

# Association Between Duration of Return of Spontaneous Circulation and Favorable Outcomes After Out-of-Hospital Cardiac Arrest

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## Research

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# Abstract

**Background:** Return of spontaneous circulation (ROSC) is a core outcome element of cardiopulmonary resuscitation (CPR), but the definition or criterion of ROSC is disputed and varies in resuscitation for out-of-hospital cardiac arrest (OHCA).

**Methods:** In this retrospective observational study from a single center in Beijing, we analyzed the records of 126 OHCA patients who achieved ROSC between January 1, 2020, and December 31, 2020. ROSC duration was defined as the entire time of ROSC from heartbeat or pulse present upon arrival at hospital or arrest again during CPR. The primary outcome was survival at 30 days with favorable neurological outcome. The probability of survival after OHCA as related to CPR duration time was further analyzed using the Probability Density Function (PDF) and the empirical Cumulative Density Functions (CDFs), and compared with ROSC sustained until emergency department arrival and ROSC sustained at least 20 minutes.

**Results:** Among all 126 OHCA patients who achieved ROSC, the median ROSC duration time was 13.6 minutes. There were no significant differences between ROSC sustained until emergency department arrival and sustained at least 20 minutes in the 24-hour survival rate (31.3% [31/99] vs. 35.7% [10/30];  $P=0.835$ ), 30-day survival rate (23.2% [23/99] vs. 25.0% [7/30];  $P=0.991$ ), or survival at 30 days with cerebral performance category (CPC) 1–2 (18.2% [18/99] vs. 10.7% [3/30];  $P=0.435$ ). The Kolmogorov-Smirnov test values from the empirical CDFs with ROSC sustained until hospital arrival and ROSC at least 20 minutes were 0.4444, 0.2000, and 0.2353 for CPC 1 or 2, CPC 3 or 4, and CPC 5 respectively.

**Conclusions:** ROSC duration was directly associated with 24-hour survival, 30-day survival and 30-day survival with favorable neurological outcomes after OHCA. ROSC as a core outcome element of CPR should be defined as sustained at least 20 minutes or until arrival at the emergency department, and as a basic standard for evaluating resuscitation success after OHCA.

## Introduction

Return of spontaneous circulation (ROSC) is a core outcome element of cardiopulmonary resuscitation (CPR) both in out-of-hospital cardiac arrest (OHCA) and in-hospital cardiac arrest (IHCA), and has been considered a standard in the evaluation of successful resuscitation [1–3]. However, the definition or criterion of ROSC is disputed, and varies in different guidelines and studies [4–6]. The 2015 American Heart Association (AHA) Guidelines for cardiac arrest and cardiopulmonary resuscitation outcome define ROSC as a clinical assessment that shows signs of life comprising a palpable pulse or generating a blood pressure [4]; the 2021 European Resuscitation Council Guidelines define ROSC as a combination of clinical and physiological signs such as waking, purposeful movement, arterial waveform or a sharp rise in end-tidal carbon dioxide (ETCO<sub>2</sub>), and recommend considering stopping chest compressions for rhythm analysis, and if appropriate, a pulse check [7]. In some studies, ROSC has been defined as *any* ROSC, including brief (approximately > 30 seconds) restoration of spontaneous circulation that provides

evidence for a favorable prognostic factor, encouraging continuing resuscitative efforts [8–10]. Other studies have defined ROSC as sustained ROSC, specifically defined as the restoration of a pulse for at least 20 minutes [11–13], and still others have defined ROSC as prehospital ROSC, the presence of a pulse upon arrival at the emergency department (ED) [14–15]. Therefore, the duration of ROSC is key to evaluating the success of resuscitation in emergency medical services (EMS), which is also recognized as a key element in the efficacy of the chain of survival [1]. In the absence of related studies, guidelines have been unable to directly address this issue [2, 4, 7], and researchers and clinicians have come to rely largely upon the literature and expert opinion to guide their practice. We hypothesized that patients with ROSC sustained at least ( $\geq$ ) 20 minutes and ROSC sustained until arrival at the hospital should have similar outcomes, including for 30-day survival and survival to discharge, and would have outcomes distinct from patients with ROSC sustained less than ( $<$ ) 20 minutes or not sustained until arrival at the hospital.

## Methods

### Study Design and EMS System

This was a retrospective observational study that included OHCA cases responded to by the 120 EMS systems in urban areas of Beijing. The study was approved by the Medical Ethics Committee of the Beijing Emergency Medical Center (No. 2019-09). We selected all cases with age  $\geq$  18 years with OHCA between January 1, 2020, and December 31, 2020. Exclusion criteria were patients aged  $<$  18 years and those with obvious noncardiac cause of OHCA (i.e., trauma, drowning or circumstantial cases).

