

# Point-of-Care Testing in Out-of-Hospital Cardiac Arrest: A Retrospective Analysis of Relevance and Consequences

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## Original research

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# Abstract

## Background

Metabolic and electrolyte imbalances are some of the reversible causes of cardiac arrest and can be diagnosed even in the pre-hospital setting with a mobile analyser for point-of-care testing (POCT).

## Methods

We conducted a retrospective observational study, which included analysing all pre-hospital resuscitations in the study region between October 2015 and December 2016. A mobile POCT analyser (Alere epoc®) was available at the scene of each resuscitation. We analysed the frequency of use of POCT, the incidence of pathological findings, the specific interventions based on POCT as well as every patient's eventual outcome.

## Results

N=263 pre-hospital resuscitations were included and in n=98 of them, the POCT analyser was used. Of these measurements, 64% were performed using venous blood and 36% using arterial blood. The results of POCT showed that 63% of tested patients had severe metabolic acidosis ( $\text{pH} < 7.2 + \text{BE} < -5 \text{ mmol/l}$ ). Of these patients, 82% received buffering treatment with sodium bicarbonate. Potassium levels were markedly divergent normal ( $> 6.0 \text{ mmol/l}$  /  $< 2.5 \text{ mmol/l}$ ) in 17% of tested patients and 14% of them received a potassium infusion. On average, the pre-hospital treatment time between arrival of the first emergency medical responders and the beginning of transport was 54 (+/- 20) min without POCT and 60 (+/- 17) min with POCT ( $p=0.07$ ). Overall, 21% of patients survived to hospital discharge (POCT 30% vs no POCT 16%,  $p=0.01$ ).

## Conclusions

Using a POCT analyser in pre-hospital resuscitation allows rapid detection of pathological acid-base imbalances and potassium concentrations and often leads to specific interventions on scene and could improve the probability of survival.

## 1 Background

Sudden cardiac arrest remains one of the main causes of death in Western industrialised countries<sup>1,2</sup>. Even with the best emergency medical care, only about 40% of patients who experience out-of-hospital cardiac arrest (OHCA) survive with return of spontaneous circulation (ROSC) to hospital admission and the average rate of survival to discharge in the Western world is less than 10%<sup>3-8</sup>.

The relevant guidelines highlight the importance of early detection and treatment of potentially reversible causes of cardiac arrest and explicitly mention potassium imbalances and other metabolic imbalances in

this regard. They recommend point-of-care testing (POCT) so that specific therapeutic measures can be taken if pathological values are found <sup>9,10</sup>.

Portable POCT devices are increasingly available today and so parameters such as electrolyte concentrations, lactate and blood glucose can quickly be determined at the site of the emergency in addition to the parameters of blood gas analysis such as pH value, partial gas pressures, base excess and bicarbonate concentration <sup>11,12</sup>. Such testing thus facilitates early, targeted treatment even before arrival at the hospital.

There are few studies available on changes in blood parameters determined in OHCA patients in the pre-hospital setting. We examined the effects of the on-scene availability of mobile POCT equipment in a physician-staffed emergency medical service.

## 2 Methods

### Research methods

Once we had obtained the approval of the ethics committee of the University of Marburg (ref. no.: 86/16), we retrospectively evaluated the POCT results of OHCA patients treated between October 2015 and December 2016. The standard emergency response for resuscitation cases in Germany and thus in the study region (1,263 km<sup>2</sup>, 199 inhabitants per km<sup>2</sup>) is to send out an emergency medical service unit with three paramedics and an emergency physician. Unusually at the time, every unit in the study region carried a POCT analyser (Alere epoc®, results available within approx. 3 min). All of these vehicles were operated by the same organisation and all staff had received the same training in advanced life support in accordance with the current applicable guidelines. There is only one hospital with a cardiac arrest centre in the study region, so, with very few exceptions, the resuscitation patients in our study were taken there. We collected the data for our evaluation from the ambulance reports and directly from the measuring instruments. It was anonymised before being stored and analysed.

We only used data from patients aged 18 years or older.

### Statistics

Depending on the scale level and the form of variable distribution, the mean value or median (central tendency), minima and maxima (extreme values) as well as standard deviation and interquartile ranges (measures of dispersion) were calculated for descriptive statistical analysis.

Frequency differences were tested for significance using the 2 X 2 contingency chi-squared test and, in the case of low cell occupancy, the Fisher's exact test.

