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Role of initial cardiac activity assessed by point-of-care ultrasonography in predicting cardiac arrest outcomes: A prospective cohort study

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Abstract:

OBJECTIVES: This study was conducted to investigate the association between visible cardiac activity in point-of-care ultrasound (POCUS) and outcomes of cardiac arrest such as the return of spontaneous circulation (ROSC), survival to inpatient admission (SIA), and survival to hospital discharge (STHD).

METHODS: This was a single-center, prospective cohort study conducted in the emergency department (ED). Adult (age >18 years) patients in cardiac arrest were included in the study. Exclusion criteria of the study were – traumatic arrest, out-of-hospital cardiac arrest resuscitated before ED admission, and patients presenting with initial shockable rhythm. Patients whose ultrasound images could not be obtained and whose resuscitation stopped following POCUS were also excluded from the study. POCUS examination was done after 2 min of initiation of cardiopulmonary resuscitation (CPR) and visible cardiac activity was defined as any visible movement of the myocardium, excluding movement of blood within cardiac chambers, or isolated valve movement. The duration of POCUS examinations was limited to 10 s. The association of initial cardiac activity in POCUS with the outcomes of cardiac arrest was investigated.

RESULTS: Out of 140 patients screened, 84 patients were included in the study. Rates of ROSC, SIA, and STHD were found in 23 (27.4%), 9 (10.7%), and 2 (2.4%) patients, respectively. Only 15 out of 84 (17.9%) patients had cardiac activity on the initial POCUS examination. Cardiac activity was seen in 52.2% of patients with ROSC, which was significantly higher ($P < 0.001$) as compared with the no-ROSC group (4.9%). Unlike the above association, there was no difference in the incidence of initial cardiac activity in patient groups who got admitted (SIA) and discharged (STHD) versus those who died. In the multivariate regression analysis, the duration of CPR and initial cardiac activity significantly predicted the rate of ROSC, with an adjusted odds ratio of 0.93 (95% confidence interval [CI]: 0.86–0.99, $P = 0.04$) and 24.8 (95% CI: 3.17–89.41, $P = 0.002$), respectively. None of the variables predicted SIA and STHD. The positive likelihood ratio of cardiac activity for predicting ROSC, SIA, and STHD were 10.6, 2.1, and 2.9, respectively.

CONCLUSION: Integration of POCUS in cardiac arrest resuscitation was shown to be helpful in terms of prognostic significance of the presence of initial cardiac activity in terms of ROSC.

Keywords:

Cardiac activity, cardiac arrest, emergency medicine, point-of-care ultrasound, return of spontaneous circulation, survival

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Box-ED section

What is already known on the study topic?

- Immediate prognostication of cardiac arrest efforts is necessary to decide whether to continue or terminate the resuscitation
- Integration of point-of-care ultrasound (POCUS) in cardiac arrest management to find out the reversible causes is well documented in the literature.

What is the conflict on the issue? Has it importance for readers?

- The role of POCUS in prognosticating cardiac arrest is unclear
- This study was conducted to investigate the association of the presence of initial cardiac activity on POCUS in the prognosis of cardiac arrest.

How is this study structured?

- This was a single-center, prospective cohort study that included data from 84 patients, who are in cardiac arrest in ED.

What does this study tell us?

- There was a significant association of initial cardiac activity assessed by POCUS, in terms of return of spontaneous circulation.

Introduction

Cardiac arrest is one of the primary emergencies that the emergency department (ED) handles. The contributions of modalities during ongoing cardiopulmonary resuscitation (CPR) in the ED such as point-of-care ultrasound (POCUS) had been evaluated in various studies.[1-4] POCUS is now widely available in EDs and it can provide immediate information on cardiac activity as well as identifies reversible causes of cardiac arrest such as pericardial tamponade or tension pneumothorax.[5] Niendorff *et al*. observed that trained emergency sonographers can obtain diagnostic images during the resuscitation of cardiac arrest patients and that obtaining sonographic images did not interfere with the resuscitation process.[6]

Integrating POCUS into cardiac arrest protocols has been suggested, but there have been no large studies to explore exactly how ultrasound should be utilized in Advanced Cardiac Life Support. Several studies suggest that a lack of cardiac activity on ultrasound during cardiac arrest indicates futility.[2,4,7] The Advanced Life Support (ALS) Task Force of the International Liaison Committee on Resuscitation (ILCOR) in 2020 reviewed the available evidence for assessing the role of POCUS as a prognostic tool for clinical outcomes and concluded that the use of uniform definitions and appropriate adjustment for other prognostic variables are necessary.[8]

We, therefore, sought to determine the association between well-defined sonographically visible cardiac activity at 2 min of CPR and the cardiac arrest outcomes. Cardiac arrest outcomes studied were the return of spontaneous circulation (ROSC), survival to inpatient admission (SIA), and survival to hospital discharge (STHD).

