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ORIGINAL RESEARCH

Point-of-Care Testing (POCT) for Blood Gas and Electrolyte Analysis in Out-of-Hospital Cardiac Arrests' Management; a Cross-sectional Study

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Abstract: **Introduction:** Hypokalemia, hyperkalemia, and acidosis are among the reversible causes of out-of-hospital cardiac arrest (OHCA) that can be promptly identified using point-of-care testing (POCT) for blood gas and electrolyte analysis. This study aimed to evaluate the efficacy of POCT in the prehospital setting for OHCA management. **Methods:** In this cross-sectional study the management and outcomes of OHCA patients were compared before and after implementing the POCT for blood gas and electrolyte analysis by EMS in the prehospital setting of Ramathibodi Hospital, Thailand. **Results:** 217 OHCA patients with a mean age of 61 ± 17.07 (range: 58.72-63.28) years were studied (64.06 % male). 148 (68.2%) patients received POCT in the prehospital setting. Patients in the POCT group received higher administration of sodium bicarbonate ($p < 0.001$) and calcium gluconate ($p < 0.001$) compared to those without POCT. Sustained ROSC was achieved in 25% of the POCT group, compared to 11.59% in the no POCT group ($p = 0.030$). POCT blood gas analysis was identified as an independent predictor of sustained ROSC based on multivariable analysis (adjusted Odds: 4.60, 95% CI: 1.35-15.69; $p = 0.015$). **Conclusion:** It seems that POCT for blood gas and electrolyte analysis in the prehospital setting could improve sustained ROSC in OHCA patients by enabling rapid and targeted management of cardiac arrest's reversible causes.

Keywords: Point-of-Care Testing; Blood Gas Analysis; Out-of-Hospital Cardiac Arrest; Emergency Medical Services; Electrolytes

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1. Introduction

Out-of-hospital cardiac arrest (OHCA) is a significant global health concern, with an average incidence of 95.9 cases per 100,000 adults annually. Incidence in Europe varies widely, ranging from 19 to 106 cases per 100,000 per year (1). Data from the Paris Sudden Death Expertise Center Registry highlight this issue, reporting 3,670 cases of sudden cardiac arrest between May 2011 and December 2012. Most incidents (72%) occurred at home, with only 34% of patients receiving hospital treatment and a mere 7% surviving discharge (2). These findings emphasize the critical need for improved strategies in OHCA management to enhance survival outcomes.

A study conducted at Ramathibodi Hospital examined outcomes for in-hospital cardiac arrest (IHCA) patients, revealing that 67.3% achieved the sustained return of spontaneous circulation (ROSC) after cardiopulmonary resuscitation (CPR). Additionally, 18.0% were discharged alive, and 9.6% survived with favorable neurological outcomes. Notably, patients with cardiac-related causes demonstrated higher survival rates to hospital discharge with favorable neurological outcomes (3). In contrast, data on OHCA showed that only 29.17% of patients achieved sustained ROSC following CPR, with 13.26% discharged alive. For trauma-related OHCA, 18.45% survived to hospital admission (4).

Emergency Medical Services (EMS) play a critical role in improving survival rates for patients experiencing OHCA (5, 6). In addition to providing immediate care, EMS teams must identify reversible causes of cardiac arrest to enhance outcomes. The 5 H's and 5 T's framework outlines potentially reversible causes of cardiac arrest in adults. Among these, hydrogen ion imbalance (acidosis) and hyper/hypokalemia are two of the ten key causes that require laboratory testing for diagnosis. In contrast, other causes can typically be identified through history-taking and physical examination

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by healthcare providers (7, 8).

Acidosis during cardiac arrest results from inadequate blood circulation during CPR and hypercarbia, characterized by the accumulation of carbon dioxide in venous blood and tissues (9, 10). Acidosis can serve as both a cause of cardiac arrest and a secondary consequence in patients with cardiac arrest from other etiologies. Utilizing point-of-care testing (POCT) for blood gas and electrolyte analysis enables the measurement of blood acidity in prehospital settings, facilitating timely interventions that can improve the rate of ROSC (11, 12). Furthermore, this approach supports the identification of hyperkalemia or hypokalemia, which are additional reversible causes of cardiac arrest.