In the individual patient groups with and without POCT analysis, differences in central tendency were assessed for significance using the t-test for independent samples and using the Mann-Whitney U-test for non-parametric differences.

## Endpoints

The primary endpoint was defined as the frequency and severity of metabolic and electrolyte imbalances in the point-of-care test results. The secondary endpoints were specific interventions by emergency physicians, time taken for POCT results to be available in practice, pre-hospital treatment time as well as course and outcome of further treatment.

## 3 Results

A total of  $n = 263$  pre-hospital resuscitations were included. In  $n = 98$  of these cases, the emergency physician on the scene used a POCT analyser. Detailed baseline patient data, POCT measurements, treatment times, and outcome are included in Table 1.

Of the patients who underwent POCT,  $n = 62$  (63%) were found to have severe acidosis with metabolic disturbance as a contributory cause ( $\text{pH} < 7.2 + \text{BE} < -5 \text{ mmol/l}$ ). There was no significant difference between patients with observed and unobserved collapse when it came to severe acidosis (observed + severe metabolic acidosis  $n = 34 / 56\%$  vs unobserved + severe metabolic acidosis  $n = 28 / 76\%$ ,  $p = 0.054$ ).

The only significant difference found between venous and arterial samples was found in terms of carbon dioxide partial pressure (Fig. 1). A severe potassium imbalance ( $< 2.5$  or  $> 6.0 \text{ mmol/l}$ ) was found in  $n = 17$  (17%) measurements (Fig. 2). We found a significant correlation between hypokalaemia and an initial shockable rhythm on electrocardiogram (ECG) (shockable + hypokalaemia  $n = 9$  (24%) vs non-shockable + hypokalaemia  $n = 2$  (3%),  $p = 0.003$ ). Patients with an initial non-shockable rhythm on ECG were more likely to be hyperkalaemic (non-shockable + hyperkalaemia  $n = 15$  (25%) vs shockable + hyperkalaemia  $n = 2$  (5%),  $p = 0.013$ ).

Sodium bicarbonate 8.4% ("bicarb") was administered to  $n = 61$  (62%) of the  $n = 98$  patients who underwent POCT and to  $n = 23$  (14%) of the  $n = 165$  who did not. Of the patients who underwent POCT,  $n = 22$  (22%) received potassium-specific treatment. Potassium chloride was used in  $n = 14$  (64%) of these cases. Of these, three patients with normal potassium levels ( $3.5\text{--}5.2 \text{ mmol/l}$ ) were treated with potassium chloride while simultaneously administration of bicarb. In  $n = 8$  (36%) cases, calcium chloride 10% was used; however,  $n = 11$  (69%) patients with a measured potassium concentration of over  $6.0 \text{ mmol/l}$  were not treated in accordance with the guidelines by the emergency physician (Fig. 3). No other specific therapeutic measures aimed at reducing serum potassium were used.

The average time from arrival on scene to the result of the POCT becoming available during resuscitation and before the first ROSC was 26 minutes ( $\pm 15 \text{ min}$ ). The total pre-hospital treatment time from arrival at the scene of the emergency to the beginning of transport to the hospital by ambulance was 57 minutes on average ( $\pm 19 \text{ min}$ ) without POCT and 60 min ( $\pm 17 \text{ min}$ ) with POCT ( $p = 0.07$ ) (Fig. 4).

Out of the n = 263 OHCA patients included in this study, n = 55 (21%) were discharged from hospital. Of the n = 98 patients who underwent POCT, n = 29 (30%) survived to be discharged, compared with n = 26 (16%) of the n = 165 who did not undergo POCT (p = 0.01) (Table 1, Fig. 5).

## 4 Discussion

In this retrospective observational study of point-of-care testing in OHCA patients, we found frequent abnormalities in acid-base balance and electrolyte concentrations. Therapeutic measures were regularly carried as a result yet on-site treatment time was not extended significantly. An improved survival probability in OHCA patients who undergo POCT was observed.

### Data acquisition

Since all of the emergency medical service units (with emergency physicians) in this study region were operated by the same organisation and all of the vehicles were equipped with identical POCT equipment, there was no bias due to lack of equipment availability nor were there differences in measurements due to differences in training or differences between devices. Furthermore, since all patients in the study region are transported to the only available cardiac arrest centre, every patient in this study received similar hospital treatment and we were able to collect a complete set of data covering the entire course of treatment.