Methods

This study was a prospective cohort study conducted in the ED of a tertiary care training and research hospital in North India, over 22 months (July 2018 to May 2020). We included adult (age >18 years) cardiac arrest patients in this study. Both out-of-hospital cardiac arrest (OHCA) presenting to ED without any prehospital interventions and in-hospital cardiac arrest (IHCA) were studied. Patients with traumatic cardiac arrest, OHCA resuscitated before ED admission, presenting with initial shockable rhythm, patients in whom ultrasound images could not be acquired (such as the abnormal shape of the chest, difficulty in acquiring subxiphoid view, and morbid obesity), and in whom resuscitation not continued after POCUS were excluded from the study. We screened the patients consecutively during the defined study period and assessed for inclusion.

The ethical clearance was obtained from the Institute's Ethics Committee (IECPG-609/08.12.2016) and approved on February 16, 2017. Consent was taken after the end of resuscitative efforts as a waiver of informed consent (written one) from legally accepted representative of the patient. A revision of ethical clearance was taken in June 19, 2022, as we excluded patients with initial shockable rhythm later from the analysis.

The POCUS examination was performed by trained emergency physicians (EPs) to assess the presence of cardiac activity. National board-certified EPs (MD or DNB Emergency medicine) with a formal training in emergency ultrasonography (EM-SONO) were the sonographer for this study. EM-SONO was a 3-day formal hands-on course conducted by the national emergency medicine organization (Academic College of Emergency Experts, India) for extensive training of EP about the use of POCUS in ED. Before the initiation of the study, all the sonographers were given a 2-h didactic lecture on the practical utility of ultrasound in cardiac arrest resuscitation and about the study-specific definitions, which was followed by hands-on simulation session.

Cardiac activity was defined as any visible movement of the myocardium, excluding the movement of blood within cardiac chambers or isolated valve movement. The first POCUS examination was done 2 min after the

initiation of CPR. Our ED consists of a resuscitation bay which was directly accessible to patients requiring CPR. In the resuscitation bay, an ultrasound machine (Sonosite Micromaxx portable ultrasound, India, 2017) was always kept connected, so that it can be used as soon as the patient arrives. The booting time of this machine is 20 s, which was within the time limit of 2 min. All examinations were performed during pauses in resuscitation, using a large curvilinear probe in the subxiphoid window, within a duration of 10 s. There was a timekeeper in the resuscitation team who recorded the CPR events. Resuscitation team leader took all the required critical decisions for the patient according to the standard guidelines without any interference from the sonographer. The resuscitation team members were blinded to the cardiac activity results. Although if there was any reversible pathology (cardiac tamponade, regional wall motion abnormality, right-sided chamber dilatation, or ventricular fibrillation) detected, the leader was informed so that appropriate measures could be taken. Images and short video clips (6 s) were recorded in the ultrasound machine for review by faculty members who were blinded to the clinical outcomes.

All the information was collected in a predesigned pro forma which included demographic characteristics, location of cardiac arrest, POCUS findings during CPR, duration of CPR, drugs given during CPR, and cardiac arrest outcomes (ROSC, SIA, and STHD). All information was collected and collated in a Microsoft Excel spreadsheet (Microsoft Office-365). Categorical variables were presented in numbers and proportion. Shapiro–Wilk test was used to test the normality of quantitative variables. Normally distributed data were presented as mean + standard deviation (SD), whereas nonnormal variables were presented as the median and interquartile range (IQR). Comparison of categorical variables was done by Chi-square test and Yate's correction was done in the contingency table with cell count <5. Comparison of quantitative variables was done by Student's *t*-test (for mean and SD) and Mann–Whitney *U*-test (for median, IQR). To assess the association of different variables with the cardiac arrest outcomes, univariate logistic regression was used. Logistic regression was done to find out the predictors of cardiac arrest outcomes. Categorical covariates considered for analysis were gender, location of arrest, bystander witnessed arrest, and presence of initial cardiac activity in POCUS. Continuous variables considered for the model were age (in years), number of epinephrine doses, and duration of CPR (in minutes). Variables which were predicting the study outcomes in the univariate analysis with a $P \leq 0.20$, were utilized in multivariate logistic regression to find out the independent predictors. All the above analyses were performed were prepared with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY, USA: IBM Corp. All tests of significance used a two-sided $P \leq 0.05$. Diagrams were prepared in GraphPad Prism version 8.0.0 for Windows, GraphPad Software, San Diego, California, USA. The study was conducted in compliance with Strengthening the Reporting of Observational Studies in Epidemiology guidelines.

