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Rhythm conversion in out-of-hospital cardiac arrest and influence on the return of spontaneous circulation at the hospital arrival: a 10-year retrospective study in Croatia

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Abstract

Background While initial non-shockable (NS) rhythms are often associated with poor prognosis, the conversion to shockable rhythms during cardiopulmonary resuscitation (CPR) can significantly influence survival rates. This retrospective cohort study investigated the impact of rhythm conversion on the return of spontaneous circulation (ROSC) in out-of-hospital cardiac arrest (OHCA) patients.

Methods The study analyzed data recorded from January 2012 to August 2022 obtained from the Utstein Templates from The Institute of Emergency Medicine of the City of Zagreb. Statistical analysis, including logistic regression, was performed to assess the likelihood of achieving maintained ROSC.

Results Study included 2791 cases of OHCA with emergency medical service attempts at resuscitation. A total of 74.92% of patients had an initial NS rhythm with a total conversion rate of 18.27%. Factors significantly associated with rhythm conversion were younger age, male sex (74.13%), public place (32.35%) of and witnessed collapse (75.98%), higher adrenaline dose, use of a mechanical compression machine (41.68%), and shorter response interval. There was no significant difference in the occurrence of conversion between the cases with initial asystole and pulseless electrical activity (PEA). However, cases with converted asystole (33.48%) compared to the ones with converted PEA (20.65%) had significantly greater ROSC maintenance ($p = 0.006$), as well as when compared to cases with sustained PEA (20.93%, $p < 0.001$). Logistic regression revealed that women with rhythm conversion, lower adrenaline doses, and provided bystander CPR were significantly more likely to achieve ROSC at hospital admission ($P < 0.001$).

Conclusions This comprehensive study sheds light on the importance of rhythm conversion in patients with OHCA, with greater ROSC achievement, especially in patients with initial asystole, than in patients with initial PEA.

Keywords Out-of-hospital cardiac arrest, Return of spontaneous circulation, Rhythm conversion

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Background

With its high mortality rate, out-of-hospital cardiac arrest (OHCA) remains a critical public health concern [1]. Initial non-shockable (NS) rhythms are commonly associated with poor prognosis; however, the conversion from an initial NS to a shockable rhythm can have a noteworthy impact on both short- and long-term survival rates [2, 3]. According to different studies, the incidence of OHCA varies between 62-167.9/100,000 people/year [4, 5], with the incidence of emergency medical service (EMS)-treated OHCA being 17.26/100,000 people/year [5]. These data are in line with the annual incidence of OHCA in Europe, which is 67 to 170 per 100,000 people, and with resuscitation attempted in 50–60% of cases [1]. Compared to Europe, Croatia has a lower rate of the return of spontaneous circulation (ROSC) achievement (21.6%) [5]. In Europe, 33% of EMS-treated patients achieved ROSC, and 8% of the patients survived to hospital discharge [6]. For more than the last two decades, multiple publications have shown a significant decline in initial shockable (IS) rhythms and a concurrent increase in initial NS rhythms [4, 7, 8], with NS rhythms accounting for approximately 75% of all registered initial rhythms [9–13]. Despite the change in the initial rhythm trends, several studies reported an increase in overall survival for all three rhythm types (IS, converted shockable (CS), and initial NS rhythms) during cardiopulmonary resuscitation (CPR) [10]. The overall rhythm conversion rate varies depending on the specific study, but most of them showcased higher conversion rates when pulseless electrical activity (PEA) was the initial rhythm compared to asystole [14, 15].

In addition to PEA, one of the most mentioned factors influencing rhythm conversion is male sex, younger age, and witnessed cardiac arrest [3, 10]. On the other hand, Rajan et al. reported that pulmonary and psychiatric diseases had a negative impact on rhythm conversion and were associated with a sustained NS rhythm [10].

With only a handful of studies on OHCA in Croatia, this is the most extensive one concerning initial rhythms, the rhythm conversion rate, conversion factors, and its impact on ROSC.

This research aimed to investigate not only the potential effect of rhythm conversion on ROSC but also the effect of an initial NS rhythm type with later conversion on ROSC. Additionally, we portrayed the 10-year trends in recorded initial rhythms, specifically concentrating on the transformation of NS rhythms into shockable rhythms, as well as exploring the factors influencing the conversion.

Materials and methods

Research ethics

The study was performed according to the Helsinki Declaration and approved by the Research Ethics Committee (REC) of the Institute of Emergency Medicine on July 30th, 2022. The requirement for informed consent was waived by the REC because of the retrospective nature of the study.

Study design and patients

This retrospective cohort registry-based study included all OHCA cases with EMS attempted resuscitation data recorded according to the Utstein-style reporting guidelines of The Institute of Emergency Medicine of Zagreb from January 1st 2012, to August 31st 2022. This research included 2791 patients. The observed OHCA cases were analysed until the moment of submission of the patient to the hospital personnel or the death outcome in the field.