### Interpretation of the results

Abnormal pre-hospital POCT results can determine the choice of treatment. Given that such abnormal results occurred so frequently in this study, it seems to be important and useful to determine them as early as possible. In some cases, however, it must also be determined whether such values really do indicate subsequent treatment. In general, the more unfavourable a patient's prognosis (due to a long period without resuscitation measures, for example), the further outside the reference range that patient's POCT results are likely to be. In such cases, these early test results could be seen as an indicator of the prognosis rather than as a trigger for therapeutic measures.

The available evidence for administering buffer substances to resuscitation patients, for instance, is inconsistent. There are also no exact pH value limits to trigger buffering and the subject is controversial<sup>13-18</sup>. On the one hand, with increasing acidosis, the oxygen-haemoglobin dissociation curve shifts favourably within a certain range and oxygen release to peripheral tissues increases. On the other hand, acidosis reduces myocardial contractility, the threshold for possible ventricular fibrillation and the effectiveness of catecholamines<sup>17,19</sup>. What is clear, however, is that alkalosis is harmful to resuscitation patients<sup>20,21</sup>. What is more, buffering has the side effect of decreasing serum potassium concentration<sup>22</sup>.

In this study, many patients had metabolic acidosis that required treatment. Patients who had collapsed unobserved and had an initial non-shockable rhythm on ECG were also often found to have pH and

potassium levels indicative of acidosis and hyperkalaemia, respectively. These observations could potentially be interpreted as a basis for further treatment options if no POCT analyser is available. Taking such treatment measures without previously recorded baseline values could result in incorrect treatment, however.

There was no significant difference between venous and arterial samples in terms of the parameters that are relevant for buffering (pH, BE). Venous sampling thus seems sufficient.

While the need for buffering is controversially discussed, electrolyte imbalances should always be treated and there are clear relevant recommendations<sup>10</sup>. The frequency of hyperkalaemia found in this study as well as the deficit in terms of its treatment even when diagnosed early both suggest a lack of awareness of the issue, at least in the cases included in our study. The precise reasons for the deficit in treatment could not be determined in this study due to its design without questionnaires.

However, irrespective of these findings, for any measure taken in an emergency situation, the time and effort required must be weighed against the benefit. We found that treatment at the scene of the emergency was not delayed to any relevant extent by performing POCT. This was likely due to the common practice of taking a blood sample when placing an intravenous catheter, which does not require additional training on the part of the emergency medical team members and can thus easily be delegated. Venous sampling also happens to be more suitable for determining acid-base status<sup>23,24</sup>.

The results of our study suggest that patients who undergo POCT have better prognosis in overall outcomes.

### Limitations

The retrospective design of this study without patient randomisation leaves some uncertainties when it comes to interpreting the results. Because the emergency medical service teams were not interviewed, their reasons for performing or, as the case may be, not performing POCT remain unclear. We compared the patient groups with and without pre-hospital point-of-care testing for a first overview of the topic even though these patient groups arose only by chance. Our assessment of the differences between these two groups is limited by these factors and any interpretations of our results must be cautious.

Because resuscitation patients are generally older and have acute pathologies, their prognosis is generally poor. Treatment for OHCA (including resuscitation) is a complex, multimodal process that is performed in a wide range of settings with many different influencing variables. All of these factors make it difficult to assess the effect of any individual measure, which, combined with the lack of proper patient randomisation in our study, means that our observations and evaluations must be interpreted with caution. However, we believe this makes it all the more important to optimise the treatment process wherever possible and appropriate.

### Perspectives

Whether POCT is globally applicable is open to debate. Germany has a comprehensive emergency medical service system with emergency physicians. We can assume therefore that emergency medical service teams in Germany have the specialist skills required to interpret the results of point-of-care testing and incorporate them into their response. Indeed, this additional measure appears to be primarily carried out by emergency medical service teams with advanced skills and training, which in itself presumably has a favourable effect on the patient's overall prognosis. In general, we recommend using POCT at least in cases of suspected metabolic or electrolyte imbalances in the peri-arrest period. Further research should determine whether POCT can be used as part of the treatment process without negative consequences (or potentially even to the benefit of the patient) if the necessary training for emergency medical service teams is provided and standard procedures for its use as a diagnostic tool and the consequent complex treatment are established.

## 5 Conclusions

This study shows that emergency physicians can easily perform POCT on resuscitation patients in the field. Such testing frequently revealed severe acidosis with metabolic imbalance as a contributory cause as well as abnormal potassium levels. Such findings are relevant for treatment and the fact that they occur so frequently demonstrates the relevance of this diagnostic tool in the pre-hospital acute setting. Since the overall duration of treatment was not adversely affected by pre-hospital point-of-care testing as an additional measure and because there was evidence of improved survival rates as a result, we believe that the benefits of this approach outweigh its disadvantages. We therefore conclude that the use of a POCT analyser could further optimise the treatment process for OHCA patients.