POCT for blood gas analysis is increasingly recognized as a critical tool in the prehospital management of OHCA. This technology provides real-time data on key parameters, including pH, lactate, potassium, and bicarbonate levels, enabling the rapid identification and management of reversible causes of cardiac arrest, such as acidosis and hyperkalemia (2, 7). Studies highlight the utility of POCT in guiding emergency teams toward targeted treatments and improving decision-making during prehospital care (12). Furthermore, evidence suggests that the timely detection of hypokalemia, hyperkalemia, and acidosis through POCT may improve rates of ROSC by enabling the immediate administration of targeted medications (13, 14).

In Thailand, the implementation of POCT for blood gas and electrolyte analysis in prehospital settings remains limited (5). Ramathibodi Hospital became the first institution in Thailand to implement POCT in prehospital care in February 2021, specifically for patients experiencing OHCA, sepsis, shock, and multiple traumas. The lack of widespread adoption restricts the ability to identify underlying causes of cardiac arrest before hospital arrival. As a result, emergency teams often face challenges in providing targeted treatments tailored to the patient's specific pathophysiological conditions, potentially leading to suboptimal outcomes (15). This study primarily aimed to evaluate the management of acidosis and hyperkalemia in prehospital OHCA patients between those who undergo POCT and those in a control group without POCT. The secondary objective was to evaluate sustained ROSC between patients who received POCT and those who did not, highlighting the broader clinical impact of integrating this diagnostic tool into prehospital emergency care.

2. Methods

2.1. Study design and setting

In this cross-sectional study, the management and outcomes of OHCA patients were compared before and after implementing the POCT for blood gas and electrolyte analysis by EMS in the prehospital setting of Ramathibodi Hospital, Mahidol University, Thailand.

We included consecutive OHCA patients aged 18 years or older who received advanced resuscitation from the EMS. As the POCT was implemented in prehospital care of OHCA cases in February 2021, a retrospective review was conducted for the period from 2020 to February 2023, and prospective patient data were collected starting from March to December 2023.

The EMS of Ramathibodi Hospital was established as the Ramathibodi Emergency Medical Operation (EMO) Unit. The EMO coordinates and deploys comprehensive life support (CLS) teams, led by an emergency physician, to provide advanced life support care for accidents or critical conditions. The EMO is assigned cases by the Bangkok EMS Center (Erawan Center) and is responsible for zone 8, which includes the areas surrounding the Faculty of Medicine, Ramathibodi Hospital, Mahidol University. Prehospital patient care incorporates specific investigative measures to enhance treatment efficiency and timeliness. One such initiative is the implementation of POCT for blood gas analysis, introduced in February 2021. This diagnostic tool is used in all cases, except in instances of device malfunctions, when results cannot be interpreted, or when the device is unavailable.

Ethical approval for this study was obtained from the Faculty of Medicine's Committee on Human Rights Related to Research Involving Human Subjects at Mahidol University's Ramathibodi Hospital, granted on February 16, 2023 (IRB COA. MURA2023/124). Written informed consent was obtained from each participant, in accordance with the ethical principles governing research involving human subjects.

2.2. Participants

Prehospital OHCA patients aged 18 years or older who received advanced resuscitation from the CLS team of the EMO Unit, Department of Emergency Medicine, Ramathibodi Hospital, were included in the study. Patients who had signed a do-not-attempt-resuscitation (DNAR) consent, showed signs of death upon arrival, resuscitation was declined by the emergency medical team, were pregnant, or had sustained traumatic injuries were excluded. A retrospective review was conducted for the period from 2020 to February 2023. Prospective data collection began in March 2023 and continued to December 2023. The study flow is illustrated in Figure 1.

2.3. Data collection

Baseline data for prehospital OHCA patients including age, gender, witness presence at the time of arrest, bystander CPR, use of automated external defibrillator (AED), initial rhythm (shockable or non-shockable), cause of cardiac arrest (cardiac, hypoxia, hypovolemia, intoxication, other, or unknown), total CPR duration, time to first dose of adrenaline, and total dose of adrenaline was collected.

During the retrospective phase, data was gathered from the Electronic Medical Record (EMR) system of Ramathibodi Hospital. For the prospective phase, data was collected from the EMO database of Ramathibodi Hospital. We collect retrospective data from January 2020 to February 2023 and prospective data from March 2023 to December 2023.