Utstein style report, data acquiry, and outcome

Croatia's out-of-hospital emergency medical teams consist of a physician, a medical technician, and a driver. The medical dispatch service can be reached through the national emergency services number (112) and the EMS number (194). Dispatchers use a modified version of the Norwegian Index for Emergency Medical Assistance, tailored to meet the needs of the Republic of Croatia's territory and population. All dispatchers receive medical training, which includes recognizing cardiac arrest and providing cardiopulmonary resuscitation (CPR) instructions over the phone. When cardiac arrest is suspected based on the questions about the patient's consciousness and breathing, the dispatcher provides CPR instructions, including alternating cycles of thirty chest compressions and two rescue breaths. The bystander is encouraged to count chest compressions out loud so the dispatcher can monitor their progress. The dispatcher remains on the line until the EMS team arrives and takes over the CPR. If possible, the dispatcher also tries to gather information from the bystander about events leading up to the arrest and any symptoms the patient experienced. The Utstein reports were completed by a physician following the resuscitation process and any potential transfer to the hospital. The time stamps for the first emergency call, dispatch of an ambulance, and arrival at the patient's side were digitally entered in the Utstein report. The time of the collapse was estimated by the bystanders. The time of rhythm conversion was taken from the electrocardiogram (ECG) strip enclosed in the Utstein report. Data from the institutional registry were entered into an Excel spreadsheet by eight researchers. UTSTEIN style reporting divides causes of cardiac arrest (CA) into two groups: medical (presumed cardiac or unknown, other medical

causes); traumatic cause; drug overdose; drowning; electrocution; or asphyxial (external) [16].

Two time intervals were used for analysis. *The bystander reaction interval* was defined as the period from the estimated time of collapse to the first emergency call made by the bystander. The *EMS response interval* was defined as the period from the received emergency call to the arrival of the EMS at the patient's side. For the bystander reaction interval, we included cases when CA was witnessed and occurred before the first emergency call. Witnesses of OHCA enabled the approximation of the CA timing. If CA occurred after the initial emergency call, the duration of this interval is not available as the Utstein report mentions only the time of the initial emergency call. For the EMS response interval, we also included cases where CA occurred before the initial emergency call, as the OHCA has the highest emergency priority and therefore the emergency medical team's turnout should be the fastest in these cases.

Because of the unavailability of hospital survival rates to the EMS, a primary outcome was defined as a maintained ROSC at hospital admission – survived event [16]. Maintained ROSC was defined as achieved ROSC in the field and maintained at the moment of the arrival to the hospital. The definition encompasses patients who suffer cardiac arrest again in pre-hospital setting after return of spontaneous circulation, but also regained spontaneous circulation before the hospital admission.

Eligibility and exclusion criteria

Exclusion criteria for this study were: inconsistencies in chronological order, Utstein reports without time stamps and noted first recorded cardiac rhythms, and cases with asystole as an initial rhythm with a bystander reaction time of more than 20 min (Fig. 1). Cases with death pronunciation without attempted EMS CPR were not included in the Institute's registry; therefore, the number of those is unknown.

Statistical analysis

The Shapiro–Wilk test was used to analyze the normality of the distribution. Continuous variables are presented as medians and interquartile ranges (IQR). Differences in quantities between the groups were analyzed by the Mann–Whitney test differences between two groups and the Kruskal–Wallis test for differences between three or more groups of nonparametric variables. The chi-squared test was used to compare categorical variables between the groups. Binomial logistic regression was used to test the probability of ROSC maintenance. JAMOVI program, vers. 2.3.21. (Jamovi project, Sydney, Australia) was used to conduct parametric and nonparametric statistical tests. Values of P less than 0.05 were considered to indicate statistical significance.

Results

A total of 2970 OHCA cases with attempted EMS resuscitation were reported in the observed period. A total of 93 cases were excluded due to inconsistencies in chronological order, missing time stamps, or missing ECG strips; 46 cases were excluded due to an unknown first recorded cardiac rhythm; and 40 were excluded as cases with asystole as an initial rhythm and a bystander reaction time of more than 20 min (Fig. 1). Cases with death pronunciation without attempted EMS CPR were not included in the Institute's registry; therefore, the number of those is unknown. The final study population comprised 2791 OHCA cases, including 1967 male patients (70.48%), 822 female (29.45%), and 2 of unknown sex (0.07%). The median age was 68.0 (IQR 57.0–77.0) years (men – 66.0 (IQR 56.0–75.0), women – 72.0 (IQR 61.0–81.0)). The first recorded rhythm was NS in 74.92% (asystole, 62.89%, PEA, 37.11%) and shockable in 25.08% (ventricular tachycardia without a pulse, 4.43%, ventricular fibrillation, 95.57%).

In 61.23% of the cases ($N=1709$), the initial NS rhythm was sustained until the end of CPR (ROSC or pronounced dead); in 21.32%, the sustained shockable (SS) rhythm was present ($N=595$); and in 17.45%, a NS rhythm converted to the shockable rhythm at one point of the CPR ($N=487$, including 105 initial shockable rhythms that converted to non-shockable, and again to shockable). A total of 227 (17.26%) patients with initial asystole and 155 (19.97%) patients with initial PEA received subsequent shocks, meaning that 18.27% of initial NS rhythms converted to shockable ones.

In total, 704 patients (25.2%) had prehospital ROSC maintained at the hospital admission.

OHCA patients' and event characteristics were investigated (Table 1) and trends in rhythm changes during CPR over the 10-year period were graphically presented (Fig. 2).

