Clinical Paper

Predicting the lack of ROSC during pre-hospital CPR: Should an end-tidal CO₂ of 1.3 kPa be used as a cut-off value?∗, ∗∗

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A B S T R A C T

Aim: The aim of this study was to investigate if an initial ETCO₂ value at or below 1.3 kPa can be used as a cut-off value for whether return of spontaneous circulation during pre-hospital cardio-pulmonary resuscitation is achievable or not.

Materials and methods: We prospectively registered data according to the Utstein-style template for reporting data from pre-hospital advanced airway management from February 1st 2011 to October 31st 2012. Included were consecutive patients at all ages with pre-hospital cardiac arrest treated by eight anaesthesiologist-staffed pre-hospital critical care teams in the Central Denmark Region.

Results: We registered data from 595 cardiac arrest patients; in 60.2% (n = 358) of these cases the pre-hospital critical care teams performed pre-hospital advanced airway management beyond bag-mask ventilation. An initial end-tidal CO₂ measurement following pre-hospital advanced airway management were available in 75.7% (n = 271) of these 358 cases. We identified 22 patients, who had an initial end-tidal CO₂ at or below 1.3 kPa. Four of these patients achieved return of spontaneous circulation.

Conclusion: Our results indicates that an initial end-tidal CO₂ at or below 1.3 kPa during pre-hospital CPR should not be used as a cut-off value for the achievable return of spontaneous circulation.

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1. Introduction

The European Resuscitation Council Guidelines for Resuscitations recommends the use of waveform capnography for confirmation of tracheal tube placement whenever endotracheal intubation (ETI) is performed during cardio-pulmonary resuscitation (CPR).1

Several authors,2–8 most recently Heradstveit et al.9 and Qvigstad et al.10 have suggested that measuring end-tidal carbon dioxide (ETCO₂) may also be useful for optimising CPR quality and as an aid for prognostication during CPR. Kolar et al. from the emergency medical system (EMS) in Maribor, Slovenia found that among 1086 non-traumatic adult cardiac arrest patients (collected during a period of eight years) none of the patients in their study with an initial ETCO₂ below 1.33 kPa achieved ROSC.11 The authors suggest using an ETCO₂ of 1.33 kPa as a cut-off value for whether return of spontaneous circulation (ROSC) following pre-hospital cardiac arrest (CA) is achievable. We are not aware of any successful validation of these findings and the knowledge of the prognostic significance of ETCO₂ – measurements during pre-hospital CPR remains limited.

1.1. Objectives

The objective of the study was to investigate if an initial ETCO₂ value at or below 1.3 kPa can be used as a cut-off value for whether ROSC during pre-hospital CPR is achievable or not.

We hypothesised that in patients with pre-hospital CA, treated according to European Resuscitation Council Guidelines for Resuscitation,1 an initial ETCO₂ at or below 1.3 kPa is a predictor for lack of ROSC and pre-hospital death.

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2. Methods

2.1. Study design

The data analysed in the present study is part of an observational study\textsuperscript{12,13} where we prospectively collected data related to pre-hospital advanced airway management (PHAAM) in accordance with the consensus-based template made by Sollid et al.\textsuperscript{14}

2.2. Setting

We investigated the anaesthesiologist-staffed pre-hospital critical care teams in the Central Denmark Region. This region covers a mixed urban and rural area of approximately 13,000 km\textsuperscript{2} with a population of 1,270,000, and an overall population density is 97.7 inhabitants per km\textsuperscript{2}.

The standard EU emergency telephone number (1-1-2) covers all Denmark and there is an Emergency Medical Dispatch Centre in each of the five Danish regions. Emergency Medical Dispatch is criteria based and telephone guided CPR is provided.\textsuperscript{15}

The Emergency Medical Service (EMS) in the region is a two-tiered system based on 64 road ambulances staffed by emergency medical technicians (EMTs) supported by pre-hospital critical care teams staffed with an anaesthesiologist (with at least 4½ years’ experience in anaesthesia) and a specially trained EMT. Rapid response vehicles deploy nine of the pre-hospital critical care teams; the tenth team staffs a Helicopter Emergency Medical Service (HEMS) helicopter.

