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An analysis of the relationship between the applied medical rescue actions and the return of spontaneous circulation in adults with out-of-hospital sudden cardiac arrest

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Abstract

Sudden cardiac arrest (SCA) is a significant medical and social issue, the main cause of death in Europe and the United States.

The aim of the research was to evaluate the effectiveness of emergency medical procedures applied by emergency medical teams in prehospital care in the context of return of spontaneous circulation (ROSC).

The case–control study was based on the medical documentation of the Rescue Service in Katowice (responsible for monitoring 2.7 million inhabitants of the region) referring to 2016. The research involved exclusively adults (ie, individuals older than 18 years) with out-of-hospital cardiac arrest (OHCA). After considering the above inclusion criteria, there were 1603 dispatch order forms (0.64% of all dispatch orders) involved in further research.

On the basis of the emergency medical procedure forms, the actions of emergency medical teams were verified as medical procedures (endotracheal intubation, the use of suction pumps, defibrillation, the use of alternatives providing airway patency and ROSC was determined.

The analysis covered 1603 cases of OHCA. SCA turned out more frequent in men than in women ($P = .000$). Most often, SCA occurred in domestic conditions during the day and was witnessed by a third person. In 59.9% of the cases, actions were taken by witnesses, which increased the probability of ROSC. Patients were usually intubated (51.4%). Respirators were used less frequently (20.2%). Ventricular fibrillation (VF) was reported only in 22.0% of the cases. The ROSC rate was higher in the group of patients with diagnosed VF than in those with nonshockable rhythms (VF, 55.43% vs asystole, 24.05%; $P = .000$).

Successful resuscitation depends on the quality of emergency medical procedures performed at the place of incident. The highest probability of ROSC is related with defibrillation (in the cases of VF or ventricular tachycardia with no pulse), intubation, the application of a respirator, and performing mechanical ventilation, as well as with a shorter time from dispatch to arrival.

Abbreviations: AED = automated external defibrillator, CPR = cardiopulmonary resuscitation, ECG = electrocardiogram, EMS = emergency medical services, ICU = intensive care unit, OHCA = out-of-hospital cardiac arrest, OR = odds ratio, ROSC = return of spontaneous circulation, SCA = sudden cardiac arrest, SCD = sudden cardiac death, VF = ventricular fibrillation, VRS = Voivodship Rescue Service.

Keywords: cardiopulmonary resuscitation, emergency medicine, return of spontaneous circulation, sudden cardiac arrest

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1. Introduction

Sudden cardiac arrest (SCA) is a significant medical and social issue, and the most important cause of death.[1] It is the main cause of death in Europe and the United States. Depending on the definition, SCA is diagnosed in 38/100,000 inhabitants of Europe per annum[2–4] and in 76/100,000 US citizens per year.[5] Globally, there are numerous registers of out-of-hospital cardiac arrest (OHCA).[6,7]

The definition of SCA is closely related with the notion of sudden cardiac death (SCD). SCD is universally defined as a natural death from a cardiovascular cause within 1 hour from the occurrence of symptoms (the 1-hour period is arbitrary).[8] However, in spite of the fact that the SCA survival rate is increasing, the overall SCA mortality still remains incredibly high: only 10.6% of patients with prehospital SCA survive to leave hospital.[9] In such a numerous population as that of the United States, shockable rhythms are reported in only 23% of patients, and the survival rate amounts to 22% versus 8% for the nonshockable rhythms.[10,11] If the rhythm is verified, for example, by means of an automated external defibrillator

(AED), immediately after loss of consciousness, the survival rate will reach 59% or even 79%.[12,13] A high number of patients with SCA may survive if the witnesses of the incident react immediately, that is, when ventricular fibrillation (VF) is still present.[14,15]

The aim of the research was to evaluate the effectiveness of emergency medical procedures applied by emergency medical teams in prehospital care in the context of return of spontaneous circulation (ROSC) in the population monitored by the Voivodship Rescue Service (VRS) in Katowice (2.7 million inhabitants).