Beijing has approximately 21.5 million inhabitants in an area of 16,410 km<sup>2</sup> and comprises 16 districts with urban, suburban and rural areas. There are two emergency medical service systems including two emergency phone numbers (120 and 999) leading to two emergency dispatch centers: the 120 EMS system conducted by Beijing Emergency Medical Center which is supported by the Beijing municipal government, and the 999 EMS system conducted by the Beijing Red Cross Emergency Rescue Center, supported by the Beijing Red Cross. In 2020, the 120 EMS system comprised 260 EMS stations, 470 ambulances, 2680 EMS staff, and provided approximately 552,000 public emergency medical transports. In China, EMS ambulances are required by law to be configured by a physician, and staffed with an ambulance driver and one nurse [16]. In Beijing, the 120 EMS system is organized into advanced life support (ALS) units in a single-tiered system. EMS physicians who are skilled in all rescue techniques (defibrillation, endotracheal intubation, intravenous access line and drug administration) can provide ALS care comparable to that in the emergency department of the hospital, and the physician can declare death or stop CPR in the field according to the AHA guidelines. When the patient is transported to the hospital, the physician completes the information in the EMS electronic medical record system. In addition, the physician continued to track whether the patients survived to the hospital admission. Survival at 24 hours and at 30 days and neurological status at 30 days were obtained from the hospital records by investigators.

# Data Source and Collection

Data were collected according to the Uststein guidelines for reporting of cardiac arrest [17]. Out-of-hospital data were based on the EMS electronic medical record system of Beijing Emergency Medical Center; the data used in this study were anonymized before use. The variables collected included age, sex, etiology of arrest, bystander-provided CPR before EMS arrival, first recordable cardiac rhythm, response time for EMS ambulances from call to arrival on site, CPR duration time, and ROSC frequency, ROSC sustained time, defibrillation, heart rate and blood pressure after ROSC. Two independent investigators reviewed each record for data completion and validity.

## Study Definitions and Endpoints

CPR duration was defined as the elapsed time from the first professional chest compression to ROSC or termination of resuscitation (TOR). ROSC duration was defined as the entire time of ROSC from heartbeat or pulse present upon arrival at hospital or arrest again during CPR.

The primary study endpoint was survival at 30 days with a favorable neurological outcome (defined as a cerebral performance category (CPC) score of 1 or 2). The secondary endpoint was 24-hour survival.

## Statistical Analyses

The methodology of this study is consistent with the STROBE (Strengthening The Reporting of Observational Studies in Epidemiology) Checklist for observational studies [18]. Continuous data were expressed as means  $\pm$  standard deviation (SD) and analyzed by T test between cases of ROSC sustained to ED and ROSC sustained  $\geq$  20 minutes. Categorical data were expressed as frequencies and percentages in each category, and analyzed by Chi-square test between cases of ROSC sustained to ED and ROSC sustained  $\geq$  20 minutes. The empirical Cumulative Density Function (CDF) was used to illustrate CPR duration time in each CPC category (CPC 1 or 2, CPC 3 or 4, and CPC 5). The log-normal distribution and Maxim Likelihood Estimation (MLE) method were employed to fit the data samples and calculate the confidence intervals. The empirical CDFs were utilized in Kolmogorov-Smirnov test to further validate the proposed hypothesis. All analysis were conducted with a 5% significance level to determine statistical significance.

All statistical analyses were performed with SPSS software version 25.0 (IBM, Armonk, NY). The distribution fitting and calculation were performed with Matlab software version 2018 (Mathworks, Natick, MA).

## Results

We identified 7,516 patients who had an out-of-hospital cardiac arrest in the EMS electronic medical record system of Beijing Emergency Medical Center during the study period; of these, 1436 (19.1%) patients had attempted resuscitation, 1100 cases (76.6%) had a cardiac or presumed cardiac etiology, and a total of 126 (11.5%) patients achieved ROSC (Fig. 1). Among the 126 ROSC cases, 99 (78.6%) had ROSC sustained until arrival at the ED, 31 (2.8%) survived 24 hours after hospital admission, 23 (2.0%)

survived to 30 days after arrest, and 18 (1.6%) recovered with a favorable neurological outcome (CPC 1 or 2) at 30 days. While 27 (21.4%) patients died who achieved ROSC before hospital arrival but could not be sustained to ED arrival, none survived to 24 hours (or 30 days) after hospital admission. Of 126 ROSC cases, 96 (76.2%) had ROSC sustained for less than 20 minutes, but 71 (74.0%) had ROSC sustained until arrival at the ED within 20 minutes.

The demographic and clinical features of patients with ROSC in this study are summarized in Table 1 and Table 2, respectively. The median duration of professional (non-bystander) CPR was 25.9 minutes overall, 25.8 minutes for those with ROSC sustained  $\geq$  20 minutes, and 26.0 minutes for those with ROSC sustained  $<$  20 minutes; this time difference was not significant ( $P = 0.962$ ). The longest observed duration of CPR was 83 minutes to ROSC; this patient arrested again after sustained ROSC of 28 minutes. There were no significant differences between the study groups in terms of sex, EMS response time, bystander CPR, CPR duration or initial rhythm.

