Cove and Federspiel *Critical Care* (2015) 19:176
DOI 10.1186/s13054-015-0769-0

CRITICAL CARE

LETTER Open Access

Veno-venous extracorporeal CO_2 removal for the treatment of severe respiratory acidosis

Matthew E Cove[1*] and William J Federspiel[2]

See related research by Karagiannidis *et al.* http://ccforum.com/content/18/3/R124

We read with interest the article by Karagiannidis and colleagues reporting the effects of extracorporeal CO_2 removal ($ECCO_2R$) in a pig model of severe respiratory acidosis [1]. However, their conclusion that blood flow rates between 750 and 1,000 ml/minute are necessary to correct severe acidosis using $ECCO_2R$ may have been biased by limitations in experimental methodology.

Firstly, the authors report CO_2 removal rates for various blood flow rates using 19Fr and 14Fr catheters. However, the data clearly demonstrated blood recirculation using the 14Fr catheter, reducing CO_2 removal efficiency. Although the authors mention this limitation, it is curious why the 14Fr data were presented at all, since recirculation confounds meaningful interpretation.

Secondly, a 15-minute equilibration time was used between experimental set points, but no evidence is provided that equilibrium was achieved. It is reasonable to expect equilibration within 15 minutes when the entire cardiac output participates in gas exchange, but in this study blood flow rates of only 200 to 1,000 ml/minute passed through the gas exchanger. Longer equilibration times may have resulted in continued pH correction, as demonstrated in a human $ECCO_2R$ pilot study using approximately 450 ml/minute blood flows [2].

Finally, this study demonstrates reductions of partial pressure of CO_2 from 107.9 to 76.9 mmHg with blood flows of 500 ml/minute. In clinical practice this may be sufficient, a reduction from 80-85 to 60-65 mmHg in chronic obstructive pulmonary disease patients with respiratory acidosis normalized pH, allowing intubation to be avoided [2].

Although $ECCO_2R$ with higher blood flows clearly increases CO_2 removal, lower flows with appropriately designed catheters may provide sufficient support for severe hypercapnic respiratory failure.

Authors' response

Christian Karagiannidis, Wolfram Windisch and Thomas Mueller

We are grateful for the comments to our recent manuscript [1] provided by Cove and Federspiel and we very much appreciate their effort in further elucidating the concept of $ECCO_2R$. We are happy to respond to their comments as follows.

Cove and Federspiel are correct in stating that $ECCO_2R$ was insufficient using 14.5Fr catheters and that this was also attributable to recirculation. It was one of the intentions of our study to explicitly show this [1]. However, $ECCO_2R$ was insufficient in our experimental setting, too, when using 19Fr catheters at blood flow rates of 500 ml/minute while recirculation was negligible. This indicates that lower blood rates *per se* contributed to insufficient $ECCO_2R$.

We agree that equilibrium for CO_2 may not have been completed after 15 minutes, because bicarbonate is stored in slow compartments. However, in addition to the information already given in the methods section we observed that CO_2 measures at the exhaust outlet were very stable after 15 minutes, supporting the assumption that equilibrium for CO_2 was largely achieved.

Finally, we acknowledge the existing, albeit small scientific evidence for the clinical application of $ECCO_2R$ in patients. The patients in the study mentioned were far less acidotic, were mostly breathing spontaneously and were in a fairly stable condition [2]. Therefore, the results of our study setting with severely acidotic pigs are not transferrable to these conditions. To normalize severe respiratory acidosis, blood flows in the range of

* Correspondence: mdcmec@nus.edu.sg
[1]Department of Respiratory and Critical Care Medicine, National University Hospital Singapore, NUHS Tower Block Level 10, Singapore 119228, Singapore
Full list of author information is available at the end of the article

750 to 1,000 ml/minute are necessary; less may be sufficient to avoid intubation in non-invasive ventilation failure under certain conditions.

Abbreviation
$ECCO_2R$: Extracorporeal CO_2 removal.

Competing interests
MEC has no competing interests to declare. WJF is head of the scientific advisory board at ALung Technologies, and has an equity interest in this company. CK received travel grants and lecture fees from Maquet, Rastatt, Germany. WW received fees for advisory board meetings and lectures from Maquet, Rastatt, Germany. TM received travel grants from Maquet, Rastatt, Germany.

Acknowledgements
This work was supported in part by new clinician scientist program (MEC) and NMRC TA grant NMRC/TA/0015/2013 (MEC).

Author details
[1]Department of Respiratory and Critical Care Medicine, National University Hospital Singapore, NUHS Tower Block Level 10, Singapore 119228, Singapore. [2]Departments of Bioengineering and Critical Care Medicine, McGowan Institute for Regenerative Medicine, University of Pittsburgh, 3025 East Carson Street, Pittsburgh, PA 15203, USA.

Published online: 17 April 2015

References
1. Karagiannidis C, Kampe KA, Sipmann FS, Larsson A, Hedenstierna G, Windisch W, et al. Veno-venous extracorporeal CO2 removal for the treatment of severe respiratory acidosis: pathophysiological and technical considerations. Crit Care. 2014;18:R124.
2. Burki NK, Mani RK, Herth FJ, Schmidt W, Teschler H, Bonin F, et al. A novel extracorporeal CO(2) removal system: results of a pilot study of hypercapnic respiratory failure in patients with COPD. Chest. 2013;143:678–86.