2. Material and methods

2.1. Study design and participants

The case–control study was based on the medical documentation of the VRS in Katowice referring to 2016 (n = 249,872 patients). The VRS in Katowice dispatches emergency medical services (EMS) units, operates 88 emergency medical teams, and monitors 2.7 million inhabitants. The research involved exclusively adults (ie, individuals older than 18 years) with OHCA. After considering the above inclusion criteria, there were 1603 dispatch order forms (0.64% of all dispatch orders) involved in further research. The study protocol was approved by the Institutional Review Board of the Polish Society of Disaster Medicine (approval number: 23.08.2017.IRB).

2.2. Data collection and processing

Data referring to patient's gender and age, as well as to the location or time of the day of the incidents with OHCA were analyzed. Calls between emergency medical dispatchers and witnesses of the incidents were investigated as far as first aid instructions and main reporting reason were concerned. Emergency medical teams were divided into 2 groups, that is, teams with physicians and teams without physicians. In Poland, the only indicator of the system quality is the median of time from team dispatch to team arrival at destination. The median was calculated for both emergency priority codes: C-1 (dispatch with a light signal within 60 seconds from giving notification to the team) and C-2 (dispatch within 120 seconds from giving notification to the team). On the basis of the emergency medical procedure forms, the actions of emergency medical teams were verified to determine emergency medical procedures (endotracheal intubation, the use of suction pumps, defibrillation, and the use of alternatives providing airway patency) and ROSC.

2.3. Follow-up and outcome definition

The case–control study did not cover actions performed after transfers of patients to intensive care units (ICUs). No hospital medical procedures were analyzed.

2.4. Statistical analysis

Descriptive statistics involved the calculation of proportions (sample size and sampling rate for nonmetric variables) and median, as well as interquartile range in the case of quantitative variables. Depending on the measurement scale, Pearson Chi-squared test or Mann–Whitney *U* test were used to compare the group of ROSC patients with the group of no-ROSC patients. The model of logistic regression was applied to estimate the probability of ROSC. The dependent variable was the presence of ROSC (value: 1) or the absence of ROSC (value: 0). The quasi-Newton method with determination of asymptotic standard errors was applied to estimate the parameters of the regression function. The particular predictors and 2-factorial interactions were added to the model by means of the forward selection method. The model with the variables that met the criteria of minimal borderline significance ($P < .1$) was considered to be the best adjusted model. Odds ratio (OR) and the 95% confidence interval were defined for each predictor added to the model to estimate the probability of ROSC incidence. The STATISTICA 13.1 (StatSoft Inc, Tulsa, OK) and the IBM SPSS 24.0 software were used to analyze the data. The default statistical significance adopted for the purpose of all analyses was 0.05.

Table 1

A comparative analysis of selected variables according to gender.

Variable	Male individuals	Female individuals	P^*
Age ≥ 65 y	486 (48.3%)	392 (69.2%)	.000
Priority code 1 (urgent)	1021 (90.0%)	576 (84.9%)	.002
Ventilation frequency – ventilation bag	621 (61.8%)	315 (55.7%)	.017
Defibrillation	256 (25.4%)	88 (15.5%)	.000
Location (at home)	692 (68.8%)	422 (74.5%)	.025
Consequence (death)	678 (67.4%)	383 (67.7%)	NS

* Pearson Chi-squared test.
NS = not significant.

3. Results

All OHCA cases involved 1005 males (62.7%) and only 566 females (35.3%). There were 32 patients (2.0%) with no gender reported in medical documentation. Moreover, the analyzed cases of OHCA included 956 (59.6%) patients aged over 65 years (the age median amounted to 65.7 years). Female patients were older than male ones (mean age, 69.3 vs 62.7; $P = .000$), which was true also for the group of patients aged over 65 years. However, defibrillation was more often performed in men than in women ($P = .000$) (Table 1). Additionally, defibrillation was more frequently performed in patients aged under 65 years than in older ones ($P = .011$) (Table 2).