Results

A total of 140 cardiac arrest patients were screened, and finally, only 84 were included in the analysis [Figure 1]. The median age of the study population was 55 years (IQR: 44–66) and 68% ($n = 57$) of participants were males. Out of 84 patients, 61 (73%) patients were IHCA, and 23 (27%) were OHCA. Among the 23 OHCA patients, 11 patients had witnessed cardiac arrest. Initial rhythm on the cardiac monitor was asystole in 56 (66.7%) patients and pulseless electrical activity (PEA) in 28 (33.3%) patients. The median duration of CPR was 20 min (IQR: 15–31.5) in our study. The rate of ROSC, SIA, and STHD was found in 23 (27.4%), 9 (10.7%), and 2 (2.4%) patients, respectively.

Only 15 out of 84 (17.9%) patients had cardiac activity on the POCUS examination. Cardiac activity was seen in 12 out of 23 patients of ROSC (52.2%), which was significantly higher ($P < 0.001$) as compared with the no-ROSC group (3 out of 61, 4.9%). There was no statistical difference in the incidence of initial cardiac activity in patient groups admitted (3 of 9, 33.3%) versus died (12 of 75, 16%). Similarly, the proportion of patients having initial cardiac activity among patients discharged (1 out of 2, 50%) was not different from that of who died (14 out of 82, 17.1%). Detailed characteristics of the study population, cardiac arrest outcomes, and POCUS findings are depicted in Table 1.

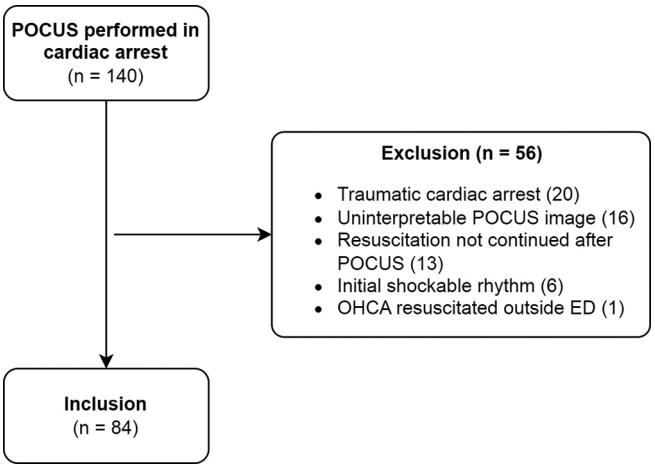

Figure 1: Flow diagram showing the number of patients screened, excluded, and included finally. POCUS: Point-of-care ultrasound, OHCA: Out-of-hospital cardiac arrest, ED: Emergency department

Table 1: Characteristics of the study population

	ROSC			SIA			STHD		
	Median (IQR) or counts (%)		*P**	Median (IQR) or counts (%)		*P**	Median (IQR) or counts (%)		*P**
	No (*n*=61)	Yes (*n*=23)		No (*n*=75)	Yes (*n*=9)		No (*n*=82)	Yes (*n*=2)	
Age (years)	58 (45-71)	58 (45-70)	0.34	57 (44-67)	50 (38-63)	0.33	56 (45-67)	22 (18-25)	0.14
Gender (male)	41 (67.2)	16 (69.6)	0.84	50 (66.7)	7 (77.8)	0.5	56 (68.3)	1 (50)	0.58
Arrest location									
IHCA	39 (63.9)	22 (95.7)	0.003	53 (70.7)	8 (88.9)	0.43	60 (73.2)	1 (50)	0.48
OHCA	22 (36.1)	1 (4.3)		22 (29.3)	1 (11.1)		22 (26.8)	1 (50)	
Witnessed arrest	10 (16.4)	1 (4.3)	0.28	10 (13.3)	1 (11.1)	0.66	10 (12.2)	1 (50)	0.25
Rhythm									
Asystole	47 (77)	9 (39.1)	0.002	52 (69.3)	4 (44.4)	0.152	56 (68.3)	0	0.11
PEA	14 (23)	14 (60.9)		23 (30.7)	5 (55.6)		26 (31.7)	2 (100)	
Number of epinephrine doses	3 (3-4)	3 (3-3)	0.005	3 (3-4)	3 (3-3)	0.62	3 (3-4)	3 (2-3)	0.29
CPR duration (min)	28 (15-33)	15 (14-20)	0.002	22 (15-33)	15 (12-18)	0.01	20 (15-32)	11 (8-14)	0.02
Presence of cardiac activity	3 (4.9)	12 (52.2)	<0.001	12 (16)	3 (33.3)	0.19	14 (17.1)	1 (50)	0.33