2.4. Definition

Out-of-hospital cardiac arrest (OHCA): refers to a cardiac arrest event that occurs before the arrival of EMS (16).
Return of Spontaneous Circulation (ROSC): is defined as the restoration of a palpable pulse and adequate blood pressure after successful CPR, without the need for mechanical support, lasting more than 20 minutes (16).
Presumed cause: refers to the most likely primary cause of cardiac arrest (16).
Response time: is the interval between the estimated time of cardiac arrest and the time the first responders or EMS arrive at the scene (16).

2.5. Outcomes

The primary outcome of this study was the administration of 7.5% sodium bicarbonate and 10% calcium gluconate for the management of acidosis and hyperkalemia in OHCA patients in the prehospital setting. The secondary outcome was sustained ROSC. These outcomes were measured to assess the impact of POCT blood gas analysis in guiding specific treatments and improving patient outcomes in prehospital settings.

2.6. Statistical analysis

The sample size was determined based on data from the EMO Unit of the Department of Emergency Medicine, Faculty of Medicine, Ramathibodi Hospital. The study focused on the administration of 7.5% sodium bicarbonate for acidosis and 10% calcium gluconate for hyperkalemia, as identified through POCT for blood gas and electrolyte analysis. The required sample size was calculated to be 88 patients. Sample size calculations were performed using STATA version 17.0, with a two-sided alpha level of 0.05, a power of 80%, and a ratio of 1.24 (No POCT group to POCT group).
Data analysis was conducted using STATA version 17.0 (StataCorp LLC, College Station, TX, USA), with statistical significance defined as a two-tailed P-value of <0.05. Categorical data were expressed as numbers and percentages, while continuous data were presented as means ± standard deviation (SD) for normally distributed variables and medians (interquartile range) for non-normally distributed variables.
The POCT group and the No POCT group were compared using t-tests or Mann-Whitney U tests for continuous variables, as appropriate. For categorical variables, proportions were compared using Exact Probability Tests. All analyzed variables were summarized in a single table.
Multivariable logistic regression analysis was performed to adjust for potential confounding variables affecting the outcome measures. Adjusted odds ratios (ORs) were calculated to interpret the results and guide subsequent applications.

3. Results

This study evaluated 280 OHCA cases over four years of service provided by the EMO unit at Ramathibodi Hospital. Patients who had signed a do-not-attempt-resuscitation (DNAR) consent, showed signs of death upon arrival, were pregnant, or had sustained traumatic injuries were excluded (figure 1). Finally, 217 patients with a mean age of 61 ± 17.07 (range: 58.72-63.28) years were included in the study (64.06 % male). Among them, 148 patients underwent POCT for blood gas analysis, with 38 (25.68%) receiving arterial blood testing and 110 (74.32%) undergoing venous blood testing.
The mean age was similar in POCT and no POCT groups (60.36 ± 18.28 vs. 62.36 ± 14.16 years; respectively p = 0.423). There was no significant difference in the proportion of males between the two groups (p = 0.650). In the POCT group, 81 (54.73%) patients experienced witnessed arrest, compared to 33.33% in the no POCT group (p = 0.004). The use of AED was significantly higher in the POCT group (34.46% vs. 11.59%; p < 0.001). The response time was longer in the POCT group compared to the no POCT group (16 vs. 11 minutes; p < 0.001). The rate of hypoxia (40.54% vs. 17, 24.64%; p = 0.023) and metabolic causes such as hypokalemia, hyperkalemia, and acidosis (56.08% vs. 10.14%; p < 0.001) were significantly higher in POCT group. The use of POCT led to higher administration of 7.5% sodium bicarbonate (83.78% vs. 34.78%; p < 0.001) and 10% calcium gluconate (52.70% vs. 21.74%; p < 0.001).
The median time to the first dose of 7.5% sodium bicarbonate was 16 (IQR 13–20.5) minutes in the POCT group and 18 (IQR 11–25) minutes in the No POCT group (p = 0.665). Similarly, the mean time to the first dose of 10% calcium gluconate was 18.59 ± 7.69 minutes in the POCT group and 21.73 ± 8.66 minutes in the No POCT group (p = 0.157), as shown in Figure 2. The rate of sustained ROSC was significantly higher in the POCT group (25.00% vs. 11.59%; p = 0.030). Finally, the number of patients undergone ongoing CPR upon arrival at the ED was higher in the No POCT group (31.88% vs. 14.19%; p = 0.003).
POCT blood gas testing at the prehospital setting was detected as an independent associated factor of sustained ROSC following OHCA (adjusted OR: 4.60; 95% CI: 1.35–15.69, p = 0.015) based on multivariable logistic regression analysis.