Most OHCA cases occurred in domestic conditions (n = 1136; 71.1%), in public places (n = 234; 14.5%), and at school (n = 1; 0.1%). Patients who suffered from OHCA at home were older than those with SCA that occurred outside their homes (mean age, 65.6 vs 63.6; $P = .027$). OHCA in male patients occurred more frequently outside their homes than at home ($P = .015$) (Table 3).

The OHCA was mostly observed during the day (between 07.01 am and 07.00 pm) (n = 1013; 63.2%), less frequently in the evening, and at night (between 07.01 pm and 07.00 am) (n = 590; 36.8%).

Table 2

A comparative analysis of selected variables according to age.

Variable	Age ≥ 65 y	Age < 65 y	P^*
Defibrillation	187 (19.5%)	162 (25.0%)	.011
Location (at home)	691 (72.0%)	445 (68.8%)	NS
Priority code 1 (urgent)	828 (86.6%)	586 (90.6%)	.017
Total time from dispatch to arrival up to 8 min	373 (39.0%)	231 (35.7%)	NS
Intubation	477 (49.9%)	347 (53.6%)	NS

* Pearson Chi-squared test.
NS = not significant.

Table 3

A comparative analysis of selected variables according to incident location.

Variable	At home	Not at home	P*
Suction	234 (20.6%)	120 (25.6%)	.027
Consequence (death)	744 (65.49%)	323 (69.1%)	NS
Priority code 1 (urgent)	1001 (88.1%)	413 (88.4%)	NS
Total time from dispatch to arrival up to 6 min	462 (40.7%)	189 (40.5%)	NS

* Pearson Chi-squared test.
NS = not significant.

There was a witness of OHCA in 1065 cases (66.4%). Further 175 cases (10.9%) occurred in the presence of emergency medical teams. In the other patients (n=363; 22.7%), OHCA took place without any witness.

According to the emergency medical documentation and the recordings of conversations with emergency medical dispatchers, there were some actions performed by a third person who witnessed the incident in 785 cases (49.0%). In 175 cases (10.9%), the witnesses were emergency medical team members. Consequently, actions were taken in 960 cases in total (59.9%). However, 643 OHCA patients did not receive any assistance.

It is worth noticing that out of the 1240 cases (77.35%) in which the incident occurred in the presence of a witness, actions were performed in 960 cases (77.41%). Most frequently, chest compressions were applied (indirect chest compressions, 865 cases; 90.1%). Defibrillation attempts were made in 104 patients (including 96 patients assisted by emergency medical teams), that is, in 10.83% of the cases. Artificial respiration was performed in 198 individuals (20.62%). A higher ROSC rate was observed in cases of any resuscitation actions performed at the place of the incident (35.1% vs 30.94% of patients with no resuscitation action performed, with a trend toward statistical significance $P=.08$).

In 980 cases of OHCA (61.1%), a specialist team was dispatched (ie, a team with minimum 3 members qualified to perform emergency medical procedures, including a physician, and a nurse, or a paramedic). In other cases (n=623; 38.9%), a basic team was dispatched (ie, a team with at least 2 members qualified to perform emergency medical procedures, including a nurse or a paramedic).

The particular emergency medical actions performed by the teams at place of incident are summarized as follows. The most frequent elements of providing patients with airway patency were endotracheal intubation (n=824; 51.4%) and laryngeal mask (n=235; 14.7%). An alarming tendency is that a respirator was used rarely (n=324; 20.2%), and the patients' breathing was provided by means of a ventilation bag (n=949; 59.2%). The first diagnosed rhythm was asystole (n=910; 56.8%). VF was reported in 354 cases (22.1%) (Fig. 1). It was observed that defibrillation was more frequently performed in younger patients, that is, in individuals aged below 65 years ($P=.011$).