Further prospective, controlled and randomised trials on this topic are needed to verify our results.

## Abbreviations

**Asys** asystole

**BE** base excess

**bicarb** sodium hydrogen carbonate

**Ca** calcium

**CPR** Cardiopulmonary Resuscitation

**ECG** Electrocardiogram

**K<sup>+</sup>** potassium

**KCl** potassium chloride

**pCO<sub>2</sub>** partial pressure of carbon dioxide

**PEA** pulseless electrical activity

**PES** pre-emergency status

**pH** potentia hydrogenii

**POCT** point-of-care testing

**pVT** pulseless ventricular tachycardia

**ROSC** return of spontaneous circulation

**VF** ventricular fibrillation

## **Declarations**

### **Ethics approval:**

The ethics committee of the Philipps-Universität Marburg approved this study (ref. no.: 86/16).

### **Consent for publication:**

All authors have consented to the publication of this study and all data are anonymised.

### **Availability of data:**

All data are available at the emergency centre of the University of Marburg.

### **Competing interests:**

The authors declare that they have no competing interests.

### **Funding:**

This study was not funded.

### **Authors' contributions:**

Gruebl, Tobias	Writing – original draft, investigation, formal analysis, visualization
Ploeger, Birgit	Investigation, data acquisition and processing
Wranze-Bielefeld, Erich	Data acquisition and processing, investigation
Mueller, Markus	Resources, software
Schmidbauer, Willi	Writing – review & editing, resources
Kill, Clemens	Supervision, validation, writing – review & editing
Betz, Susanne	Project administration, methodology, investigation, writing – review & editing

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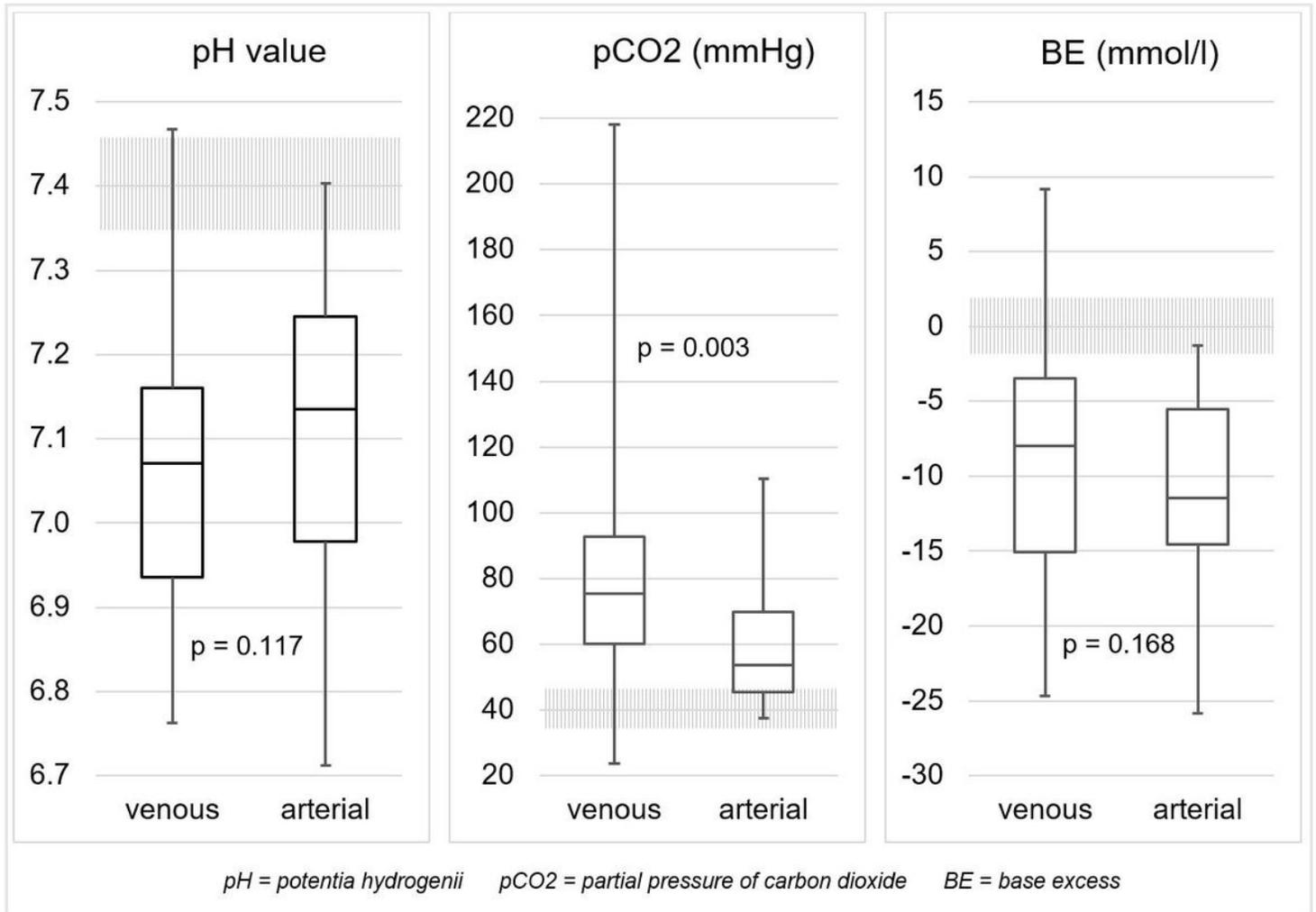
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## Tables