4. Discussion

POCT has demonstrated its value as a crucial tool for blood gas analysis in patients experiencing prehospital cardiac arrest. The application of POCT was associated with an increased rate of sustained ROSC, even after adjusting for potential confounding factors. These findings underscore the pivotal role of POCT in optimizing real-time clinical decision-making by delivering immediate diagnostic insights. This capability facilitates targeted interventions, such as administering 7.5% sodium bicarbonate and 10% calcium gluconate, to address critical conditions like metabolic acidosis and hyperkalemia. By enabling the detection and management of these underlying factors during resuscitation, POCT significantly improves the precision and effectiveness of prehospital care, ultimately enhancing patient outcomes.

We observed that traditional predictors, such as bystander CPR and witnessed arrests, were not significantly associated with sustained ROSC. However, definitive conclusions cannot be drawn due to an insufficient sample size. Additionally, we found that longer CPR durations and higher doses of adrenaline were associated with poorer outcomes, highlighting the importance of timely and targeted interventions to improve patient prognosis(2, 17, 18).

Gruebl et al. (12) investigated the impact of POCT during prehospital resuscitation, focusing on its role in guiding specific treatments such as administering sodium bicarbonate and potassium chloride. Their study analyzed 263 prehospital resuscitations, with POCT applied in 98 cases. The findings revealed that 63% of tested patients exhibited severe metabolic acidosis, while 17% showed significant potassium imbalances. Notably, 30% of patients in the POCT group survived hospital discharge, compared to 16% in the No POCT group. However, it is important to note that our study did not assess survival outcomes extending to hospital discharge.

In contrast, Heikkilä et al. (17) reported no significant association between the use of POCT and improved rates of ROSC or survival to hospital discharge in patients with non-traumatic OHCA. Their study highlights that while POCT facilitates the identification of metabolic disturbances, it does not consistently translate into improved long-term outcomes. This discrepancy could be attributed to variations in study design, the timing of POCT implementation, or differences in resuscitation strategies employed across studies.

Furthermore, POCT blood gas results, such as pH and potassium levels, revealed trends that could potentially guide resuscitation strategies. However, the differences in metabolic parameters (e.g., pH, potassium) between the sustained ROSC and no sustained ROSC groups were not statistically significant. These findings suggest that while POCT blood gas analysis provides valuable real-time diagnostic data, its parameters may not directly predict or determine ROSC outcomes. This contrasts with previous studies that underscored the utility of POCT in OHCA patients with non-shockable rhythms, where potassium (K) levels have been identified as a potential predictor of ROSC (2, 19).

The varying outcomes reported in studies on resuscitation scenarios highlight that the effectiveness of POCT may depend on multiple factors in OHCA cases (20). These factors include the timing of interventions, the specific metabolic disturbances present, and the overall resuscitation strategy employed. POCT blood gas analysis offers real-time diagnostic insights that can guide clinical decisions and enable targeted treatments, potentially enhancing the quality of prehospital care and improving sustained ROSC rates.

However, the impact of POCT for blood gas and electrolyte analysis on neurological outcomes and survival to hospital discharge remains unclear. Further research involving larger sample sizes or randomized controlled trials is essential to determine its definitive role in improving survival rates and neurological outcomes. Additionally, evaluating the cost-effectiveness of integrating widespread POCT into EMS systems is crucial to guide its implementation on a larger scale.

5. Limitations

This study had several limitations. Firstly, some data were collected retrospectively from 2020 to February 2023, introducing the potential for information bias due to incomplete records. Secondly, the study was conducted at a single center, which may limit the generalizability of the findings to other settings or populations. Lastly, critical outcomes such as survival to hospital discharge and neurological outcomes, which are highly impactful for ROSC patients, were not recorded. These limitations should be considered when interpreting the results and their broader applicability.

6. Conclusions

It seems that POCT for blood gas and electrolyte analysis significantly enhances sustained ROSC in prehospital OHCA patients by enabling rapid identification and targeted treatment of metabolic imbalances, particularly acidosis and hyperkalemia. These findings underscore the value of POCT in optimizing prehospital cardiac arrest care and suggest its potential to refine resuscitation protocols, ultimately improving patient outcomes.

7. Declarations

7.1. Acknowledgements

None.