In Poland, the only indicator of the emergency medical system quality is the median of time from team dispatch to team arrival at destination. Depending on the priority code of the incident, the average median of the highest priority code C-1 was 6 minutes 29 seconds from dispatch to arrival at destination. It is worth emphasizing that the time from dispatch to arrival in the case of the C-2 code (lower priority code) is much longer (9 minutes 32 seconds). The performance of advanced emergency medical procedures increases the survival rate in the C-1 code. It is in this priority code that a higher frequency of defibrillation was observed (332 vs 22; $P=.000$).

In 1603 cases of diagnosed OHCA with cardiopulmonary resuscitation (CPR), ROSC was reported in 536 patients

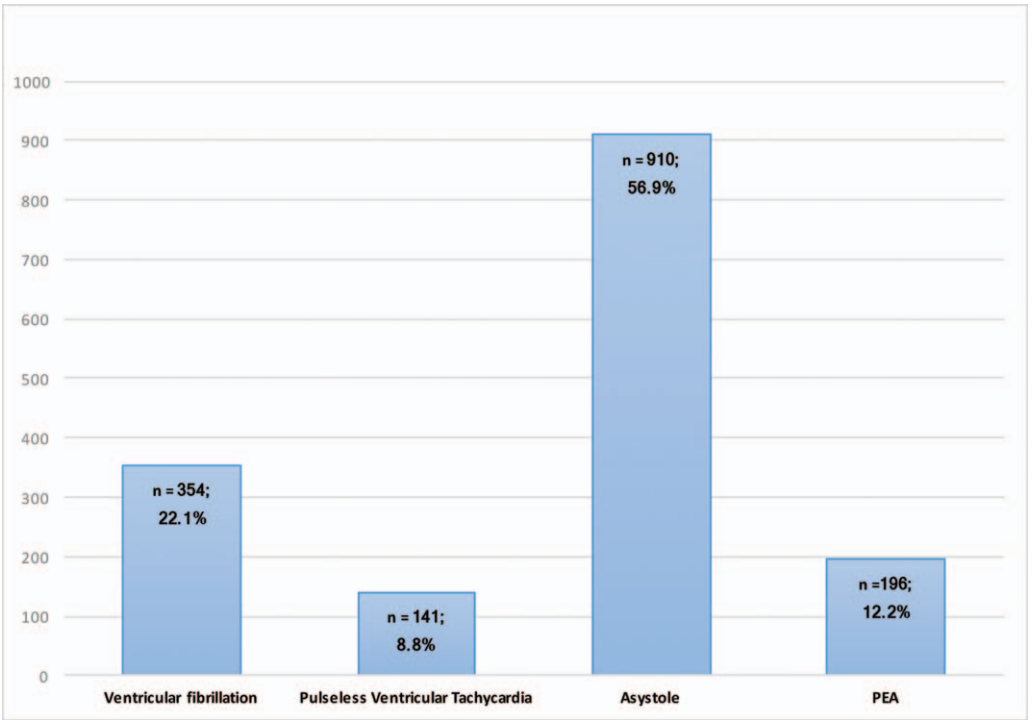

Figure 1. Type of initial rhythms during out-of-hospital cardiac arrest. PEA = pulseless electrical activity.

Table 4

A comparative analysis of variables (particular components of rescue procedures) and ROSC in cases of out-of-hospital sudden cardiac arrest.

Variable	ROSC (n = 536)	No ROSC (n = 1067)	P*
Endotracheal intubation	318 (59.3%)	506 (47.4%)	.000
Respirator	189 (35.2%)	135 (12.7%)	.000
Ventilation – ventilation bag	345 (64.4%)	604 (56.7%)	.003
Defibrillation	161 (30.0%)	193 (18.0%)	.000
Venipuncture	514 (95.9%)	865 (81.0%)	.000
Total time from dispatch to arrival up to 8 min	314 (58.5%)	691 (64.7%)	.018

* Pearson Chi-squared test.
ROSC = return of spontaneous circulation.