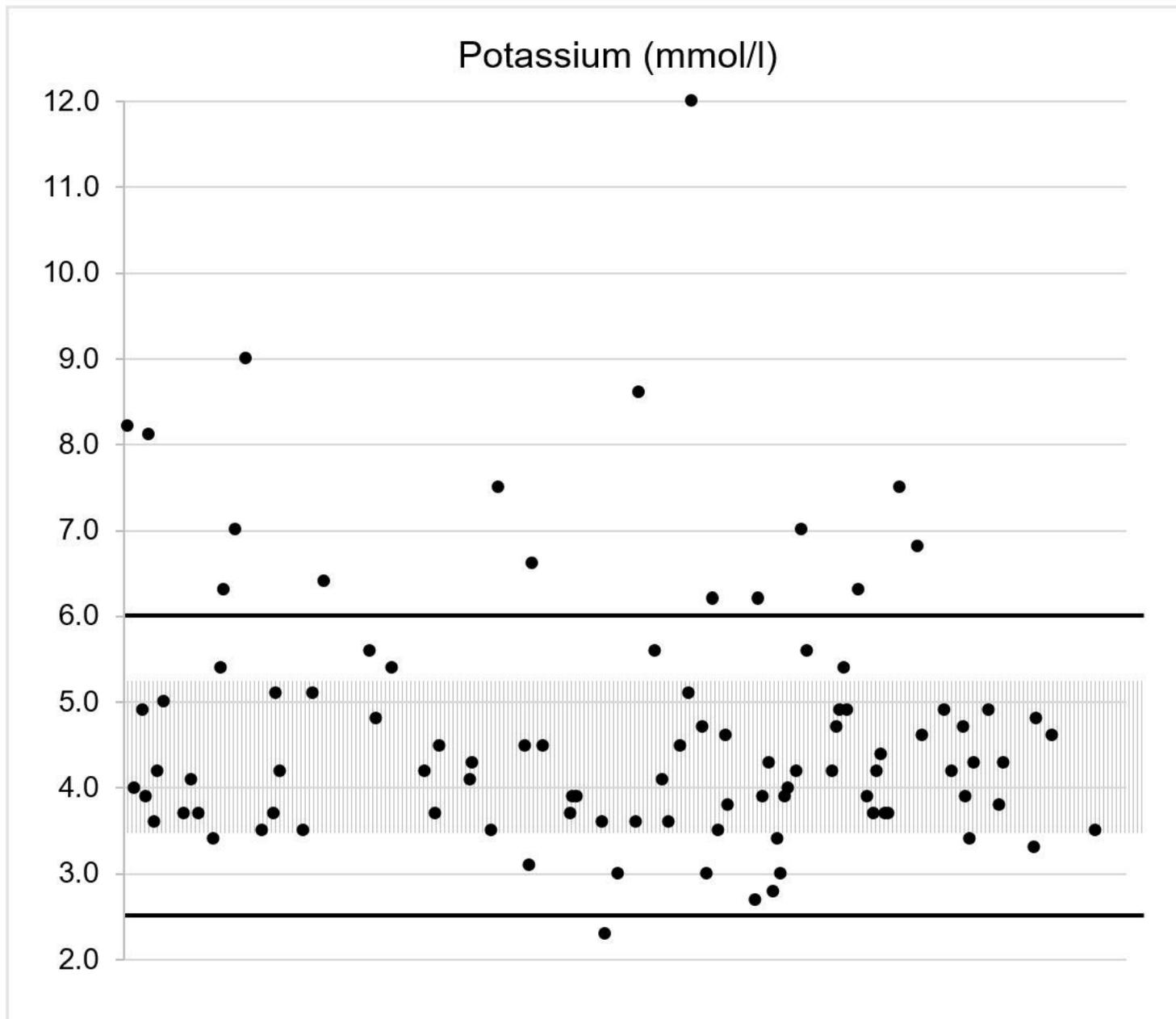
Due to technical limitations, table 1 is only available as a download in the Supplemental Files section.