Patients with SS rhythm were younger, more often men, with higher rates of public CA, witnessed CA, bystander CPR, had CA recognized via the dispatcher, and their bystanders received CPR instructions more often (all $P<0.001$). The median bystander reaction and EMS response intervals were shorter in cases with SS rhythm ($P=0.005$, $P<0.001$). They were also more likely to achieve and maintain ROSC until hospital admission (50.01%). These patients were less likely to have a history of diabetes mellitus, malignancies, pulmonary disease, or neurological disease (Table 1).

Patients with a sustained NS rhythm were older and less likely to be men than patients in the other two groups; more often CA occurred in private residences (72.23%) without witnesses (31.89%), without bystander CPR (73.14%), and more often was not recognized via a dispatcher (64.54%). These patients had lower rates of

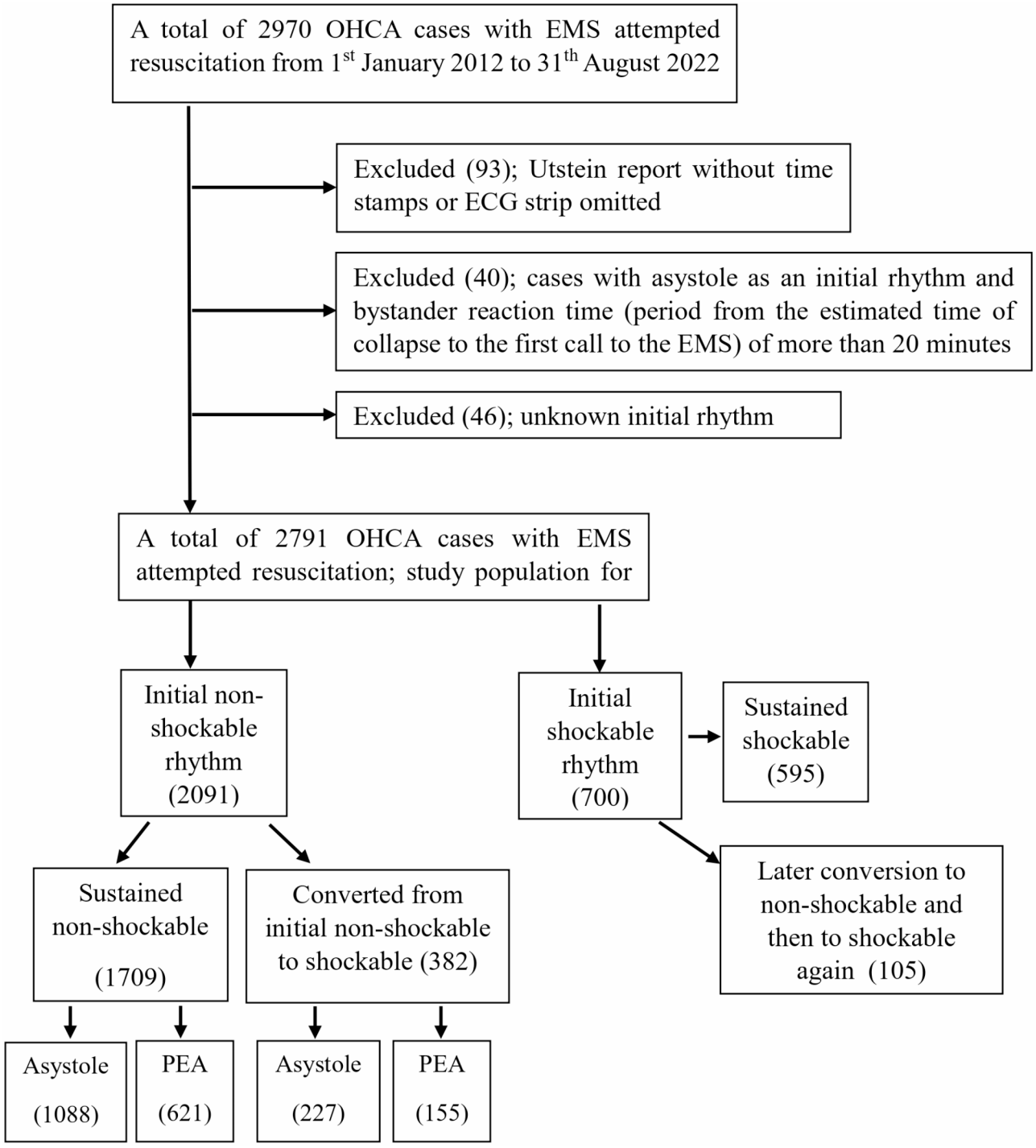

Fig. 1 Study population selection process with exclusion criteria. OHCA – out-of-hospital cardiac arrest, EMS – emergency medical service, PEA – pulseless electrical activity

maintained ROSC at hospital admission (15.04%), and made up the greatest proportion of patients in all comorbidity categories.

On the other hand, cases where rhythm conversion occurred showcased the rates between these two groups, with equal median bystander reaction and EMS response intervals, and with the exceptions of a higher median adrenaline dosage and the use of a mechanical compression machine.

Conversion.