Of the 126 patients who achieved ROSC, ROSC occurred only once in 107 patients (84.9%), twice in 17 patients (13.5%), and three times in 2 patients (1.6%); there were significant differences in the number of occurrences between those with ROSC sustained  $\geq$  20 minutes and

Table 1  
Baseline Characteristics of Patients with ROSC

	All Patients (n = 126)		Sustained $\geq$ 20 min (n = 30)		Sustained < 20 min (n = 96)	
	Arrive ED (n = 99)	No to ED (n = 27)	Arrive ED (n = 28)	No to ED (n = 2)	Arrive ED (n = 71)	No to ED (n = 25)
Age (years)	65.1 $\pm$ 14.7	68.1 $\pm$ 11.4	70.2 $\pm$ 11.9	70.5 $\pm$ 6.4	63.1 $\pm$ 15.3	67.9 $\pm$ 11.8
Male, n (%)	75 (75.8)	19 (70.4)	20 (71.4)	1 (50.0)	55 (77.5)	18 (72.0)
Arrest at home	70(70.7)	23(85.2)	26(92.9)	2(100.0)	44(62.0)	21(84.0)
Bystander CPR, n (%)	31 (31.3)	8 (29.6)	11 (39.3)	0 (0.0)	20 (28.2)	8 (32.0)
Response time (min)	13.1 $\pm$ 4.4	13.5 $\pm$ 4.0	13.5 $\pm$ 4.8	14.5 $\pm$ 3.5	13.0 $\pm$ 4.3	13.4 $\pm$ 4.1
CPR duration (min)	20.8 $\pm$ 14.7	44.5 $\pm$ 18.4	13.7 $\pm$ 2.6	47.4 $\pm$ 33.5	19.6 $\pm$ 14.9	44.1 $\pm$ 16.4
No. ROSC occurrence	1.1 $\pm$ 0.4	1.3 $\pm$ 0.5	1.0 $\pm$ 0.2	1.0 $\pm$ 0.0	1.2 $\pm$ 0.4	1.3 $\pm$ 0.5
ROSC duration (min)	14.6 $\pm$ 11.7	10.2 $\pm$ 7.3	29.6 $\pm$ 8.8	27.0 $\pm$ 1.4	8.7 $\pm$ 6.1	8.9 $\pm$ 5.7
Initial rhythm VF/VT	21 (21.2)	4 (14.8)	5 (17.9)	1 (50.0)	16 (22.5)	4 (16.0)
Defibrillation (yes)	36 (36.4)	10 (37.0)	7 (25.0)	0 (0.0)	29 (40.8)	10 (40.0)
Waking	9(9.1)	0(0.0)	2(7.1)	0 (0.0)	7(9.9)	0 (0.0)
HR	107.5 $\pm$ 35.2	109.5 $\pm$ 30.9	122.0 $\pm$ 33.5	117.0 $\pm$ 32.5	101.8 $\pm$ 34.4	108.9 $\pm$ 31.4
SBP	102.9 $\pm$ 48.8	71.5 $\pm$ 63.3	107.4 $\pm$ 45.4	95.0 $\pm$ 134.4	101.0 $\pm$ 50.4	69.1 $\pm$ 58.2
DBP	63.9 $\pm$ 32.5	43.8 $\pm$ 42.5	65.8 $\pm$ 28.3	32.5 $\pm$ 46.0	63.1 $\pm$ 34.3	45.0 $\pm$ 43.3
24-h survival	31 (31.3)	0 (0.0)	10 (35.7)	0 (0.0)	21 (29.6)	0 (0.0)

Response time is defined as the length between the call and ambulance arrival. CPR, cardiopulmonary resuscitation; ROSC, return of spontaneous circulation; ED, emergency department; VF, ventricular fibrillation; VT, ventricular tachycardia; SBP, systolic blood pressure; DBP, diastolic pressures; CPC, cerebral performance categories.

	<b>All Patients (n = 126)</b>		<b>Sustained ≥ 20 min (n = 30)</b>		<b>Sustained &lt; 20 min (n = 96)</b>	
30-day survival	23 (23.2)	0 (0.0)	7 (25.0)	0 (0.0)	16 (22.5)	0 (0.0)
30-day CPC 1 or 2	18 (18.2)	0 (0.0)	3 (10.7)	0 (0.0)	15 (21.1)	0 (0.0)
<p>Response time is defined as the length between the call and ambulance arrival. CPR, cardiopulmonary resuscitation; ROSC, return of spontaneous circulation; ED, emergency department; VF, ventricular fibrillation; VT, ventricular tachycardia; SBP, systolic blood pressure; DBP, diastolic pressures; CPC, cerebral performance categories.</p>						