## Figures



**Figure 1**

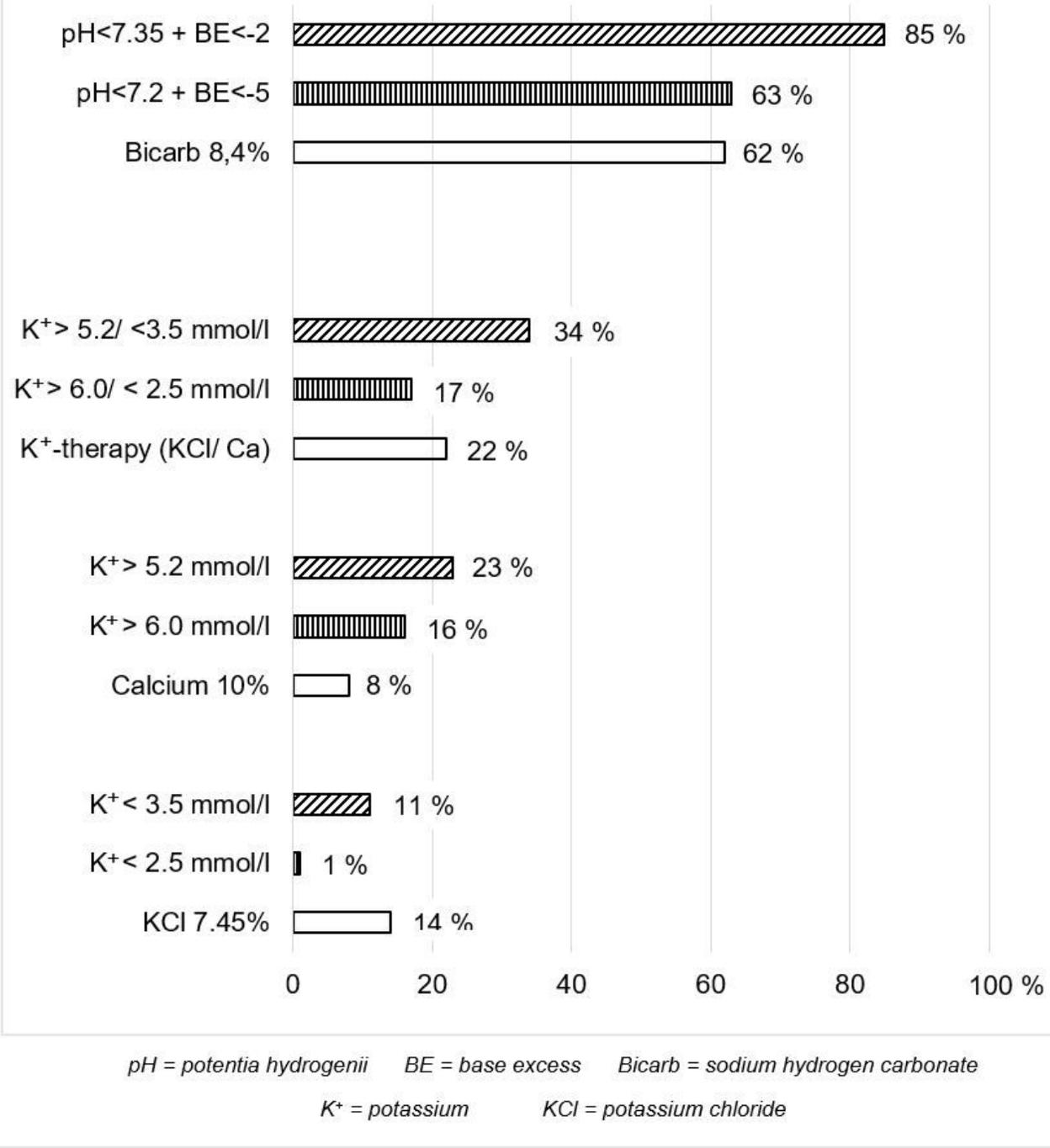
Acid-base status in POCT results of OHCA patients (upper / lower whiskers: maximum / minimum value; box: 75% to 25% quartile; median as line in the box. Normal ranges hatched)



