Hospital admission	322	407	729	127	158	285

Notes: [a]C/V-CPR – compressions with ventilation CPR, [b]CO-CPR compression-only CPR, [c]DA-CPR – dispatcher assisted CPR. Chi-squared test: BYSTANDER CPR: place of collapse χ^2 (5, 2426) = 157.00, $P < 0.001$, φc = 0.246, DA-CPR (χ^2 (1, 1623) = 610.00, $P < 0.001$, OR = 27.50 (20.10–37.80), φc = 0.613), ROSC (χ^2 (1, 2426) = 30.60, $P < 0.001$, OR = 1.67 (1.39–2.00), φc = 0.112), ROSC at the hospital admission (χ^2 (1, 2426) = 33.30, $P < 0.001$, OR = 1.75 (1.44–2.12), φc = 0.117), outcome: χ^2 (2, 2426) = 34.00, $P < 0.001$, φc = 0.118. TYPE OF CPR: place of collapse χ^2 (5, 753) = 20.30, $P = 0.001$, cc = 0.162, DA-CPR (χ^2 (1, 630) = 4.90, $P = 0.027$, OR = 2.22 (1.08–4.57), φc = 0.09), ROSC (χ^2 (1, 753) = 8.34, $P = 0.004$, OR = 1.57 (1.16–2.14), φc = 0.105), ROSC at the hospital admission (χ^2 (1, 753) = 9.81, $P = 0.002$, OR = 1.64 (1.21–2.27), φc = 0.114), outcome: χ^2 (2, 753) = 13.70, $P = 0.001$, Cc = 0.133.

Patients who received bystander CPR showed significantly greater success in achieving ROSC later in CPR (yes: 34.7% vs no: 24.2%, χ^2 (1, 2426) = 30.6, $P < 0.001$, φc = 0.112) and maintaining ROSC (yes: 30.2%; no: 19.8%; χ^2 (1, 2426) = 33.3, $P < 0.001$, φc = 0.117, OR 1.75 (1.44–2.12)), both with moderate effects (Table 2). Bystander CPR, including both ventilation and compressions, showed significantly greater (Table 2) success in achieving (42.0% vs 31.4%, χ^2 (1, 754) = 8.69, $P = 0.003$, φc = 0.107, OR = 1.59, 95% CI 1.17–2.16) and maintaining (38.41% vs 27.20%, χ^2 (1, 754) = 10.2, $P = 0.001$, φc = 0.116, OR = 1.67, 95% CI 1.22–2.29) ROSC later in CPR than compression alone.

Binary logistic regression was conducted to determine whether maintained ROSC (Table 3, Figure 1A-D) could be predicted by the bystander reaction interval, EMS response interval, patient age, and whether bystanders provided CPR. The overall model was significant (χ^2 (4) = 186, $P < 0.001$), with between 9.9% and 10.4% variance ($R^2CS = 0.0998$, $R^2N = 0.104$) in the odds of failure to achieve and maintain ROSC, as explained by the predictor set. All covariates, besides the patient's age ($P = 0.184$),

Table 3 Binary Logistic Regression for Predicting ROSC Maintenance at the Hospital Admission with the Following Covariates

	Predictor	Odds Ratio	95% Confidence Interval		B	P
			Lower	Upper		
	EMS response interval (minutes)	1.093	0.06019	0.1172	0.08870	< 0.001
	Age (years)	1.005	−0.00243	0.0126	0.00511	0.184
	Bystander reaction interval (minutes)	1.223	0.15588	0.2465	0.20117	< 0.001
Bystander CPR	No – Yes	2.119	0.51175	0.9905	0.75113	< 0.001