Table 2  
Characteristics of Patients Compared with ROSC Duration

	All Patients (n = 126)	Sustained $\geq$ 20min (n = 30)	Sustained < 20min (n = 96)	Statistic Value	P
Age (years)	65.8 $\pm$ 14.1	70.2 $\pm$ 11.6	64.3 $\pm$ 14.6	2.022*	0.045
Male	94(74.6)	21(70.0)	73(77.7)	0.440	0.507
Arrest at home	93(73.8)	28(93.3)	65(67.7)	7.764	0.005
Response time (min)	13.2 $\pm$ 4.3	13.6 $\pm$ 4.7	13.1 $\pm$ 4.2	0.569*	0.571
Bystander CPR	39(31.0)	11(36.7)	28(29.2)	0.602	0.438
CPR duration (min)	25.9 $\pm$ 18.3	25.8 $\pm$ 17.1	26.0 $\pm$ 18.7	0.047*	0.962
No. ROSC occurrence	1.2 $\pm$ 0.4	1.0 $\pm$ 0.2	1.2 $\pm$ 0.5	3.053	0.003
ROSC duration (min)	13.6 $\pm$ 11.1	29.4 $\pm$ 8.5	8.7 $\pm$ 6.0	12.341*	< 0.01
Initial rhythm VF/VT	25(19.8)	5(16.7)	20(20.8)	0.250	0.617
Defibrillation (yes)	46(36.5)	7(23.3)	39(40.6)	2.948	0.086
Waking	9(7.1)	2(6.7)	7(7.3)	0.013	0.908
Heart Rate	107.9 $\pm$ 34.2	121.7 $\pm$ 33.0	103.7 $\pm$ 33.6	2.573*	0.011
SBP	96.3 $\pm$ 53.4	106.4 $\pm$ 51.5	92.9 $\pm$ 53.9	1.090*	0.278
DBP	59.7 $\pm$ 35.6	63.2 $\pm$ 30.1	58.5 $\pm$ 37.3	0.566*	0.573
24-h survival	31(24.6)	10(33.3)	21(21.9)	1.618	0.203
30-day survival	23(18.3)	7(23.3)	16(16.7)	0.681	0.409
30-day CPC 1 or 2	18(14.3)	3(10.0)	15(15.6)	0.591	0.442
Response time is defined as the length between the call and ambulance arrival. CPR, cardiopulmonary resuscitation; ROSC, return of spontaneous circulation; VF, ventricular fibrillation; VT, ventricular tachycardia; SBP, systolic blood pressure; DBP, diastolic pressures; CPC, cerebral performance categories.					
*T test.					

A: 24-h survival rate; B:30-day survival rate

those with ROSC sustained < 20 minutes ( $P = 0.003$ ). Median ROSC duration was 13.6 minutes overall, 29.4 minutes for those with ROSC sustained  $\geq 20$  minutes, and 8.7 minutes for those with ROSC sustained < 20 minutes; ROSC duration time was significantly different between groups ( $P < 0.01$ ). There were 71 (56.3%) patients who had ROSC sustained until arrival at the emergency department, although of those with ROSC sustained for < 20 minutes, 21 (29.6%) survived to 24 hours, 16 (22.5%) survived to 30 days after arrest, and 15 (21.1%) recovered with a favorable neurological outcome (CPC 1 or 2) at 30 days.

As shown in Table 3 and Fig. 2, there was no significant difference between those patients who had ROSC sustained until arrival at the ED and those who had ROSC sustained  $\geq 20$  minutes in the 24-hour survival rate (31.3% [31/99] vs. 35.7% [10/30],  $P = 0.835$ ) or the 30-day survival rate (23.2% [23/99] vs. 25.0% [7/30],  $P = 0.991$ ). Of the 23 patients who survived to 30 days, 18 (78.3%) recovered with a favorable neurological outcome at 30 days with no difference between the two groups (18.2% [18/99] vs. 10.7% [3/30];  $P = 0.435$ ).

Table 3  
Outcomes Compared with ROSC Duration

	Sustained to ED (n = 99)	Sustained $\geq 20$ min (n = 30)	<i>P</i> Value	<i>P</i> Value
24-h survival	31 (31.3)	10 (35.7)	0.043	0.835
30-day survival	23 (23.2)	7 (25.0)	0.000	0.991
30-day CPC 1 or 2	18 (18.2)	3 (10.7)	0.610	0.435
ROSC, return of spontaneous circulation; ED, emergency department; CPC, cerebral performance categories.				