Patient and prehospital factors associated with conversion from initial NS to shockable rhythm were shown in

Table 1 Characteristics of OHCA patients according to the rhythm changes during CPR

	Sustained non-shockable rhythm	Sustained shockable rhythm	Converted from non-shockable to shockable rhythm	*p*	χ^2
Cases	1709	595	487	-	-
Median age (IQR)	69.0 (58.0–78.0)	63.0 (55.0–73.0)	67.0 (57.0–77.0)	< 0.001	38.7
Men (%)	1134 (66.43)	472 (79.33)	361 (74.13)	< 0.001	39.0
CA characteristics, and ALS					
Medical cause (vs. non-medical)	1554 (90.93)	574 (96.47)	464 (95.28)	< 0.001	25.6
Public CA (%)	393 (27.77)	247 (49.30)	143 (32.35))	< 0.001	83.5
Witnessed (%)	1164 (68.11)	500 (84.03)	370 (75.98)	< 0.001	59.5
Bystander CPR (%)	459 (26.86)	257 (43.19)	143 (29.36)	< 0.001	65.5
CA recognized* (%)	606 (35.46)	296 (49.75)	190 (39.01)	< 0.001	32.1
DA-CPR* (%)	448 (26.21)	250 (52.02)	155 (31.83)	< 0.001	43.0
ET (%)	189 (11.06)	50 (8.40)	58 (11.91)	0.118	4.27
i-GEL (%)	1465 (85.72)	482 (81.01)	419 (83.04)	0.016	8.33
Adrenaline total dose, mg	5.0 (2.0)	5.0 (4.0)	6.0 (4.0)	< 0.001	59.8
Mechanical compression machine (%)	502 (29.37)	167 (28.07)	203 (41.68)	< 0.001	30.3
Comorbidities (%)					
CVD*	737 (43.12)	245 (41.18)	228 (46.82)	0.168	3.56
Diabetes mellitus	208 (12.17)	38 (6.39)	59 (12.11)	< 0.001	16.0
Malignancy	110 (6.44)	19 (3.19)	21 (4.31)	0.005	10.4
Renal disease	42 (2.46)	7 (1.18)	8 (1.64)	0.129	4.09
Pulmonary	124 (7.26)	19 (3.19)	18 (3.70)	< 0.001	18.1
Psychiatric disease	116 (6.79)	17 (2.86)	12 (2.46)	< 0.001	22.8
Neurological	114 (6.67)	16 (2.69)	25 (5.13)	0.001	13.5
Median time intervals, min (IQR)					
Bystander reaction interval ($n=1222$)	2.0 (1.0–4.0)	2.0 (1.0–3.0)	2.0 (1.0–4.0)	0.005	10.6
EMS Response interval ($n=2101$)	9.0 (7.0–13.0)	8.0 (6.0-10.3)	9.0 (7.0–12.0)	< 0.001	49.6
ROSC at hospital admission (%)	257 (15.04)	298 (50.01)	149 (30.60)	< 0.001	296.0

*ALS – advanced life support

* CA – cardiac arrest

*CPR – cardiopulmonary resuscitation

*EMS – emergency medical service

*ET – endotracheal intubation

*IQR – interquartile range

*ROSC - return of spontaneous circulation

*witnessed CA – included all bystander witnessed cases as well as, CA witnessed by EMS

*CA recognized – recognition of CA via dispatcher

*DA-CPR – dispatcher assisted CPR

*CVD – cardiovascular disease

*CA recognition, DA-CPR, and EMS response intervals ($n=2101$) were only observed for cases where CA occurred before the initial emergency call

*Bystander reaction interval was observed for layperson witnessed CA, and occurred before the initial emergency call ($n=1222$)

*Public CA was observed for cases that occurred before the EMS arrival

*I-gel - a second generation supraglottic airway device

Table 2. Factors significantly associated with conversion were younger age, age group 15–64 years (25.65%), male sex, public place of CA, witnessed CA, higher adrenaline dose, use of a mechanical compression machine, absence of pulmonary and psychiatric diseases, shorter EMS response interval, specifically EMS response interval under 8 min. The difference in the conversion rates between the initial PEA and asystole was not significant ($p=0.121$).

ROSC

Regarding initial NS rhythms, cases with initial rhythm as asystole and later conversion to shockable rhythm (Table 3) were more likely to achieve and maintain ROSC at the hospital admission ($p=0.006$) than cases with converted initial PEA. However, cases with sustained PEA were more likely to maintain the ROSC until hospital admission than cases with sustained asystole ($p<0,001$). Comparing sustained PEA and converted asystole, the cases with later were more likely to maintain ROSC at the