**P* value denotes level of significance. ROSC: Return of spontaneous circulation, SIA: Survival to inpatient admission, STHD: Survival to hospital discharge, IQR: Interquartile range, OHCA: Out-of-hospital cardiac arrest, IHCA: In-of-hospital cardiac arrest, CPR: Cardiopulmonary resuscitation, PEA: Pulseless electrical activity

In the univariate analysis, the ROSC was predicted significantly by in-hospital location of arrest, lesser duration of CPR, lesser requirement of epinephrine, presence of PEA compared to asystole, and presence of initial cardiac activity in POCUS. After conducting the multivariate analysis of these above-mentioned covariates, only lesser duration of CPR (adjusted odds ratio [aOR]: 0.93, 95% confidence interval [CI]: 0.86–0.99, $P = 0.04$) and the presence of initial cardiac activity (aOR: 24.8, 95% CI: 3.17–89.41, $P < 0.002$) independently predicted the ROSC. The results of these regression analyses for the prediction of ROSC are presented in Table 2 and Figure 2. In our study, none of the covariates independently predicted the SIA and STHD [Supplementary Tables 1 and 2].

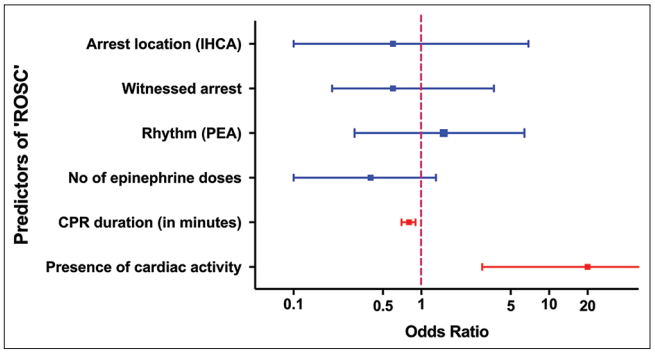

Figure 2: Forest plot depicting the adjusted odds ratio of predictors of "Return of spontaneous circulation." Footnotes: ROSC: Return of spontaneous circulation, IHCA: In-hospital cardiac arrest, PEA: Pulseless electrical activity, CPR: Cardiopulmonary resuscitation

It was found that the presence of sonographic cardiac activity was specific in predicting cardiac arrest outcomes, although sensitivity was poor. Diagnostic statistics of cardiac activity for arrest outcomes are depicted in Table 3. The positive likelihood ratio of cardiac activity for predicting ROSC was 10.6, which implies a large and significant increase in the probability of ROSC if cardiac activity is present.

Although our objective of the study was to investigate the association of initial cardiac activity with cardiac arrest outcomes, during our study, we found a worth-mentioning entity, i.e., in three patients, the rhythm on the cardiac monitor was asystole, but during sonography, they were found to be in ventricular fibrillation.

Discussion

Our study attempted to predict the outcome of cardiac arrest patients presenting to ED by assessing initial cardiac activity by bedside sonography. We conducted this study in a low-resource setting where the volume of cardiac arrest is very high. Here, the initial prognostication of cardiac arrest outcomes takes the upper hand as we can allocate the resources sustainably. Only a few studies on this field were conducted in a low-resource setting.[9,10]

A wide variation in characterization of cardiac activity was found in the existing literature.[8] We have defined initial cardiac activity as any visible cardiac movement in POCUS, after 2 min of initiation of CPR. Few studies worth mentioning that strictly defined the timing of POCUS were Kim *et al*.,[7] Gaspari *et al*.,[4] Salen *et al*.,[11] and Zengin *et al*.,[9] whereas many studies have not defined the timing of POCUS examination.[10,12-14]