7.2. Authors' contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis, and interpretation, or in all these areas; took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

7.3. Ethical considerations

Ethical approval for this study was obtained from the Faculty of Medicine's Committee on Human Rights Related to Research Involving Human Subjects at Mahidol University's Ramathibodi Hospital, granted on February 16, 2023 (IRB COA. MURA2023/124).

7.4. Availability of data and material

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

7.5. Funding source

No funding was obtained for this study.

7.6. Competing interests

The authors declare that they have no competing interests.

7.7. Using Artificial intelligence chatbots

During the preparation of this work, the author(s) used ChatGPT4.0 and Grammarly AI to check and correct grammatical errors during the manuscript writing process. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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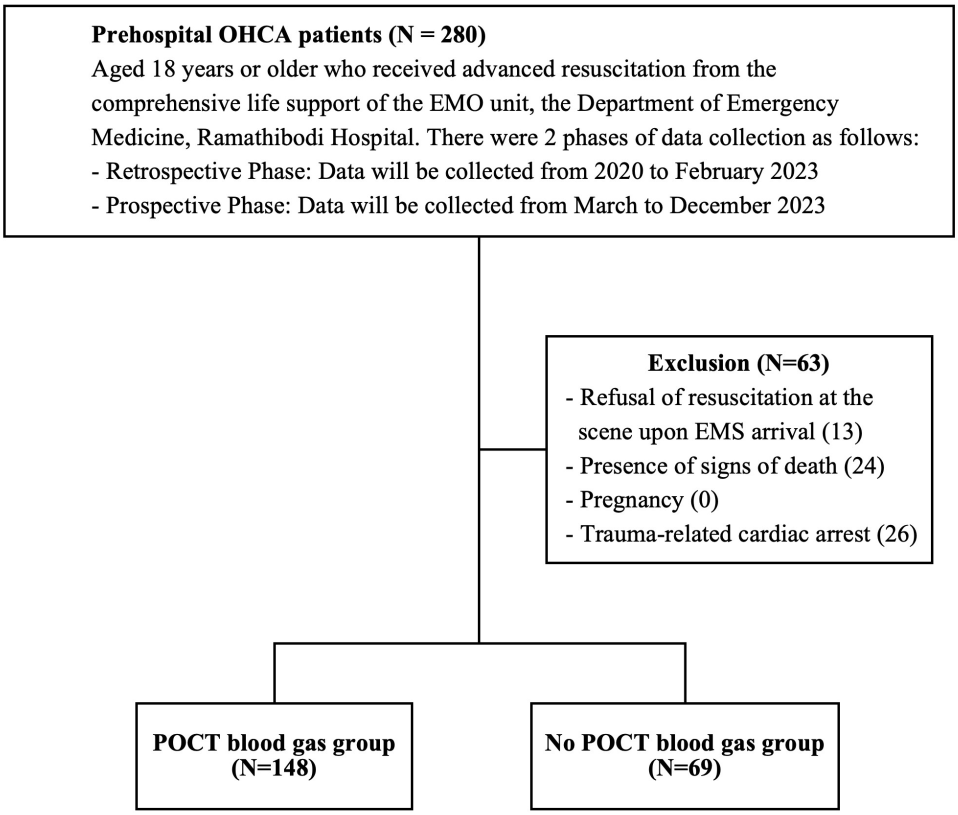

Figure 1: Study flow chart of patients' inclusion to the study.