The pre-hospital critical care teams covered by this study employ approximately 90 anaesthesiologists as part time pre-hospital physicians. All pre-hospital critical care anaesthesiologists in the region primarily work in one of the five regional emergency hospitals or at the university hospital and they all have in-hospital emergency anaesthesia and advanced airway management both in- and outside the operating theatre as part of their daily work. Intensive care is part of the Danish anaesthesiological curriculum.

EMTs and the pre-hospital critical care teams are expected to follow the European Resuscitation Council Guidelines for Resuscitation.\textsuperscript{1} The LUCAS\textsuperscript{6} automated chest compression device is available on all the anaesthesiologist-staffed rapid response vehicles as well as on the HEMS. We have described the EMS system in our region in more detail elsewhere.\textsuperscript{12,13,16}

We collected data between February 1st 2011 and November 1st 2012.

2.3. Participants

2.3.1. Inclusion criteria

Consecutive pre-hospital cardiac arrest patients of all ages where the pre-hospital critical care anaesthesiologist performed PHAAM beyond bag-mask ventilation (BMV).

2.4. Endpoints and variables

Primary endpoints were: (1) initial ETCO\textsubscript{2} after PHAAM during CPR and (2) return of spontaneous circulation.

Secondary endpoints were: (1) Pre-hospital mortality.

We defined initial ETCO\textsubscript{2} as the first ETCO\textsubscript{2} obtained after PHAAM and return of spontaneous circulation as any period (no time limit) of spontaneous circulation following PHAAM.

We collected all core data proposed in the consensus-based template by Sollid et al. and we defined the variables as in this template.\textsuperscript{14}

The indications for performing PHAAM are categorised by Sollid et al.\textsuperscript{14} We included patients where the pre-hospital critical care physician had marked “cardiac arrest” as the reason for performing PHAAM.

The pre-hospital critical care teams or the EMTs on the road ambulances measured oxygen saturation, heart rate and blood pressure by using a LifePak 12 monitor (Physio-Control, Redmond, USA). The pre-hospital critical care teams monitored ETCO\textsubscript{2} either via the LifePak 12 or via a Nellcor NPB-75 capnograph (Tyco Healthcare Group LP, Pleasanton, USA). None of these devices can display the ETCO\textsubscript{2} as 1.33 kPa; it is either 1.3 or 1.4. Therefore, we chose at or below 1.3 kPa as the cut-off value in this study.

The physicians registered the initial ETCO\textsubscript{2} as a free-text variable. During data analysis, we labelled the initial ETCO\textsubscript{2} as being either under 1.3 kPa, at 1.3 kPa or above 1.3 kPa.

2.5. Data sources and data collection

We collected data from eight of the ten pre-hospital critical care teams, including the HEMS. Due to substantial differences in staffing, caseload, case mix and routines during the study period, only eight of the ten pre-hospital critical care teams provided data for the study.

The anaesthesiologists filled in a registration form (providing as a Supplemental File) containing all the core data recommended by Sollid et al.\textsuperscript{14} If the patient died on-scene, we reviewed the written pre-hospital charts as well as the entry made in the electronic patient journal for any evidence of temporary ROSC. For patients transported during ongoing CPR, we evaluated the same sources for evidence of temporary ROSC. If there were any doubt, whether the patient achieved ROSC or not we included the patient in the “no ROSC” group during data analysis.

2.6. Bias

To reduce the risk of recall bias and selection bias, the primary investigator reviewed the registration forms on a day-to-day basis. We crosschecked the registration forms with the standard pre-hospital records from the pre-hospital critical care teams to ensure the highest possible data coverage. In cases of missing data or inconsistencies, we asked the attending pre-hospital critical care physician to provide additional details for clarification.