In our study, the initial cardiac activity was seen in half of the patients with ROSC which was significantly higher than in the no-ROSC group where less than a twentieth of patients had cardiac activity. This was in line with a previous study by Blaivas *et al*.[2] Our study showed that the patients with initial cardiac activity had a higher odds

Table 2: Predictors of return of spontaneous circulation

	Univariate analysis		Multivariate analysis	
	Unadjusted OR	*P*	Adjusted OR	*P*
Age	1.01 (0.98-1.04)	0.34		
Gender (male)	1.12 (0.39-3.14)	0.84		
Arrest location (IHCA)*	0.08 (0.01-0.64)	0.02	0.56 (0.01-6.89)	0.99
Witnessed arrest	0.23 (0.03-1.92)	0.18	0.55 (0.21-3.65)	0.89
Rhythm (PEA)**	5.22 (1.87-14.60)	0.002	1.47 (0.34-6.44)	0.61
Number of epinephrine doses	0.35 (0.16-0.76)	0.009	0.43 (0.15-1.19)	0.1
CPR duration (min)	0.91 (0.86-0.97)	0.003	0.93 (0.86-0.99)	0.04
Presence of cardiac activity	21.1 (5.09-87.25)	<0.001	24.8 (3.17-89.41)	0.002

*Reference for "arrest location" was OHCA, **Reference for "rhythm" was asystole. Variables which were predicting the study outcomes in the univariate analysis with a $P \leq 0.20$, were utilized in multivariate logistic regression to find out the independent predictors. OR: Odds ratio, IHCA: In-hospital cardiac arrest, PEA: Pulseless electrical activity, OHCA: Out-of-hospital cardiac arrest, CPR: Cardiopulmonary resuscitation

Table 3: Diagnostic statistics of "initial cardiac activity" in predicting cardiac arrest outcomes

Cardiac arrest outcomes	Diagnostic statistics of "initial cardiac activity" in POCUS			
	Sensitivity	Specificity	PPV	NPV
ROSC	52.2% (30.6-73.2)	95.1% (86.3-99)	80% (55.4-92.8)	84.1% (77.4-89)
SIA	33.3% (7.5-70.1)	84% (73.7-91.5)	20% (8-42)	91.3% (86.8-94.4)
STHD	50% (1.3-98.7)	82.9% (73-90.3)	6.7% (1.6-23.6)	98.5% (94.4-99.6)

ROSC: Return of spontaneous circulation, SIA: Survival to inpatient admission, STHD: Survival to hospital discharge, PPV: Positive predictive value, NPV: Negative predictive value, POCUS: Point-of-care ultrasound

of achieving ROSC (aOR: 24.8, 95% CI: 3.17–89.4). This was supported by few studies. Two similar ED-based observational studies reported the odds ratio for ROSC ranging from 6.33 to 16.11.[4,7] Gaspari *et al*.[4] and Kim *et al*.[7] had included only OHCA patients, whereas our study included both OHCA and IHCA patients.

The presence of initial cardiac activity did not predict the SIA, which is similar to a large multicentric study by Gaspari *et al*.[4] In our study, none of the covariates predicted the STHD. This finding was also similar to the previously conducted studies.[4,9,15]

Interestingly, in three patients, the monitor rhythm analysis showed asystole, but sonography identified it as ventricular fibrillation. Thus, in these cases ultrasonography (USG) helped in making critical decisions and prompt defibrillation. We found two case reports, in which VF was mimicking asystole and diagnosed only by doing USG.[16,17] During resuscitation electrocardiogram leads can be displaced and monitor may show asystole or sometimes it is very difficult to differentiate between asystole and fine VF by analyzing only one lead. In these cases, POCUS can diagnose the actual rhythm and appropriate steps can be taken as the treatment modality of the two rhythms is different.

In 2019, in a review by SHoC investigators included 10 (1486 participants) studies, cardiac activity on POCUS had the odd ratios of 16.90 (6.18–46.21) for ROSC, 10.30 (5.32–19.98) for survival to hospital admission and 8.03 (3.01–21.39) for STHD.[18] In contrast to this, a review conducted by the ALS Task Force of the ILCOR in 2020 concluded that no sonographic finding was sufficient to predict clinical outcome and POCUS should not be used as the sole method to terminate resuscitation.[8] Our study was one of the studies supporting the use of POCUS in predicting at least one of the cardiac arrest outcomes, i.e., the ROSC. Larger studies with stringent protocols will be able to answer the discrepancy regarding POCUS as a prognostic marker.

