Letter

Carbon dioxide removal device: how long is long enough?

Manuel E Cevallos and Joseph B Zwischenberger

Cardiothoracic Surgery Department. The University of Texas Medical Branch, 301 University Boulevard, Galveston, Texas 77555-0828, USA

Correspondence: Manuel Cevallos, mecevall@utmb.edu

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See related research by Livigni *et al*., http://ccforum.com/content/10/6/R151

Livigni and coworkers [1] reported on the safety and efficacy of a venovenous carbon dioxide removal ($VVCO_2R$) circuit in a short-term study (to 12 hours) conducted in healthy sheep. During extracorporeal carbon dioxide removal, carbon dioxide is transferred across a gas exchanger whereas oxygen diffuses across the native lungs.

In 1969 Kolobow and coworkers [2] described use of $VVCO_2R$ in healthy sheep for 1 week, and they later demonstrated improved survival in injured sheep [3]. Clinical trials, however, failed to show improved outcomes [4]. Arteriovenous carbon dioxide removal ($AVCO_2R$), as a simple arteriovenous shunt, eliminates several circuit components. $AVCO_2R$ removes near total carbon dioxide production with only 1 l/min (approximately 15% of cardiac output) blood flow and appears to be effective in acute respiratory distress disorder (ARDS), as shown in prospective randomized large animal and preliminary clinical trials.

Our sheep model of severe ARDS is based on a third degree burn to 40% of the total body surface area and 48-breath smoke inhalation injury [5]. Because the median duration of $AVCO_2R$ treatment for ARDS is 4.8 days, our model allows comparison of ventilatory techniques over 5 days to evaluate pathophysiology and outcomes [6].

Based on the experience with carbon dioxide removal, two major concerns arise. First, the circuit blood flow employed by Livigni and coworkers is only 5% of the cardiac output, which was inadequate to achieve normalization of arterial carbon dioxide pressure ($PaCO_2$). Use of larger cannulae (12 to 15 Fr) would allow flows up to 1 l/min. Second, studies of such short duration in healthy animals have limited clinical relevance [7].

We wonder whether the methods employed by Livigni and coworkers would have an impact on survival in 5-day large animal studies of lung injury or in clinical application.

Authors' response

Sergio Livigni, Marco Vergano and Guido Bertolini

In response to the concerns raised by Cevallos and Zwischenberger, we should like to stress the following points.

First, since the 1970s many things have changed both in research methodology and in clinical practice. From a research perspective, clear evidence of the efficacy/futility of techniques (in this case arteriovenous and venovenous) now requires much greater effort in terms of patient numbers (in some cases the number of patients required to achieve statistical significance is greater than the number actually available) and study design. From a clinical perspective ventilatory strategies are now rather different, with much greater emphasis on protective approaches and avoiding high tidal volume and high pressure.

Second, our target was not to normalize carbon dioxide. However, we believe that 20% carbon dioxide removal using low flows is an interesting result.

Third, in accordance with the prevailing desire to employ gentle ventilatory strategies, we are simply looking for an easy and feasible technique to allow routine ventilation in ARDS patients to confer greater protection.

Fourth, we favor a venovenous technique because it is more easily managed in intensive care units with basic experience in continuous renal replacement techniques and can easily be integrated into multiple organ support therapy.

ARDS = acute respiratory distress disorder; $PaCO_2$ = arterial carbon dioxide pressure; $VVCO_2R$ = venovenous carbon dioxide removal.

Finally, it is clear that higher flow rates permit a more consistent carbon dioxide removal; for low flow rates (<1 l/min) we believe that the risk/benefit ratio of arteriovenous access would be too high. If the patient's condition mandates higher rates, then we would prefer extracorporeal membrane oxygenation or a method that would improve not only carbon dioxide control but also oxygenation.

Competing interests

JBZ has worked with MC3 Corporation and MedArray Inc. as a collaborator on peer-reviewed grants that design low resistance gas exchange devices, and as an advisor to Novalung Inc, a German company that develop extracorporeal circuits for cardiopulmonary support. There is no direct conflict or relationship with this publication.

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