2.7. Study size and statistical methods

In-depth discussions with an expert statistician at Aarhus University resulted in the following:

In theory, it would only take one single patient with a true initial ETCO\textsubscript{2} at or below 1.3 kPa and subsequent ROSC for us to have to reject the hypothesis. However, this one case could be due to for instance equipment malfunction and we therefore decided that we would reject the hypothesis if two or more patients with an initial ETCO\textsubscript{2} at or below 1.3 kPa achieved ROSC.

Sample size calculations made by the statistician in the statistical software Stata 12 (StatCorp LP) showed that to be able to confirm the hypothesis with a power of at least 80% and a level of significance of 95% we would need to include 100 patients with an ETCO\textsubscript{2} of less than 1.3 and no ROSC. In cases of unobtainable missing data, we performed complete case analyses.

2.8. Ethics

No patients had their treatment altered because of the study. All physicians participated in the study on a voluntary basis – there were no refusals.

The study did not involve any alterations from normal practice and according to Danish law, it did not need the approval of the Regional Ethics Committee, nor did we need the patients’ consent to register and publish the data. The Danish Data Protection Agency approved the study (Journal number 2013-41-1462).
Consequently, measured.

They achieved 1.3 kPa with these patients who had an initial ETCO2 below 1.3 kPa; additional seven patients had an initial ETCO2 = 1.3 kPa.

Three patients with an initial ETCO2 below 1.3 kPa and one patient with an initial ETCO2 of 1.3 kPa achieved ROSC. We describe these four patients in detail in Table 2.

4. Discussion

4.1. Main results

Based on an retrospective analysis of over 700 pre-hospital cardiac arrest patients Kolar et al. suggests an initial ETCO2 of less than 1.33 kPa as a cut-off value to identify patients who will not achieve ROSC. Our results cannot confirm their findings. We identified four CA patients with an initial ETCO2 at or below 1.3 kPa who all achieved ROSC, and our hypothesis that an initial ETCO2 at or below 1.3 kPa during pre-hospital CPR can be used as a predictor of pre-hospital death, must therefore be rejected. It is unlikely that all four cardiac arrest cases who achieved ROSC following an initial ETCO2 of 1.3 kPa or less should have experienced a falsely low ETCO2 value.

The results published by Callaham et al. support our findings. They investigated 55 patients in CA and found that four of those with an initial ETCO2 below 1.3 kPa achieved ROSC.

In a study of 575 Norwegian pre-hospital cardiac arrest patients treated by physician-staffed HEMS, Heradstveit et al. found many confounding factors complicating the interpretation of ETCO2 monitoring during CPR. The authors could not identify a “clear generalised cut-off value determining whether ROSC would be achieved or not”. Our results seem to support this view.

In our opinion, ETCO2 monitoring during CPR provides important information but the results of the current study does not allow us to support the use of an initial ETCO2 at or below 1.3 kPa as a cut-off value for the achievement of ROSC in pre-hospital CA patients. Basing the decision of whether or not to terminate CPR on this cut-off value may diminish patients’ safety and impair patient outcome following pre-hospital CA.

We advocate the use of ETCO2 measurements as one parameter among others (such as the result of focused ultrasound assessment) to guide the critical decision-making during pre-hospital CPR.

4.2. Limitations

The study was designed according to the Utstein-style template for reporting data from pre-hospital advanced airway management by Solld et al., and not according to the template for reporting data from pre-hospital cardiac arrest. Consequently, readers should interpret the non-airway management related results in the current study with caution.

We measured the ETCO2 values on one of the two portable capnographs and we did not routinely check the readings by measurement of ETCO2 on both capnographs or by measuring the partial pressure of CO2 in arterial blood. Never the less, our way of measuring ETCO2 depicts daily clinical practice.