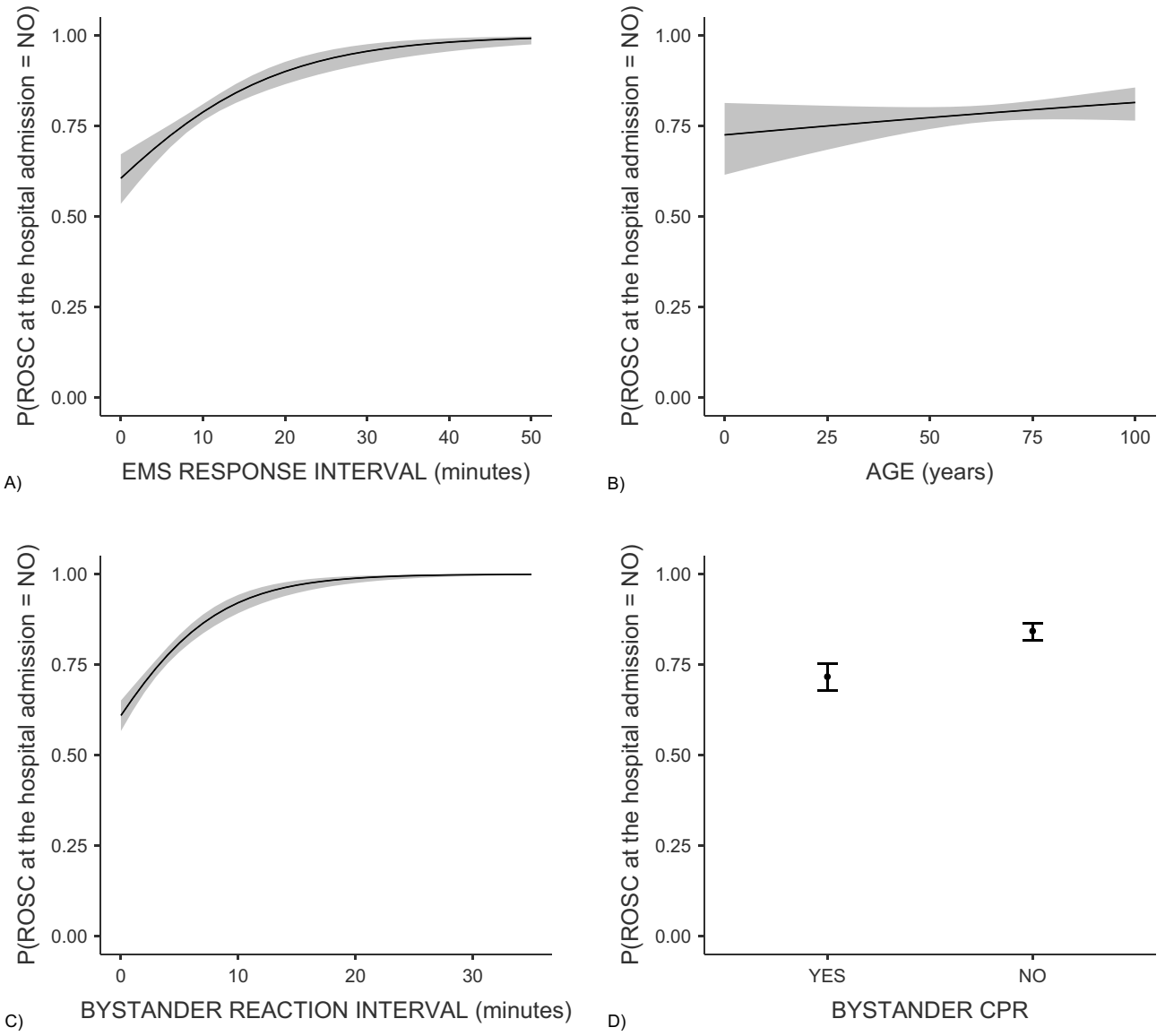

Figure 1 Binary logistic regression model for maintained ROSC at the hospital admission. (**A**) association of EMS response interval and maintained ROSC at the hospital admission (**B**) association of patients' age and maintained ROSC at the hospital admission (**C**) association of bystander reaction interval and maintained ROSC at the hospital admission (**D**) association of bystander CPR and maintained ROSC at the hospital admission.

were statistically significant in the model with $P < 0.001$ for each (bystander CPR: NO vs YES OR = 2.119, bystander reaction interval OR = 1.223, EMS response interval OR = 1.093). The means and medians of age, EMS response and bystander reaction intervals in patients with maintained ROSC at the hospital admission, and cases with out-of-hospital death (failed to maintain ROSC) are presented in Table 4.