Figure 3 provides the empirical CDFs of CPR duration time in each of the CPC classes. Figure 3A shows the empirical CDFs with confidence intervals of CPC 1 or 2; the estimated parameters of the empirical CDFs with log-normal hypothesis are  $\mu = 2.1007$  (95% confidence interval (CI): 1.7261–2.4753),  $\sigma = 0.7533$  (95% CI: 0.5652–1.1292) for ROSC sustained to ED and  $\mu = 1.7269$  (95% CI: 0.5133–2.9406),  $\sigma = 0.7627$  (95% CI: 0.4321–2.8439) for ROSC  $\geq 20$  minutes. In Fig. 3B, the results with CPC 3 or 4 are provided; the estimated parameters are  $\mu = 2.6540$  (95% CI: 1.8042–3.5038),  $\sigma = 0.6844$  (95% CI: 0.4100–1.9666) for ROSC sustained to ED and  $\mu = 2.8275$  (95% CI: 1.6926–3.9625),  $\sigma = 0.4569$  (95% CI: 0.2379–2.8714) for ROSC  $\geq 20$  minutes. The corresponding results of CPC 5 are  $\mu = 2.9309$  (95% CI: 2.7594–3.1024),  $\sigma = 0.7506$  (95% CI: 0.6474–0.8934) for ROSC sustained to ED and  $\mu = 3.3268$  (95% CI: 3.1120–3.5416),  $\sigma = 0.5204$  (95% CI: 0.4063–0.7239) for ROSC  $\geq 20$  minutes, as shown in Fig. 3C. As expected,

the large confidence intervals for categories with CPC 1 or 2 and CPC 3 or 4 are due to the limited number of samples, with only 5 patients in the category with CPC 3 or 4.

Although the similarity between ROSC sustained until ED arrival and ROSC sustained  $\geq 20$  minutes can be simply intuited from Fig. 2, we used the Kolmogorov-Smirnov test at a 5% significance level to quantitatively validate whether these groups can be distinguished. The values of the Kolmogorov-Smirnov test are 0.4444, 0.2000, and 0.2353 for the three CPC categories respectively, and  $H = 0$  which means there was no difference between ROSC sustained to arrive at ED and ROSC sustained  $\geq 20$  minutes for all three CPC categories.

## Discussion

In this study, there were no overall differences in survival for patients with out-of-hospital cardiac arrest who achieved ROSC sustained until arrival at the emergency department or sustained less than 20 minutes versus sustained at least 20 minutes. We found that no patients with ROSC sustained less than 20 minutes and not sustained until emergency department arrival survived to 24 hours after hospital admission, or of course to 30 days. These findings suggest that ROSC sustained less than 20 minutes and not sustained to emergency department arrival may be of little value for evaluating resuscitation, and defining ROSC as being sustained at least 20 minutes is bias. In fact, transferring patients with OHCA and ROSC to the hospital as soon as possible by EMS may take less than 20 minutes in most cities. Therefore, we suggest that ROSC should be defined as either being sustained at least 20 minutes or sustained until arrival at the emergency department, and that this definition should likewise be used as a basic standard for evaluating resuscitation success after OHCA.

Few studies related to the association between duration of ROSC and outcomes after OHCA have been published, though some related studies have focused on the definition of ROSC and as an inclusion or exclusion criteria for study according to researcher needs [11–13, 19]. Some studies have defined ROSC as the restoration of a pulse at least consecutive 20 minutes, and some have defined it as being sustained until arrival at the emergency department, also called prehospital ROSC [20–24]. Therefore, we divided the patients who achieved ROSC after OHCA into two groups, ROSC sustained at least 20 minutes versus less than 20 minutes, and divided those into subgroups based on whether ROSC was sustained until emergency department arrival. However, the results of this study suggest that there are no significant differences in outcomes between ROSC sustained to arrive at emergency department and sustained at least 20 minutes regardless of overall ROSC duration subgroups (sustained at least 20 minutes or less than 20 minutes). Our data can therefore address two clinical questions regarding exactly how to define ROSC. The first is in terms of defining ROSC as inclusion and exclusion criteria in OHCA clinical studies. The second regards duration of CPR. Previous studies [20, 25] have shown that CPR duration was independently and inversely associated with favorable 1-month neurological outcomes. For example, Goto et al [20] reported that a cumulative proportion of  $> 99\%$  was reached after CPR durations of 35 minutes (95% CI: 34–39 minutes) in patients with initial shockable rhythms and pulseless electrical

activity for 1-month survival with favorable neurological outcomes. These findings are supported by Fig. 3 as well, and hinted a longer CPR duration time may be indicative of worse CPC expectations.

The consecutive and steady duration of ROSC in cardiopulmonary resuscitation is expectant. However, only 11.5% of OHCA patients achieved ROSC in this study, and 9.0% patients had ROSC sustained to arrival at the ED, 2.8% of patients survived to 24 hours post-hospital admission, and 2.0% survived to 30 days after arrest, with 1.6% overall recovering with a favorable neurological outcome at 30 days. Of the 2.4% of patients who died after achieving prehospital ROSC that could not be sustained until ED arrival, none of these survived to 24 hours after hospital admission. Our data demonstrate that ROSC sustained for less than 20 minutes that could not be sustained to emergency department may be of little value for evaluating resuscitation.