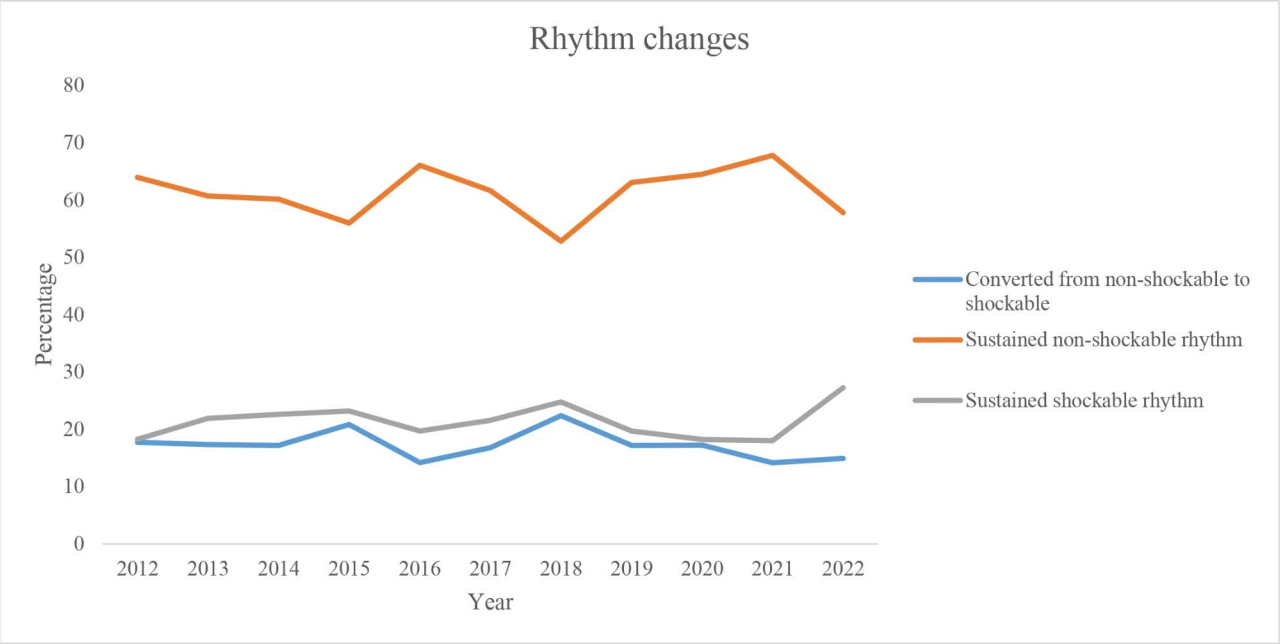

Fig. 2 Trends in rhythm changes emergency medical service-attempted resuscitation in out-of-hospital cardiac arrests over the observed 10-year period. There were no significant differences in rhythm change groups during this period, $p=0.091$

hospital admission ($p<0.001$). The incidence of conversion was significantly greater in cases with ROSC at hospital admission (30.41 vs. 15.92%, χ^2 (1)=52.0, $p<0.001$).

The time from the first recorded rhythm, when NS, to the first applied shock conversion time was not significantly different in cases with maintained ROSC ($P=0.100$).

Logistic regression was performed to assess the effects of age, sex, adrenaline dose, rhythm conversion from NS to shockable rhythm, and bystander CPR on the likelihood of achieving a maintained ROSC at hospital admission (Table 4; Figs. 3 and 4). The overall model was significant (χ^2 (5)=240, $P<0.001$), with between 12.9% and 21.7% of the variance ($R^2CS=0.129$, $R^2N=0.217$). Maintained ROSC was more likely to be accomplished in women, cases with rhythm conversion, lower adrenaline dose, and provided bystander CPR.

Discussion

In this single-center, 10-year retrospective study encompassing 2791 cases of OHCA with EMS attempted CPR, the primary question was whether rhythm conversion has made ROSC achievement more likely, with the answer unquestionably being affirmative. Furthermore, when rhythm conversion occurred, our findings underscored the significant influence of the initial NS rhythm type on ROSC achievement. Findings concerning trends of the initial rhythms during the 10-year period showcased the decline in initial NS rhythms at the end of the period compared to those at the beginning, but with no significant difference in the rhythm conversion rate. Finally, factors associated with a higher conversion rate were younger age, male sex, a public place of CA, witnessed CA, higher adrenaline dose, the use of a mechanical compression machine, the absence of pulmonary and psychiatric diseases, and a faster EMS response time.

This is the first study in Croatia to question the effect of rhythm conversion on ROSC and factors associated with rhythm conversion. Changes in the initial rhythm of cardiac arrest were also observed over a 10-year period.

The rhythm distribution in our research matches previously published data, with approximately 25% being IS rhythms and approximately 75% being initial NS rhythms [4, 9–13]. Contrary to many publications, over these 10 years, we observed a decrease in the number of initial NS rhythms, causing the ratio of an overall IS to initial NS rhythms to increase [4]. With a rhythm conversion rate of 18.27%, our results are between the reported ranges of 3.3% [17] and 26% [18].

Numerous studies have reported an array of conversion factors with significant overlap between them. In contrast to prior studies, our study did not find a difference in the occurrence of rhythm conversion between initial asystole and PEA, which differs from earlier studies that attested to higher rhythm conversion occurrence of PEA [17, 19, 20]. Also, cardiac etiology of CA [3, 10, 17, 19, 20], advanced airway management [14, 17], and bystander CPR [3, 14] were not significantly associated with rhythm conversion in our research.

Table 2 Patient, and pre-hospital factors associated to conversion from initial non-shockable to shockable rhythm