Discussion

Although some predictors are seemingly evident, the implications for many others remain uncertain. The prognostic factors affecting survival following OHCA can be categorized into four main groups: patient, event, system, and therapeutic factors.[8]

Multiple studies have confirmed that one of the key factors influencing the success of resuscitation efforts is the presence of VF, which is time-dependent in nature, meaning that the chances of successful resuscitation decrease as time progresses since the onset of VF. However, this study focused on bystander CPR and its surroundings in OHCA.[1]

Table 4 Differences in EMS Response Intervals, Bystander Reaction Intervals, and Age in Cases Where ROSC Was and Was Not Maintained Until the Hospital Admission

	Maintained ROSC	Mean	Median	SD	p	Effect Size
EMS response interval (minutes)	YES	8.75	8.00	4.68	< 0.001	0.210
	NO	10.53	10.00	5.70		
Bystander reaction interval (minutes)	YES	2.60	2.00	2.52	< 0.001	0.320
	NO	4.75	3.00	4.54		
Age (years)	YES	63.40	65.00	15.50	0.062	0.06
	NO	64.50	67.00	16.50		

Note: Mann Whitney *U*-test.

BYSTANDER CPR

Bystander CPR improves resuscitation outcomes by delaying VF rhythm deterioration to asystole before EMS arrival.[9] In the city of Zagreb, bystander CRP is provided in 36% of cases, which falls below the average compared to the European average of 58% (range 13–83%).[10]

Some studies showed a significantly lower rate of bystander CPR in witnessed than in unwitnessed arrests (50% vs 74.7%). Our study showed no significant difference in witnessing CA and CPR, but bystanders performed CPR more frequently in witnessed cases (36.99% vs 33.94%).

Although Zhan et al demonstrated that compression-only CPR had a higher survival to hospital discharge than chest compression CPR with rescue breathing, our study showed the opposite when observing ROSC at hospital admission (27.20% vs 38.41%, $P < 0.001$), and a more recent study showed results with a higher chance of survival with compression and rescue breathing combinations.[11,12]

Although we did not identify a significant difference in compressions and compressions with ventilation between the sexes, our results regarding the higher probability of men being resuscitated compared to women (35.3% vs 28.0%, $P < 0.001$) are in concordance with previous studies.[13]

Initiation to start bystander CPR often depends on the dispatcher's assistance, and some reported that it was found crucial in cases where OHCA was witnessed by family members, as it was less likely that they would provide resuscitation to their loved ones. Some studies reported that the reason for that could be psychological barriers, or simply fear of harm.[14] A study from Ho et al listed some explanations for denied bystander CPR even with the dispatcher's assistance as – inability to move the patient (37.2%), unwillingness to perform CPR (15%), or abrupt disconnection of the call (11%).[15]

Gräsner et al reported DA-CPR in 30% of calls, which is lower than the percentage in our study (36.6%). DA-CPR was found to increase the probability of bystander CPR, and our results showed a very strong effect of dispatcher assistance on bystander CPR, followed in 68.4% of cases, while non-instructed bystander CPR was provided in only 7.9% of cases ($P < 0.001$).[16]

WITNESS

Witness numbers in our research are very similar to other studies; Hassager et al reported that in 54.3% of cases, the collapse was witnessed by bystanders (vs 55.1%) and in 11.9% by the EMS (vs 14.5%).[17]

The witnessed change of consciousness was found to be an independent factor and significantly lowered the chances of providing bystander CPR.[18] Another study showed the opposite – witnessed cardiac arrest resulted in more frequent bystander CPR.[19] However, Brinkrolf et al enhanced the possible false positive report of bystanders or relatives that were present at home as the place of CA in the matter of providing CPR.[20]

A possible reason for denying bystander CPR is the presence of agonal breaths and confusion regarding breathing. Agonal breathing is linked to witnessed arrests but still has a higher probability of ROSC, although some studies have found significantly less CPR in cases with agonal breaths.[20–22]

Location

Some studies have also concluded that a strong independent predictor of outcomes is the place of collapse, with adverse effects on private residences.[17,23]

Herlitz et al reported significantly worse outcomes for patients who suffered CA at home, and 11.3% of patients in whom the arrest took place at home were admitted to the hospital alive vs 19.4% in the elsewhere group ($P < 0.001$); the corresponding survival rates after one month were 1.7% vs 6.2% ($P < 0.001$).[23]