## Limitations

There are several limitations to this study. First, this is a single-center study with a small sample size that limits the study's statistical power and generalizability of the results. We recognize that the size of our patient population is limited, although we have included all patient data available at our center that met inclusion criteria. Second, we assumed that the EMS physician and hospitals provided standard ALS according to the AHA CPR guidelines. Furthermore, some patients were transported to hospital during ongoing resuscitation; it is unknown whether this may have affected the duration time of CPR and the likelihood of favorable outcomes. Finally, we did not evaluate in-hospital clinical treatment and care processes, such as induced therapeutic hypothermia, extracorporeal membrane oxygenation and administration of drugs (e.g., epinephrine) etc., that may have affected the results, as such comparisons were beyond the scope of this study.

## Conclusions

ROSC duration was directly associated with 24-hour survival, 30-day survival, and 30-day survival with favorable neurological outcomes after OHCA. ROSC as a core outcome element of CPR and as a basic standard for evaluating resuscitation success after OHCA should be defined as being sustained at least 20 minutes or sustained until arrival at the emergency department.

## Abbreviations

AHA

American Heart Association; ALS:advanced life support; CDF:Cumulative Density Functions; CPC:cerebral performance categories; CPR:cardiopulmonary resuscitation; DBP:diastolic pressures; ED:emergency department; EMS:emergency medical services;ETCO<sub>2</sub>:end-tidal carbon dioxide; ROSC:return of spontaneous circulation; OHCA:out-of-hospital cardiac arrest; PDF:Probability Density Function; IHCA:in-hospital cardiac arrest; SBP:systolic blood pressure; VF:ventricular fibrillation; VT:ventricular tachycardia.

# Declarations

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## Availability of data and materials

The datasets used during the current study are available from the corresponding author upon reasonable request.

## Authors' contributions

JJZ, and FQ conceived and designed the study. SJT, XQK, LXZ and SMN collected data. ADX, FQ and SJT analysed data. HXL, JJZ and XYQ wrote the first draft. All authors read and approved the final manuscript.

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## Ethics approval and consent to participate

The study was approved by the Medical Ethics Committee of the Beijing Emergency Medical Center (No. 2019-09). As it was a retrospective analysis, consent to participate does not apply.

## Consent for publication

Not applicable.

## Competing interests

The authors declare that they have no competing interests.