	CONVERSION				
	YES	**NO**	**p**	**Contingency coefficient**	**Effect size**
Cases	487	1709	-	-	-
Median age (IQR)	67.0 (57.0–77.0)	69.0 (58.0–78.0)	0.007	-	0.003
0–14 years	2	23	0.003	0.0748	
15–64 years	208	603			
65 + years	258	1028			
Men (%)	361 (74.13)	1134 (66.35)	0.001	0.0685	-
CA characteristics, and ALS					
Medical cause (%)	464 (95.28)	1554 (90.93)	0.002	0.0660	-
Public CA* (%)	143 (32.35)	393 (27.77)	0.031	0.0494	-
Witnessed* (%)	370 (75.98)	1164 (68.11)	< 0.001	0.0710	-
Bystander CPR (%)	143 (29.36)	459 (26.86)	0.776	0.0065	-
CA recognized* (%)	190 (39.01)	606 (35.46)	0.626	0.0129	-
DA-CPR* (%)	155 (31.83)	448 (26.21)	0.135	0.0423	-
ET (%)	58 (11.91)	189 (11.06)	0.600	0.0112	-
i-GEL (%)	419 (83.04)	1465 (85.72)	0.861	0.0037	-
Median adrenaline total dose, mg (IQR)	6.0 (4.0–8.0)	5.0 (4.0–6.0)	< 0.001	-	0.030
Mechanical compression machine (%)	203 (41.68)	502 (29.37)	< 0.001	0.1090	-
Comorbidities (%)					
CVD	228 (46.82)	737 (43.12)	0.148	0.0309	-
Diabetes mellitus	59 (12.11)	208 (12.17)	0.973	0.0007	-
Malignancy	21 (4.31)	110 (6.44)	0.081	0.0372	-
Renal disease	8 (1.64)	42 (2.46)	0.288	0.0227	-
Pulmonary	18 (3.70)	124 (7.26)	0.005	0.0600	-
Psychiatric disease	12 (2.46)	116 (6.79)	< 0.001	0.0764	-
Neurological	25 (5.13)	114 (6.67)	0.219	0.0262	-
Median time intervals, min (IQR)					
Bystander reaction interval	2.0 (1.0–4.0)	2.0 (1.0–4.0)	0.695	-	0.168
EMS Response interval	9.0 (5.0–12.0)	10.0 (7.0–13.0)	0.005	-	0.005
EMS response interval < 8 min	189 (38.81)	559 (32.71)	0.012	0.0534	-
ROSC at hospital admission (%)	149 (30.60)	257 (15.04)	< 0.001	0.164	

* CA – cardiac arrest

*CPR – cardiopulmonary resuscitation

*CVD – cardiovascular disease

*DA-CPR – dispatcher assisted cardiopulmonary resuscitation

*EMS – emergency medical service

*ET – endotracheal intubation

*IQR – interquartile range

*ROSC - return of spontaneous circulation

*witnessed CA – included all bystander witnessed cases as well as, CA witnessed by EMS

*CA recognized – recognition of CA via dispatcher

*CA recognition, DA-CPR, and EMS response intervals were only observed for cases where CA occurred before the initial emergency call

*Bystander reaction interval was observed for layperson-witnessed CA

*Public CA was observed for cases that occurred before the EMS arrival

On the other hand, in addition to mechanical compression machine, which was not mentioned in earlier studies, we reaffirmed that younger age, male sex, witnessed arrest coupled with the public place of the arrest, and shorter EMS response time impact rhythm conversion.

Contrary to earlier studies, of which Goto et al. [19] included all-cause CA similar to ours and the other two studies included exclusively CA of presumed cardiac etiology [10, 17], we did not observe a greater proportion of patients with cardiovascular comorbidities in the rhythm conversion group. Moreover, the presence of any comorbidity was notably associated with the sustained NS rhythm group.

Opinion divergence is present regarding ROSC achievement among converted and non-converted initial NS rhythms. With regard to continuous NS rhythms,

Table 3 Asystole and PEA changes in cases with maintained ROSC at the hospital admission

ROSC at the hospital admission	**Converted asystole and PEA**						
	A-C*	PEA-C*	Total	χ^2	*P*	OR (CI 95%)	CC
	76 (33.48%)	32 (20.65%)	108 (28.27%)	7.48	0.006	1.93 (1.20–3.12)	0.139
	Non-converted asystole and PEA						
	A-NC*	PEA-NC*	Total	χ^2	*P*	OR (CI 95%)	CC
	127 (11.67%)	130 (20.93%)	257 (15.04%)	26.50	< 0.001	2.00 (1.53–2.62)	0.124
	Converted asystole and non-converted PEA						
	A-C*	PEA-NC*	Total	χ^2	*P*	OR (CI 95%)	CC
	76 (33.48%)	130 (20.93%)	206 (24.29%)	14.20	< 0.001	0.526 (0.376–0.737)	0.128

Chi squared test, asystole-converted (AC), PEA converted (PEA-NC), asystole non-converted (A-NC), PEA non-converted (PEA-NC)

*CC - contingency coefficient

*OR – odds ratio

*PEA - pulseless electrical activity

*ROSC - return of spontaneous circulation

Table 4 Logistic regression analysis for the maintained ROSC at the hospital admission

Predictor	**β**	***P***	**Odds ratio [CI 95%]**
Intercept	0.07	0.831	1.076 [0.552–2.097]
AGE (years)	-0.01	0.100	0.993 [0.985–1.001]
SEX – female vs. male	0.63	< 0.001	1.877 [1.407–2.504]
ADRENALINE TOTAL DOSE (mg)	-0.40	< 0.001	0.669 [0.623–0.719]
CONVERSION yes vs. no	1.60	< 0.001	4.947 [3.652–6.701]
BYSTANDER CPR yes vs. no	0.45	0.002	1.562 [1.170–2.084]

Note. Estimates represent the log odds of "ROSC at the hospital admission = YES" vs. "ROSC at the hospital admission = NO". Reference level for sex; male, conversion; NO, bystander CPR; NO

*CPR - cardiopulmonary resuscitation

*CI – confidence interval

*ROSC - return of spontaneous circulation

PEA as the initial rhythm appears to have a greater effect on ROSC than does asystole in some studies [14]. Contrary to Eilevstjonn et al. and Goto et al., who reported that compared with converted asystole, converted PEA has a greater rate of ROSC attainment [21] and a greater 1-month survival rate [19]. Our results also revealed the opposite findings - that is, higher rates of ROSC maintenance with converted asystole. These results are in concordance with the outcomes of Luo et al. [2]. Even when comparing the achieved ROSC in the non-converted PEA group and the converted asystole group, we observed greater maintenance of ROSC in the latter group. These data contrast with those of Cournoyer et al., who did not observe significant differences between the two groups in ROSC maintenance [12].

