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Clinical paper

Arterial blood gases during and their dynamic changes after cardiopulmonary resuscitation: A prospective clinical study☆

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ABSTRACT

Purpose: An arterial blood gas analysis (ABG) yields important diagnostic information in the management of cardiac arrest. This study evaluated ABG samples obtained during out-of-hospital cardiopulmonary resuscitation (OHCPR) in the setting of a prospective multicenter trial. We aimed to clarify prospectively the ABG characteristics during OHCPR, potential prognostic parameters and the ABG dynamics after return of spontaneous circulation (ROSC).
Methods: ABG samples were collected and instantly processed either under ongoing OHCPR performed according to current advanced life support guidelines or immediately after ROSC and data ware entered into a case report form along with standard CPR parameters.
Results: During a 22-month observation period, 115 patients had an ABG analysis during OHCPR. In samples obtained under ongoing CPR, an acidosis was present in 98% of all cases, but was mostly of mixed hypercapnic and metabolic origin. Hypocapnia was present in only 6% of cases. There was a trend towards higher paO_2 values in patients who reached sustained ROSC, and a multivariate regression analysis revealed age, initial rhythm, time from collapse to CPR initiation and the arterio-alveolar CO_2 difference ($AaDCO_2$) to be associated with sustained ROSC. ABG samples drawn immediately after ROSC demonstrated higher paO_2 and unaltered pH and base excess levels compared with samples collected during ongoing CPR.
Conclusions: Our findings suggest that adequate ventilation and oxygenation deserve more research and clinical attention in the management of cardiac arrest and that oxygen uptake improves within minutes after ROSC. Hyperventilation resulting in arterial hypocapnia is not a major problem during OHCPR.
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Introduction

In the management of cardiac arrest, arterial blood gas (ABG) analysis can yield important diagnostic information and guide therapeutic management during in-hospital treatment of life-threatening conditions but also during out-of-hospital cardiopulmonary resuscitation (OHCPR), thus serving as part of advanced cardiac life support.[1–3] However, clinical data on blood gas analyses during OHCPR are sparse, owing to its technical challenges and personnel requirements on-site.[4,5]

Recent retrospective studies from our group suggested prognostic importance for the arterial base excess (BE) and oxygen partial pressure (paO_2), obtained at a singular measurement, especially for the prediction of the return of spontaneous circulation (ROSC),[5,6] however, prospective data investigating that issue are lacking at the moment for the prehospital setting. Investigations evaluating in-hospital ABG analyses obtained during the first 24 h after admission from OHCPR reported carbon dioxide partial pressure ($paCO_2$) derangements after ROSC,[7–9] however these data do

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not necessarily reflect $paCO_2$ during OHCPR or briefly after ROSC, as most intensive care units aggressively treat cardiorespiratory derangements. Despite the lack of systematic evidence for $paCO_2$ values under CPR conditions, current CPR guidelines advise that hyperventilation may contribute to a poor outcome. As ventilation rates are often excessive and outcome in animal models deteriorates with hyperventilation, respiratory rates of 10–12 breaths per minute are recommended.[10–12] Moreover, dynamic changes of the acid-base metabolism as well as arterial blood gases from the low-flow state during resuscitation to a reperfusion state immediately after ROSC are mainly known for animal models[13], and few studies on blood gas analysis during CPR exist.[14] As this is a current matter of interest, especially in light of the extensive debate of hyperoxia-induced oxygen toxicity, evidence is needed here.[15] This study comprises a data set obtained during the "Blood Gas Analysis and Bicarbonate Buffering in Cardiac Arrest" trial (BABICA) which was a prospective randomized controlled multicenter trial investigating bicarbonate buffering targeted by a measured BE value during OHCPR. We herein describe for the first time prospective human data on blood gases and the acid-base metabolism obtained during OHCPR and their dynamics briefly after ROSC. In addition, we investigated prospectively, whether blood gas data may yield an important prognostic value for patient survival to hospital admission.