(33.4%), and an unsuccessful resuscitation was noted in 1067 patients (66.6%). Consequently, the mortality of the group until patients were transferred to hospitals equaled 66.6%. Patients with diagnosed VF presented a higher ROSC rate than those with nonshockable rhythm (VF, 55.43% vs asystole, 24.05%; $P = .000$) (Table 4).

The resulting stepwise regression model was statistically significant ($\chi^2 = 238.9$; $P = .000$; log-likelihood ratio = –777.5; AIC = 1575; Nagelkerke $R^2 = 0.216$) and well matching with data (Hosmer–Lemeshow test, 6.012; $P = .538$). The resulting model consisted of 4 predictors (the use of a respirator, oxygen therapy, monitoring/electrocardiogram [ECG], and other activities) and 5 2-factorial interactions (Table 5).

Among all performed procedures, 2 exerted a positive influence on ROSC: the use of a respirator (OR = 3.76; $P = .000$) and oxygen therapy (OR = 5.15; $P = .000$). Other procedures (OR = 0.56; $P = .001$) and monitoring/ECG (OR = 0.44; $P = .001$) decreased the probability of ROSC. As far as the interactions between predictors are concerned, the most interesting were the ones between chest compressions and monitoring/ECG (OR = 3.25; $P = .000$) and between intubation and the use of oxygen (OR = 0.50; $P = .003$). The proposed model of ROSC probability estimation in the population under research was characterized by an average level of prediction ability of this condition (area under curve = 0.739).

4. Discussion

In the population under research within 12 months, there were 1603 cases of OHCA, which results in an indicator amounting 59.4/100,000 inhabitants. The indicator value was significantly lower than that provided by Gach et al[16] for Podbeskidzie (a region in southern Poland bordering with the VRS in Katowice) (170). Simultaneously, the SCA indicator value was much higher than in countries such as Denmark (34),[14] Finland (51),[17] Sweden (52),[18] and Ireland (88).[19]

The most frequent place of SCA incident was home, probably because a significant percentage of the elderly may present a higher risk of SCA as a result of numerous complaints. The SCA incident was usually witnessed by a third person; however, the percentage of incidents with a witness (about 77%) was much lower than in other publications, where it amounted to about 90%.[20–22]

The medical documentation and the analyses of phone conversations with emergency medical dispatchers provide evidence that in 60% of cases, the witness of the incident provided the patient with first aid before the arrival of qualified emergency services. It is worth noticing that almost 11% of cases were SCA incidents in the presence of emergency medical team members. The available literature provides a publication about Beijing, China, stating that it is only in 25% of cases that the witness performs medical actions.[23] A low rate of witnesses performing CPR was also described in a few other studies,[24,25] including Polish research.[26] Early resuscitation is crucial because rescue actions performed by witnesses and advanced procedures performed by emergency medical teams are significant elements in the chain of survival, and, at the same time, important factors that increase the probability of ROSC.[27] The results indicate that witnesses performing CPR increase the probability of ROSC (35.1% vs 30.9%). Current recommendations suggest that the witness of the incident should perform only chest compressions. In cases of OHCA, the role of emergency medical dispatchers should be limited to providing first aid phone instructions on how to perform heart massage.

The increasing access to AED should lead to a rising number of applications of this device. Unfortunately, it was only in 8 cases that the witness of the incident applied a defibrillator, although in numerous other cases, the device was available and close to the place of incident. This phenomenon may be caused by a low social awareness as far as the use of defibrillators is concerned. With this aspect of social awareness, Poland is different from Western Europe and the United States.[28]

The emergency medical dispatcher plays a significant role in the EMS as it is the first person with medical qualifications that witnesses contact. Frequently, the patient's health condition and life depend on the decisions taken by dispatchers. The analysis of

Table 5

The results of the logistic regression.