Although male sex and a higher adrenaline dosage had a positive impact on rhythm conversion in this study, female sex and a lower adrenaline dosage, along with rhythm conversion and bystander CPR, were significant for achieving ROSC according to multivariate logistic regression analysis.

Limitations

Our study has several limitations. First, because of its retrospective observational design, the present analysis may be subject to bias, such as recall bias. An example of this would be a situation where the bystander is in a highly emotional and stressed state, which may result in an inaccurate perception of the time of collapse, thereby distorting the bystander reaction interval. Additionally, the bystander may overlook or dismiss the patient's symptoms and complaints which preceded the collapse. Therefore, our results need to be interpreted with caution. Second, the generalizability of our findings to other populations may be restricted due to only encompassing data from the Institute of Emergency Medicine of the City of Zagreb. Third, the moment of rhythm conversion was tracked as the moment when the first shock was delivered in cases with initial non-shockable rhythm, so the time of conversion was approximated. Fourth, patients' hospital records are not available for out-of-hospital Emergency medical service. Therefore the hospital-survival rates are unknown to us. Furthermore, we could not include the exact time of hospital arrival, as the Utstein report was completed by the physician only after the patient was handed over at the hospital, which could sometimes lead to significant delays and distort the recorded time intervals for hospital arrival by a significant margin. Fifth, as already mentioned, this was a retrospective observational study, and the fact that the Utstein reports were written

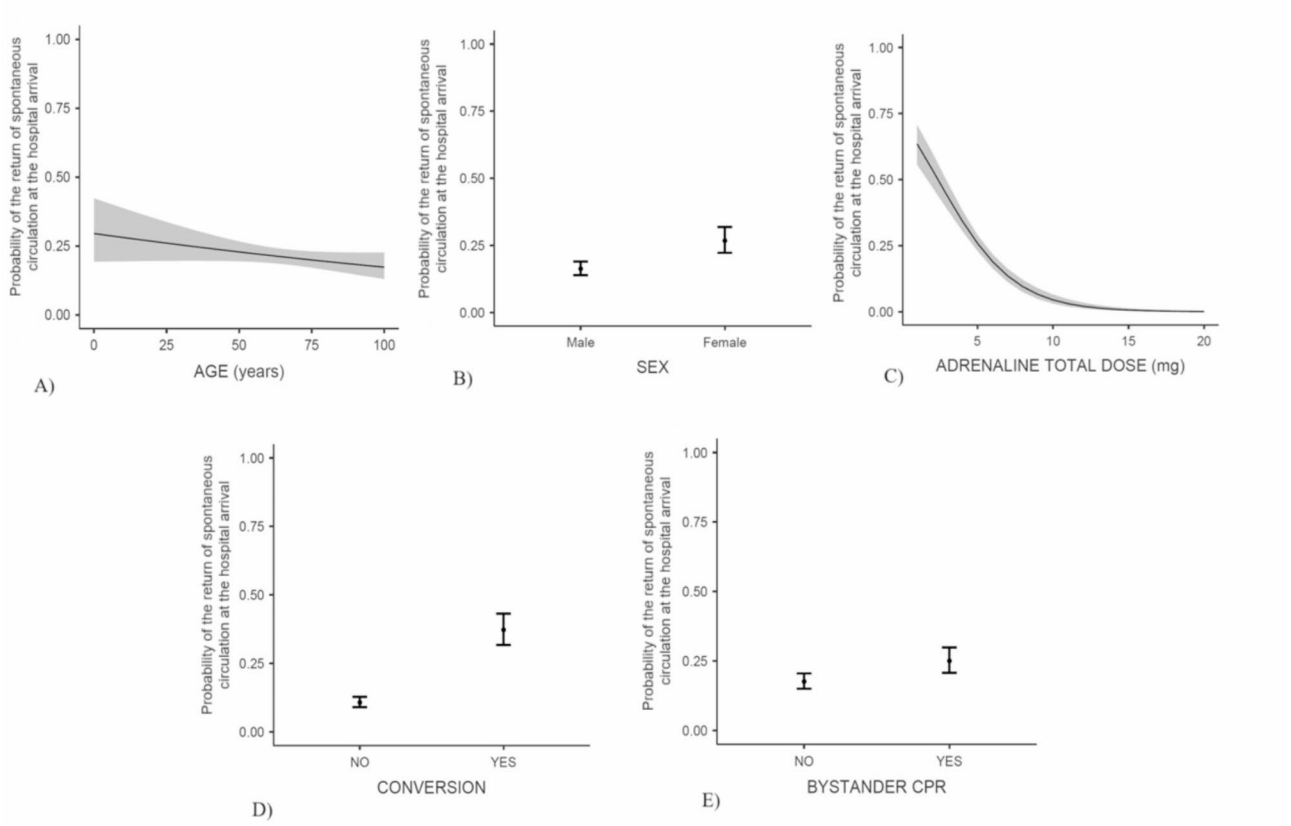

Fig. 3 Logistic regression analysis illustrating the predicted probability of ROSC at hospital admission according to the: (A) patients' age (B) sex (C) total adrenaline dose (D) rhythm conversion (E) provided bystander CPR. In Figures A) and C), black line represents the predicted probability and the shaded gray area indicates the 95% confidence interval. ROSC – return of the spontaneous circulation, CPR – cardiopulmonary resuscitation