Limitations

Our study was a single-center study, limiting the findings' generalizability. Consecutive sampling was done which lead to selection bias in our study. It also suffered from sampling bias as both IHCA/OHCA patients were included in the study. Along with that, due to a smaller sample size, the odds ratios had a wide range of CIs. We have excluded a subgroup of patients, in whom it was difficult to acquire ultrasound images due to anatomical difficulties, which in fact again limits the generalizability of our study. We have investigated the role of the "initial cardiac activity" as a predictor of outcomes, but the subsequent cardiac activity records were not reviewed. The cardiac arrest outcomes in our study were far below the international standards, hence findings might not be generalizable to developed countries.

Conclusion

In our study, initial cardiac activity assessed by POCUS predicted the rate of ROSC significantly but it was not associated with other arrest outcomes such as SIA and discharge. Further studies including larger sample size,

subsequent sonographic cardiac activity information, and involving a single group (IHCA or OHCA) should be conducted.

Author contributions statement

- Dr. Soumitra – conceptualization, methodology, data curation, writing – original draft, supervision
- Dr. Ankit – writing – original draft, statistical analysis, visualization, methodology, revision
- Dr. Sanjeev – conceptualization, investigation, resources, data curation, writing – review and editing, supervision
- Dr. Tej – conceptualization, data curation, writing – review and editing, supervision.

Conflicts of interest

None declared.

Ethical approval

- Name of the board: Institute Ethics Committee, All India Institute of Medical Sciences, New Delhi, India
- Approval number: IECPG-609/08.12.2016
- Approval Date: 16/02/2017
- Again revised on: 19/06/2022.

Consent to participate

Consent was taken after the end of resuscitative efforts as waiver of informed consent from legally accepted representative of the patient.

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Supplementary Table 1: Predictors of survival to inpatient admission

	Univariate analysis		Multivariate analysis	
	Unadjusted OR	*P*	Adjusted OR	*P*
Age (years)	0.98 (0.94-1.02)	0.29		
Male gender	1.75 (0.34-9.05)	0.51		
Arrest location (IHCA)*	0.30 (0.04-2.55)	0.27		
Witnessed arrest	0.81 (0.09-7.21)	0.85		
Rhythm (PEA)**	2.83 (0.70-11.5)	0.15	1.72 (0.31-9.61)	0.54
Number of epinephrine doses	0.75 (0.30-1.85)	0.53		
CPR duration (min)	0.89 (0.79-0.99)	0.04	0.90 (0.80-1.01)	0.06
Presence of cardiac activity	2.63 (0.58-11.97)	0.16	1.53 (0.24-9.82)	0.66

*Reference for "arrest location" was OHCA, **Reference for "rhythm" was asystole. Variables which were predicting the study outcomes in the univariate analysis with a $P \leq 0.20$, were utilized in multivariate logistic regression to find out the independent predictors. OR: Odds ratio, IHCA: In-hospital cardiac arrest, PEA: Pulseless electrical activity, CPR: Cardiopulmonary resuscitation. OHCA: Out-of-hospital cardiac arrest

Supplementary Table 2: Predictors of survival to hospital discharge

	Univariate analysis		Multivariate analysis	
	Unadjusted OR	*P*	Adjusted OR	*P*
Age (years)	0.83 (0.65-1.07)	0.25		
Male gender	0.46 (0.03-7.72)	0.59		
Arrest location (IHCA)*	2.73 (0.16-45.5)	0.49		
Witnessed arrest	7.21 (0.41-12.43)	0.18	4.69 (0.23-9.57)	0.16
Rhythm (PEA)**	1.24 (0.03-14.57)	0.99		
Number of epinephrine doses	0.17 (0.01-2.13)	0.17	0.76 (0.05-10.62)	0.84
CPR duration (min)	0.64 (0.36-1.14)	0.13	0.73 (0.45-1.16)	0.18
Presence of cardiac activity	4.86 (0.29-82.38)	0.17	0.77 (0.01-14.65)	0.92

*Reference for "arrest location" was OHCA, **Reference for "rhythm" was asystole. Variables which were predicting the study outcomes in the univariate analysis with a $P \leq 0.20$, were utilized in multivariate logistic regression to find out the independent predictors. OR: Odds ratio, IHCA: In-hospital cardiac arrest, PEA: Pulseless electrical activity, CPR: Cardiopulmonary resuscitation, OHCA: Out-of-hospital cardiac arrest