LETTER

How to treat combined respiratory and metabolic acidosis after extracorporeal cardiopulmonary resuscitation?

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Establishing a venoarterial extracorporeal membrane oxygenation (vaECMO) in cardiac arrest is known as extracorporeal cardiopulmonary resuscitation (eCPR). After eCPR, patients commonly present with a combined respiratory and metabolic acidosis [1]. It is clear that acidosis negatively impacts survival after eCPR [2] and that a respiratory acidosis can be easily corrected by vaECMO. Current guidelines for conventional CPR suggest normocapnia as targeted after return of spontaneous circulation [3]. This recommendation is based on heterogeneous data. While a recent meta-analysis found adverse outcome in both hyper- and hypocapnia [4], a randomized trial reported no difference in survival in low normal and high normal $paCO_2$ [5].

The aim of the present study was to correlate arterial $paCO_2$ and pH with hospital survival in eCPR.

A single-center retrospective register analysis was performed. All eCPR patients treated between 2010 and 2017 were included. We analyzed arterial blood gases after 1 h, 3 h, 6 h, 12 h, and 24 h as well as hospital mortality. We detected a total of 186 eCPR. The mean age was 58.6 ± 14.9 years, and total hospital survival rate was 26.3%. After cannulation, $paCO_2$ and pH values were (mean $\pm$ standard deviation) 38.3 ± 8.9 mmHg/7.28 ± 0.14 (+ 1 h), 38.5 ± 8.5 mmHg/7.30 ± 0.11 (+ 3 h), 38.72 ± 7.42 mmHg/7.31 ± 0.11 (+ 6 h), 38.62 ± 7.26 mmHg/7.34 ± 0.10 (+ 12 h), and 38.22 ± 5.62 mmHg/7.38 ± 0.09 (+ 24 h), respectively. When comparing patients with $paCO_2 < 35$, 35–45, and > 45 mmHg, survival was statistically similar for all observed time points. There was however a highly significant association between hospital survival and pH when comparing groups with pH < 7.3, 7.3–7.4, and > 7.4 (see Fig. 1).

As secondary endpoint and surrogate for neurological outcome, neuron-specific enolase (NSE) was analyzed. Maximum NSE measured within 72 h after eCPR was 150.8 ± 145.1 μg/l (mean $\pm$ standard deviation). When correlating maximum NSE with $paCO_2$ at 1, 3, 6, 12, and 24 h after eCPR, no statistical significant linear correlation was found ($p > 0.4$ for all time points). There was however a significant linear correlation of maximum NSE and pH at 1, 3, and 6 h after eCPR ($p = 0.037$, 0.029, and 0.018, respectively).

In this registry study, we found a strong correlation between hospital survival and arterial pH but no such

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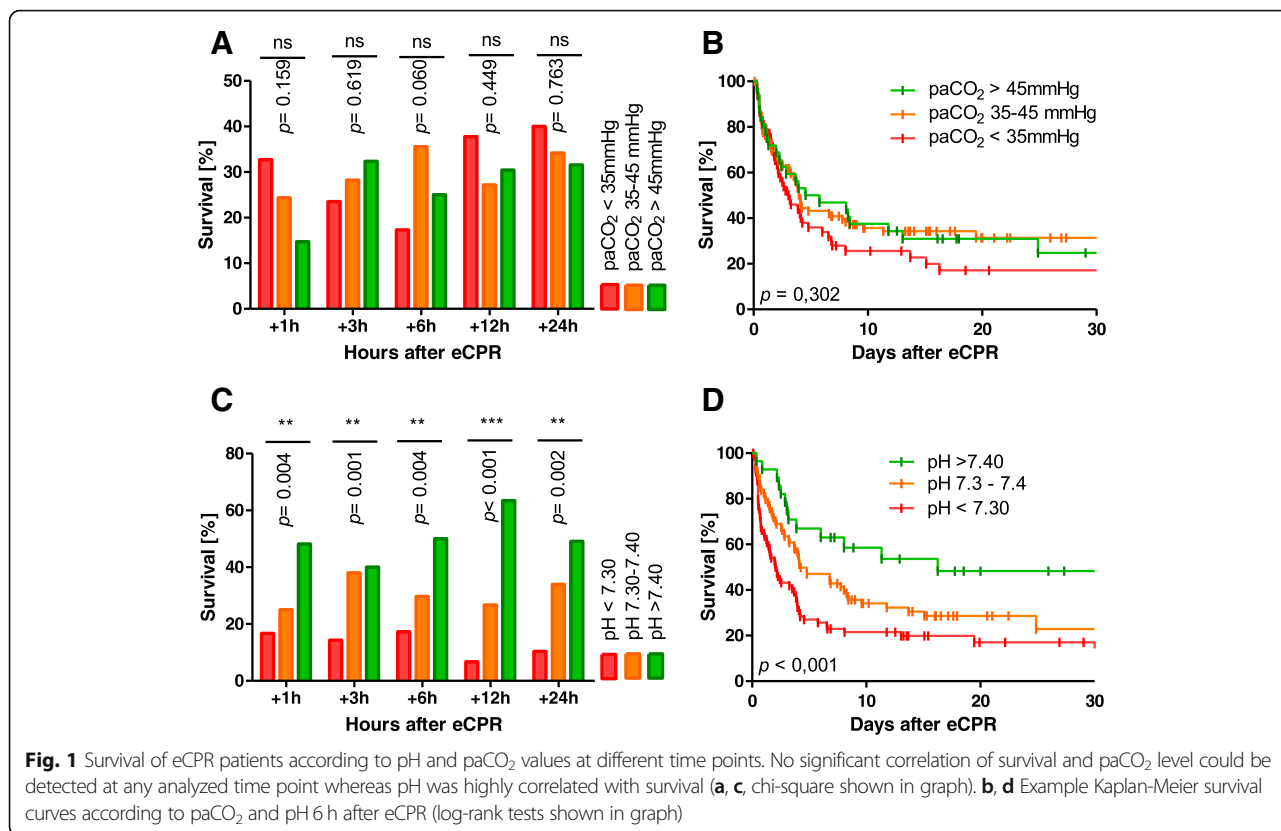
Fig. 1 Survival of eCPR patients according to pH and $paCO_2$ values at different time points. No significant correlation of survival and $paCO_2$ level could be detected at any analyzed time point whereas pH was highly correlated with survival (**a**, **c**, chi-square shown in graph). **b**, **d** Example Kaplan-Meier survival curves according to $paCO_2$ and pH 6 h after eCPR (log-rank tests shown in graph)

correlation with $paCO_2$. Also elevated NSE as a marker for neural injury did correlate with pH but not with $paCO_2$. Being a retrospective, observational, single-center study, inherent limitations and biases are to be presumed and findings are to be considered hypothesis generating. Until further data are available however, it might be reasonable to correct both respiratory and metabolic acidosis in eCPR patients.

Abbreviations
eCPR: Extracorporeal cardiopulmonary resuscitation; NSE: Neuron-specific enolase; $paCO_2$: Partial pressure of carbon dioxide in arterial blood; vaECMO: Venoarterial extracorporeal membrane oxygenation

Availability of data and materials
The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions
FS, DS, and XB carried out the data collection, design, and planning of this study. XB and DS performed the statistical analysis and drafted the manuscript. All authors participated in the critical discussion of the study and interpretation of data. All authors read and approved the final manuscript.

Ethics approval and consent to participate
This retrospective study was approved by the ethics committee of the University of Freiburg, Germany (525/17).

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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