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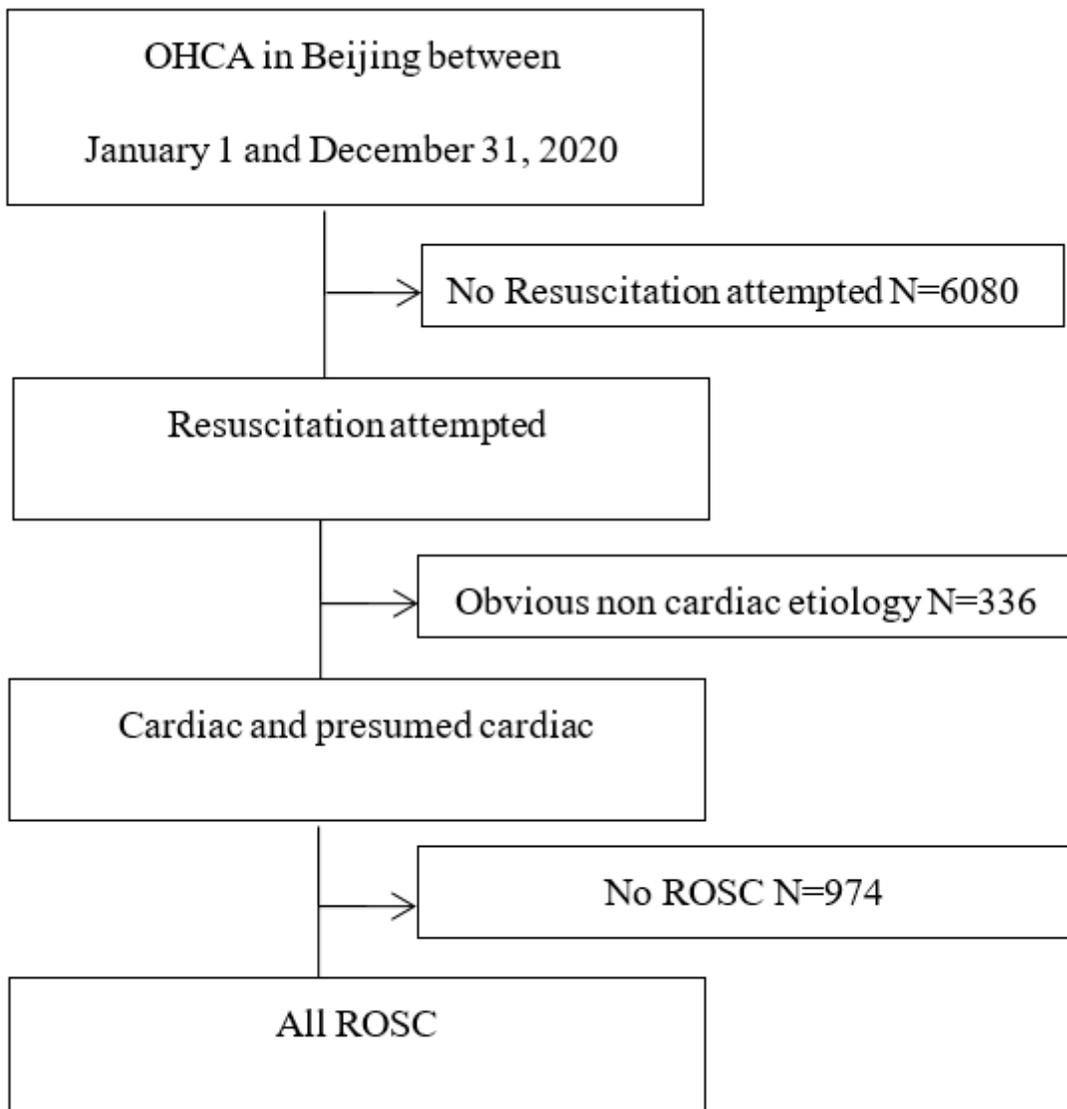
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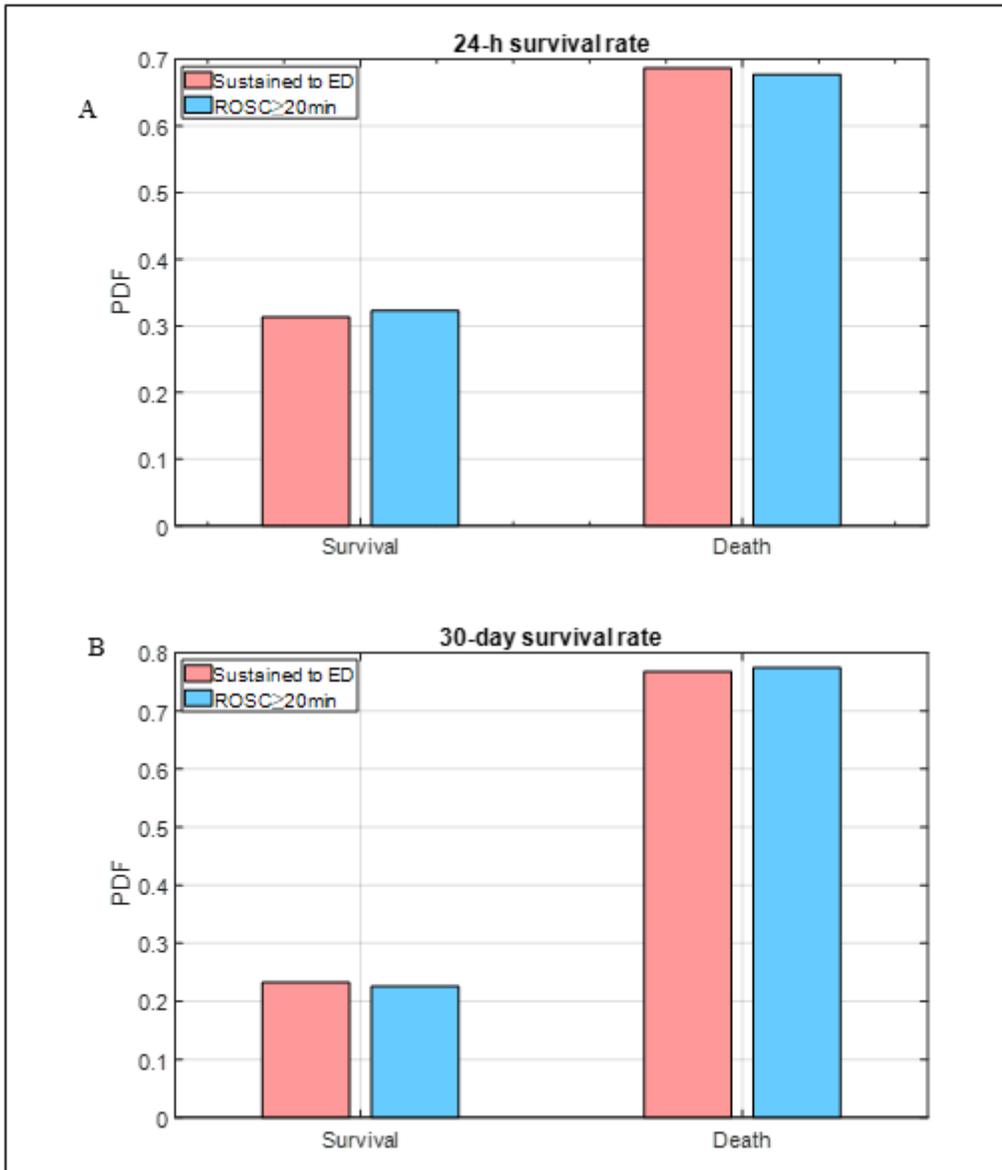
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# Figures