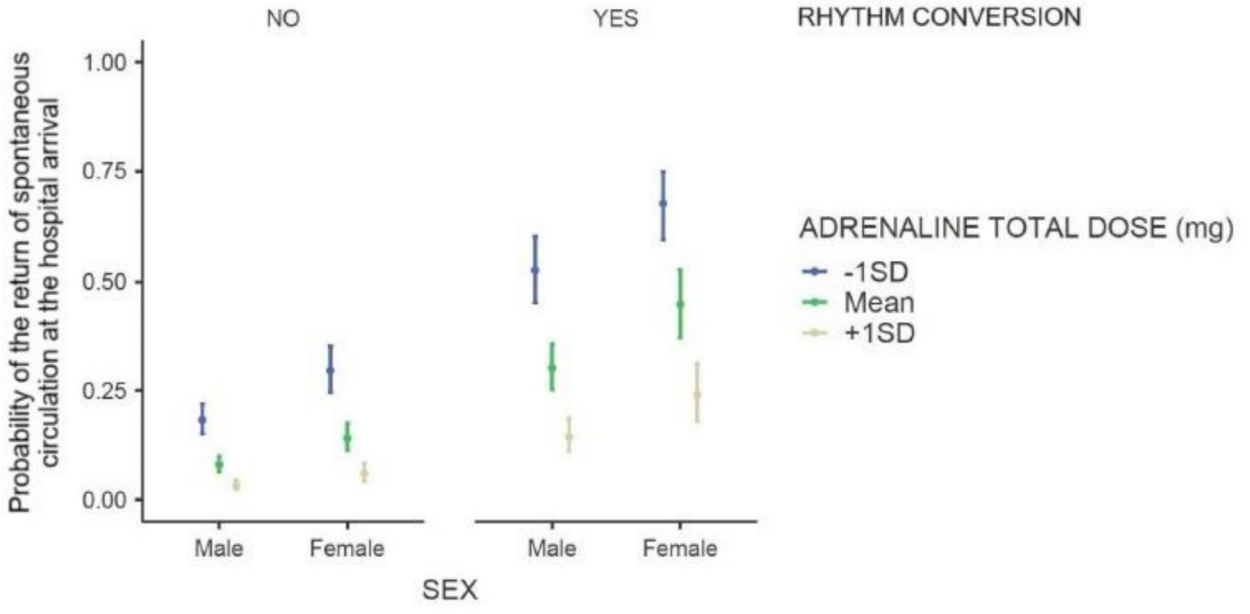

Fig. 4 Logistic regression analysis illustrating the predicted probability of ROSC at the hospital admission according to the rhythm conversion. Model included bystander CPR, sex, rhythm conversion, and total adrenaline dosage. ROSC – return of the spontaneous circulation, CPR – cardiopulmonary resuscitation, SD – standard deviation

in the field often means that the patient's personal history was unavailable. Last, in this Institute of Emergency Medicine, Utstein reports were fulfilled only when CPR was attempted by the EMS and not for OHCA patients whose deaths were pronounced without attempted CPR, unlike in other Croatian cities.

Conclusion

This study reinforced the claim that the rhythm conversion from initial NS to shockable rhythm positively impacts the short-term survival rate, especially from initial asystole. Although this research has its limitations, particularly because hospital data were not available to us, this is the first Croatian study analyzing the decade of OHCA, enhancing the importance of rhythm changes during the CPR and their role in the survival of the event – ROSC at hospital admission. Understanding the dynamics of rhythm conversion and its impact on ROSC is essential for refining resuscitation strategies and improving survival rates in OHCA cases.

Abbreviations

OHCA	Out-of-hospital cardiac arrest
ROSC	Return of spontaneous circulation
PEA	Pulseless electrical activity
CPR	Cardiopulmonary resuscitation
EMS	Emergency medical service
DA-CPR	Dispatcher assisted CPR
CVD	Cardiovascular disease
NS	Non-shockable
IS	Initial shockable
CS	Converted shockable
SS	Sustained shockable

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Author contributions

Conceptualization: J.L, L.T. Data curation: J.L., P.S., I.R., L.M.M., J.M., Đ.Č., L.T., D.M., F.R., Ž.R. Formal analysis: L.T. Methodology: L.T., J.L. Project administration: J.L. Visualization: J.L., L.T. Writing – original draft: J.L. Writing – review & editing: J.L., P.S., I.R., L.M.M., J.M., Đ.Č., L.T., D.M., F.R., Ž.R.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

The study was performed according to the Helsinki Declaration and approved by the Research Ethics Committee (REC) of the Institute of Emergency Medicine on July 30th, 2022. The requirement for informed consent was waived by the REC because of the retrospective nature of the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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