Our research showed that 65.2% of OHCA cases occurred in private residences, which is in concordance with other studies (65–69%), with significantly less provided bystander CPR (30.20% vs 47.93%, $P < 0.001$), but resulted in 21.84% of patients with ROSC at hospital admission (χ^2 (6, 2838) = 51.40, $P < 0.001$, CC = 0.133).[17,23]

AED USE

Although rapid defibrillation plays a significant role in the chain of survival, AED use is not expected to be accomplished by laymen, as usage rates are extremely low (<5% in France and 1.8% in our study).[24] Delay of defibrillation has shown a decrease in survival by 10–12% per minute.[25]

The utilization of AED in Europe remains relatively limited, with an average rate of 28% and a range between 3.8% and 59%.[26] Unfortunately, in Zagreb, the use of AED devices during bystander CRP remains low (only 1.8%), although a total of 198 AED devices can be found in the territory of the City of Zagreb and its suburban area.[27] The outstanding problem of AED use could be the location awareness of such devices. Only 5% of individuals from the United Kingdom study knew where they might find the AED, but another problem is that they were often inaccessible during closing hours, with up to 54% of OHCA cases reported in some studies.[28,29]

In some rural areas, the problem of AED inaccessibility has been solved with aerial devices (such as drones) or by informing the nearest volunteer who owns AED.[30,31]

From 2016 to 2019, the Emergency Medical Institute of Zagreb introduced motorcycle emergency technicians - T3 teams, specialized in high-priority cases, such as OHCA, using automated external defibrillator (AED) devices and facilitating early defibrillation during OHCA cases.[32]

Norway, a country that has a high percentage of bystander CRP owes it to the incorporation of DA-CPR in Emergency Medicine Core Competencies as early as 1995 and systematical implementation of BLS education in schools and adult life.[33] According to a study conducted by Li et al, it has been observed that school bystander CPR training has led to a significant improvement in participants' understanding of crucial aspects such as compression depth, compression rate, and the compression-to-artificial respiration ratio.[34] The likelihood of school children sharing newly acquired information with their parents and friends highlights the potential for training student bystander CPR to have a ripple effect, ultimately leading to a greater number of individuals acquiring basic life support skills in the long term.[34] The implementation of obligatory school bystander CPR training in Croatia has the potential to significantly enhance the bystander CPR rate in the country. The incorporation of telemedicine and telecardiology in the prehospital management of cardiac arrest could also represent a significant stride toward a more interconnected and responsive healthcare ecosystem with great potential for further improvements in bystander CPR rates and overall survival outcomes.[35]

Limitations

This was a single-center study. The UTSTEIN reporting style has changed over the past 10 years, and additional data were included in the report that were not available at the time of the study for the first few years of the observed period. The times of collapse were approximated by laymen, and it is up for discussion if cardiac arrest was recognized in time (agonal respirations mistaken for breathing), as well as if the bystander CPR was adequate.

Conclusion

In our study, the maintenance of ROSC was predictive of bystander reaction time, patient age, and bystander CPR performance.

The rate of bystander CPR in Zagreb is below the European numbers, with no available data on the reasons for bystanders' decision not to provide CPR. Dispatcher assistance has shown a significant role in increasing bystander CPR rates.

More event-related factors, such as the location and witnessed status with affiliation between the bystander and the patient, should be implemented in the OHCA survival analysis, as it was shown to influence bystander CPR.

We would like to enhance the need for a more detailed UTSTEIN reporting style, including the relationship between the bystander and the patient, and the presence of agonal breaths. In addition, the imperative lies in obligatory layman basic life support education outside the driver's license education in Croatia.

Abbreviations

OHCA, out-of-hospital cardiac arrest; EMS, emergency medical service; CPR, cardiopulmonary resuscitation; EMT, emergency medical team; AED, automated external defibrillator; DA-CPR, dispatcher-assisted CPR; VF, ventricular fibrillation; VT, ventricular tachycardia; ROSC, return of spontaneous circulation.

Disclosure

The authors report no conflicts of interest in this work.

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