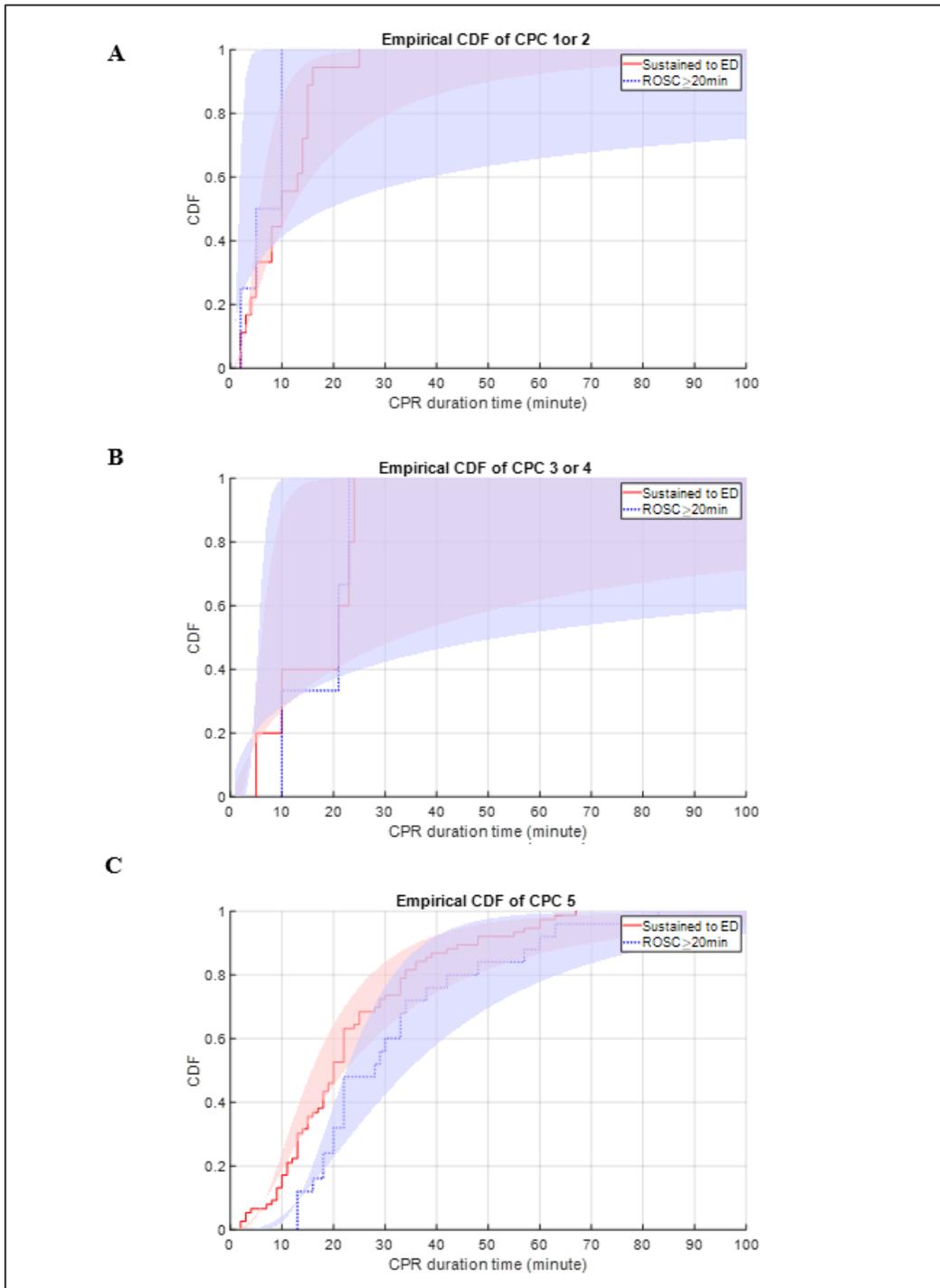
**Figure 1**

Study flowchart and exclusions



**Figure 2**

The PDF of survival rate by ROSC sustained to ED and sustain at least 20 minutes. A: 24-h survival rate; B:30-day survival rate



**Figure 3**

The empirical CDFs of CPR durations with ROSC sustained to ED and ROSC  $\geq 20$  minutes A: CPC 1 or 2; B: CPC 3 or 4 ; C: CPC 5