**Figure 2**

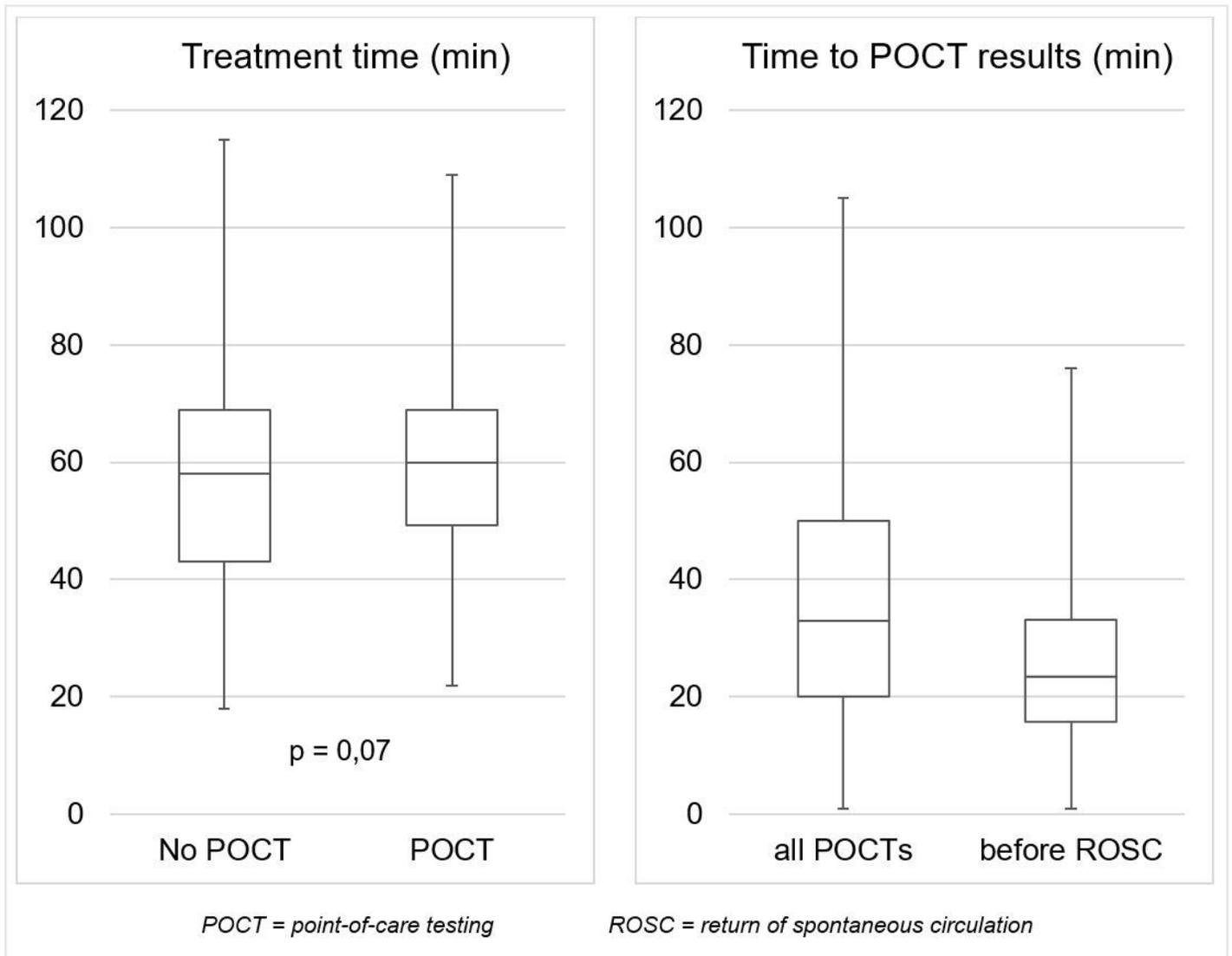
Potassium levels in POCT results of OHCA patients (normal range hatched, lines in bold: threshold for treatment according to ERC guideline 2015)