The 23% lacking measurements of ETCO2 is a potential source of bias. We do not know the reason for these missing data. It could be because of equipment malfunction or unavailable equipment due to maintenance. It could also be because the attending anaesthesiologist chose not to use capnography, which is not in adherence with current guidelines. However, the missing data does not change the fact that four patients with an initial ETCO2 at or below 1.3 kPa achieved ROSC and it does therefore not influence our conclusion. In a more general perspective, our findings indicate a need for an increased use of ETCO2 measurements during CPR in our service.

We did not design this study to investigate the different factors influencing ETCO2 during CPR and our results are merely an attempt to investigate the use of an initial ETCO2 at or below 1.3 kPa as a cut-off value in the critical decision making process during pre-hospital CPR in a non-selected population of pre-hospital CA patients.

Survival beyond survival to admission was outside the scope of this study. This is in coherence with the paper by Kolar et al.

The attending anaesthesiologists registered all the data. They are therefore potentially subject to registration bias (systematic errors in the registration of data) or recall bias. The high capture rate reduces the risk of selection bias. Based on the day-to-day crosscheck of the registration forms against both the written pre-hospital journals and the compulsory entries made by the anaesthesiologists in the patients’ hospital records, the extent of selection bias is probably limited.

4.3. Generalisability

This was a study from one homogenous Danish system of anaesthesiologist-staffed pre-hospital critical care teams. This limits the ability to generalise the findings to other systems with different staffing, caseload or case mix. Never the less, treatment were according to current guidelines and we believe that our results can be of use to other physician-staffed as well as paramedic-staffed pre-hospital services performing pre-hospital advanced airway
management with ETCO₂ monitoring during pre-hospital cardiac arrest.

4.4. Perspectives

Further research is needed to confirm or reject the existence of a universal cut-off value of ETCO₂ for the achievement of ROSC during pre-hospital CPR. Based on our results, we find it doubtful whether such a value does exist.

5. Conclusion

In this study of 271 pre-hospital cardiac arrest patients treated with pre-hospital advanced airway management other than bag-mask ventilation by pre-hospital critical care anaesthesiologists, we identified four patients with an initial ETCO₂ at or below 1.3 kPa who achieved return of spontaneous circulation. Our results cannot confirm the hypothesis that an initial ETCO₂ at or below 1.3 kPa found during pre-hospital CPR is a predictor for the lack of return of spontaneous circulation. We advise against using our results to discard the use of ETCO₂ measurements as one important parameter among several in the critical decision making process during pre-hospital CPR.

Conflict of interest statement

The authors declare that they have no conflict of interests.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.resuscitation.2013.12.009.

Table 2

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age (years)</th>
<th>ASA-PS® score</th>
<th>Pre-existing disease</th>
<th>Type of cardiac arrest</th>
<th>First ECG</th>
<th>First ETCO₂ (kPa)</th>
<th>ETCO₂ (kPa) in the ED</th>
<th>Spontaneous circulation in the ED</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>74</td>
<td>2</td>
<td>None</td>
<td>Medical</td>
<td>Sinus rhythm&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.1</td>
<td>1.3</td>
<td>Yes</td>
</tr>
<tr>
<td>F</td>
<td>84</td>
<td>2</td>
<td>Other</td>
<td>Medical</td>
<td>PE&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.8</td>
<td>3.3</td>
<td>Yes</td>
</tr>
<tr>
<td>M</td>
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<td>3</td>
<td>Cardiac + other</td>
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<td>1.3</td>
<td>8.0</td>
<td>Yes</td>
</tr>
<tr>
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<td>2</td>
<td>Cardiac</td>
<td>Medical</td>
<td>VF</td>
<td>1.2</td>
<td>2.5</td>
<td>No&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> Cardio-pulmonary resuscitation.
<sup>b</sup> American Society of Anesthesiologists Physical Performance.
<sup>c</sup> Female.
<sup>d</sup> Ventricular fibrillation occurred after arrival of the Emergency Medical Services.
<sup>e</sup> Pulseless electrical activity/non-shock able rhythm.
<sup>f</sup> Male.

<sup>g</sup> Short pre-hospital period of ROSC, transported during ongoing CPR with LUCAS® automated chest compression device.

References