Predictors	β	OR	0.95 CI		Walda	P
			Low	High		
Intercept	−1.054	0.348	0.277	0.438	82.3	.000
Respirator (no/yes)	1.324	3.757	2.756	5.123	70.1	.000
Oxygen therapy (no/yes)	1.639	5.151	3.280	8.088	50.7	.000
Other activities (no/yes)	−0.572	0.564	0.398	0.799	10.4	.001
Monitoring/ECG (no/yes)	−0.825	0.438	0.265	0.725	10.3	.001
Heart massage × Age	−0.025	0.975	0.968	0.983	43.6	.000
Defibrillation and monitoring	0.648	1.912	1.301	2.810	10.9	.001
Intubation and the use of oxygen	−0.693	0.500	0.317	0.789	8.9	.003
Venipuncture × Age	0.012	1.012	1.006	1.019	13.7	.000
Heart massage and monitoring/ECG	1.178	3.247	1.794	5.878	15.1	.000

β = regression coefficient; CI = confidence interval, ECG = electrocardiogram, OR = odds ratio; Walda = value of the test statistic.

reporting reasons indicates that only in about 37% of cases, the information provided by the witness pointed to OHCA (the patient was unconscious), although lack of consciousness does not necessarily determine CPR. Very frequently, the reported reasons were chest pain, dyspnea, fainting, and others. Specialist teams (with a physician) were sent to OHCA more often than basic teams (61.1% vs 38.9%). One should emphasize that in 2016, the number of specialist teams and the number of basic teams (with paramedics) was equal. However, according to some legal aspects, a physician was required at the place of incident. Numerous publications provide evidence that no significant ROSC increase can be observed when comparing CPR supervised by physicians with CPR supervised by paramedics or nurses.[29]

It has been estimated that the most frequent primary SCA mechanism is the defibrillation mechanism (VF and ventricular tachycardia with no pulse).[30] In 22.8% of the cases under research, the primary diagnosed rhythm was VF, and in 9.8%, the rhythm was ventricular tachycardia with no pulse. In other publications, about 20% to 25% of cases present VF or ventricular tachycardia with no pulse as the first registered rhythm, which is true for both Europe and the United States.[31,32] However, there are also countries where more frequent VF has recently been reported.[33] The primary rhythm diagnosed by medical emergency team members is to a large extent the indicator of ROSC probability. This probability rate amounts to 55.4% for VF, and reaches only 24.1% for asystole.

There are 2 emergency priority codes in Poland: C-1 and C-2. This research indicates that teams dispatched in the highest priority code (C-1) frequently go with VF, which has a significant impact on the effectiveness of resuscitation. Therefore, the shorter the time from dispatch to arrival at destination, the higher the probability of ROSC.

Securing airway patency is an important aspect of resuscitation.[34,35] Recommendations indicate that a person qualified in endotracheal intubation should use this method.[36] According to the research, 51.4% of patients were intubated, and a large number of them were provided assistance with supraglottic airway methods. An alarming fact is that in more than 20% of cases, emergency medical teams applied respirators at the place of incident. It is difficult to explain this phenomenon by means of short time routes to the closest hospitals with ICU capacities. The research pointed out that endotracheal intubation and the use of a respirator significantly increased the probability of ROSC. Ventilation by means of a ventilation bag with facial mask alone is often unsuccessful and causes leaks that result in hypoventilation and a high amount of air flow to the stomach, increasing the risk of regurgitation.[37,38] Endotracheal intubation should be perceived as an optimal method of providing SCA patients with airway patency.[39]

In the group under research, the ROSC rate amounted to 33.43% (546 cases), whereas the average value for Europe reaches 38%. The value in Cyprus equals 50%; in Greece, in turn, the share is about 9%.[31]

5. Conclusion

Successful resuscitation depends on the quality of emergency medical procedures performed by emergency team members at the place of incident. The ROSC rate is significantly higher when procedures are performed in accordance with current medical knowledge. Physicians, paramedics, and nurses should be trained at least once per year as far as advanced resuscitation procedures in adults are concerned. Regular trainings will ensure the maintenance of the teams' skills and knowledge at the highest level.

Author contributions

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