## POCT Results and Treatment



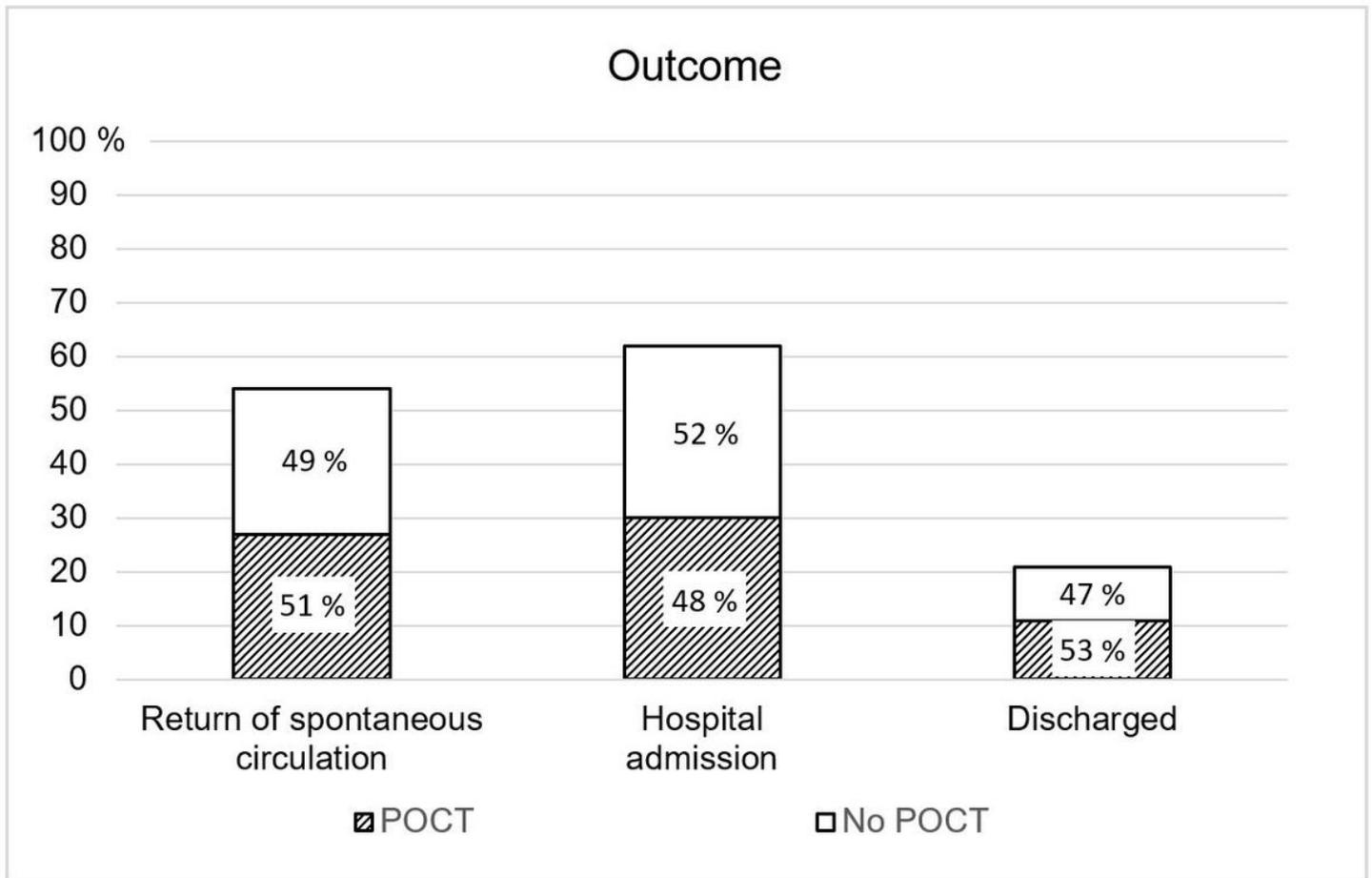
**Figure 3**

Abnormal POCT results and treatment of OHCA patients (n=98)



**Figure 4**

Time from arrival on scene to start of transport by ambulance; and time from arrival on scene to output of results of POCT of OHCA patients (upper / lower whiskers: maximum / minimum value; box: 75% to 25% quartile; median as line in the box)



**Figure 5**

Outcome for OHCA patients (n=263)

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Tab1POCTLabinOHCA.xlsx](#)