Methods

Data were obtained during a prospective randomized controlled multicenter trial (BABICA, Blood gas Analysis and Buffering In Cardiac Arrest, clinicaltrials.gov: NCT01362556, EudraCT: 2010-020162-19) in out-of-hospital cardiac arrest patients. Following approval from the ethical committee of the Medical University of Graz (number: 21-357 ex 09/10) five emergency physician bases in Austria participated in the study. The emergency physicians involved were senior doctors with additional training in intensive care medicine or anaesthesia and were experienced in the interpretation of arterial blood gas analysis. All vehicles were equipped with a portable blood gas analyser (OptiCCA, OPTI Medical, Atlanta, USA) and responsible staff were instructed in its operation. Only one single arterial blood sample was gathered and analyzed in one patient, therefore each ABG sample represents a different patient. Samples were drawn on site during OHCPR or briefly after ROSC by arterial cannulation or single arterial sampling as described earlier.[4,5,16] All obtained values were collected using a separate case report form, which was based on the Utstein style. The timepoint of measurement was documented exactly. Samples with $paO_2 < 35$ mmHg were considered to be venous and thus excluded. Patients were resuscitated per 2010 guidelines,[17] all patients were intubated and ventilated by an ambu bag or a portable emergency respirator. Patient transport under ongoing CPR was not performed; in case of unsuccessful resuscitation attempts patients were declared dead on scene by the attending emergency physician. No ventilation protocols (predefined tidal volume or frequency) were applied, rather, ventilation was left to the discretion of the physician. End-tidal carbon dioxide ($etCO_2$) at the time of ABG recording was measured by infrared spectroscopy; $etCO_2$ values were only documented when a stable reading could be obtained. Only $etCO_2$ values documented synchronously with ABG measurements were included. None of the patients included in this dataset received any randomized treatment or buffer therapy before the arterial blood sample was obtained. Data were input into a specific database and statistics were calculated with SPSS 22 (IBM®, USA). Categorical data are reported as proportions and were assessed for significance by Chi-square or Fishers-exact test. Numerical data were tested for normal distribution by the Kolmogorov–Smirnov-test and Shapiro–Wilk-test. Data were compared with Student's *t*-test or the Mann–Whitney-*U* test as appropriate. For better readability all numerical data are presented as median (interquartile range). A $p < 0.05$ was assumed to indicate statistical significance. Hospital admission (HA), i.e. sustained ROSC upon hospital admission, was used as the outcome endpoint for all calculations. A receiver operating characteristic curve was calculated for each blood gas parameter and Youden's index was determined. For univariate binary logistic regression coefficients for all variables were calculated separately. Thereafter a multivariate regression (backward conditional, exclusion at >0.05) model was applied. Variables generally accepted to be of possible prognostic interest (age, sex, time from collapse to CPR initiation, bystander CPR and initial rhythm) were included into the analysis in addition to the blood gas parameters paO_2, $AaDCO_2$ (arterio-alveolar carbon dioxide difference, calculated from $paCO_2$ and $etCO_2$) and BE. Only 31 of 83 patients received randomized treatment, and this had no effect on the rate of hospital admission (9/16 vs 5/15, $p = 0.38$) such that we chose not to control for randomized treatment in the analysis. Nagelkerke's Pseudo-R^2 is given for each model as a measure of goodness-of-fit. A multivariate logistic regression with bootstrapping (1000 reiterations) was also applied to estimate the prediction error. Spearman's rank test was used to determine correlations between blood gas parameters and other variables of interest. Due to the limited number of patients achieving HA, we chose not to report short-term or long-term neurologic outcome because of an anticipated lack of precision of the results.

Results

During the observation time of 22 months 1295 patients in cardiac arrest were recorded (Fig. 1), of which 676 were declared dead by the attending emergency physician upon the first examination. 91 patients had to be excluded from the study on the grounds of the predefined exclusion criteria and 38 patients achieved ROSC before they could be included in the study. In the remaining 490 patients, a blood gas sample could be obtained during OHCPR in 124 cases

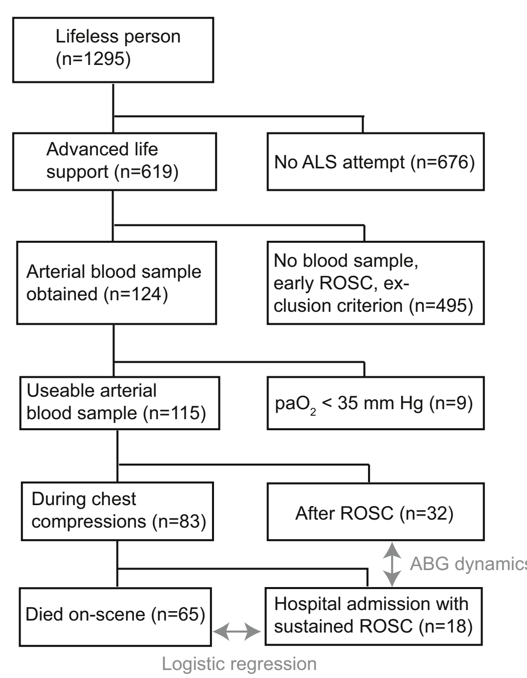

Fig. 1. Patient flow chart. Only one single arterial blood gas (ABG) analysis was obtained per patient, thus one sample represents one patient. ALS = advanced life support, paO_2 = arterial oxygen partial pressure, ROSC = return of spontaneous circulation.

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