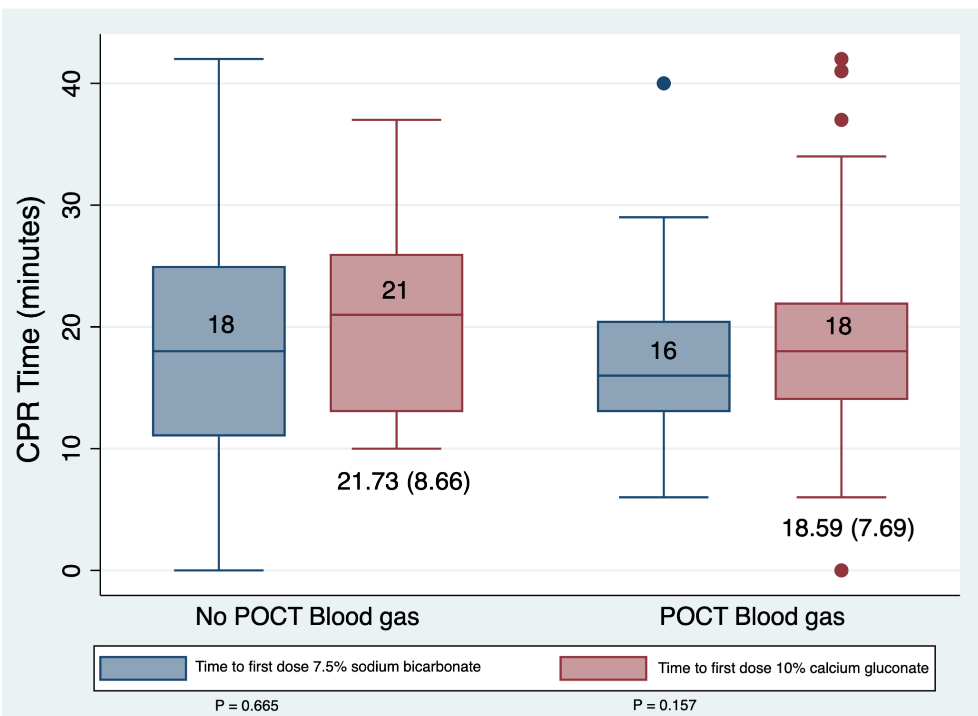

Figure 2: Time to first dose 7.5% sodium bicarbonate and 10% calcium gluconate (specific treatment) in prehospital Out-of-hospital Cardiac Arrest patient (POCT Blood gas group and No POCT Blood gas group)

Table 1: Comparing the baseline characteristics as well as outcomes between groups with and without doing point-of-care testing (POCT) following Out-of-hospital cardiac arrest

Prognostic Factors	**POCT Blood Gas**		**P-value**
	Yes (n = 148)	**No (n = 69)**	
Age (years)			
Mean ± SD	60.36 ± 18.28	62.36 ± 14.16	0.423
Gender			
Male	93 (62.84)	46 (66.67)	0.650
Witness arrest			
Yes	81 (54.73)	23 (33.33)	0.004
Bystander CPR			
Yes	137 (92.57)	59 (85.51)	0.137
Using AED			
Yes	51 (34.46)	8 (11.59)	< 0.001
Response time (minutes)			
Median (IQR)	16 (12-20)	11 (8-15)	< 0.001
Initial shockable rhythm			
Yes	25 (16.89)	11 (15.94)	1.000
Defibrillation			
Yes	65 (43.92)	20 (28.99)	0.038
Cause of cardiac arrest			
Cardiac cause	64 (43.24)	38 (55.07)	0.111
Hypoxia	60 (40.54)	17 (24.64)	0.023
Hypovolemia	13 (8.78)	5 (7.25)	0.797
Metabolic	83 (56.08)	7 (10.14)	< 0.001
Intoxication	4 (2.70)	1 (1.45)	1.000
Others (e.g. PE)	33 (22.30)	11 (15.94)	0.365
Unknown	17 (24.64)	2 (1.35)	< 0.001
7.5% sodium bicarbonate administration			
Number of patients	124 (83.78)	24 (34.78)	< 0.001
Total dose	2 (1-2)	1 (1-2)	0.009
Time to first dose (minutes)	16 (13-20.5)	18 (11-25)	0.665
10% calcium gluconate administration			
Number of patients	78 (52.70)	15 (21.74)	< 0.001
Total dose	3 (2-6)	3 (3-4)	0.673
Time to the first dose (minutes)	18.59 ± 7.69	21.73 ± 8.66	0.157
Total dose adrenaline	7 (5-8)	5 (3-7)	< 0.001
Time to the first dose adrenaline (minutes)			
Median (IQR)	5 (4 -6)	6 (4-10)	0.027
Total CPR time (minutes)			
Mean ± SD	33.24 ± 13.64	29.43 ± 10.86	0.043
Sustained ROSC > 20 minutes			
Yes	37 (25.00)	8 (11.59)	0.030
Ongoing CPR to ED			
Yes	21 (14.19)	22 (31.88)	0.003

Data are presented as mean ± standard deviation (SD), median (IQR), or frequency (%). IQR: interquartile range; CPR: cardiopulmonary resuscitation; AED: automated external defibrillator; PE: Pulmonary embolism; ROSC: return of spontaneous circulation; ED: Emergency department.