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VCO_2 calorimetry is a convenient method for improved assessment of energy expenditure in the intensive care unit

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See related article by Stapel et al., http://ccforum.biomedcentral.com/articles/10.1186/s13054-015-1087-2, and related article by Singer, http://ccforum.biomedcentral.com/articles/10.1186/s13054-016-1251-3

In their interesting article, Stapel et al. [1] suggested the use of carbon dioxide production (VCO_2) calorimetry with energy expenditure (EE; kcal/day), calculated as $8.19 \times VCO_2$ (ml/min), where VCO_2 is provided by the built-in capnometer of the mechanical ventilator. This calculation on average overestimated EE by 7.7 % compared to indirect calorimetry (IC) with a standard deviation (SD) of ±8.4 %. This is within the ±10 % limits of acceptance used in many studies [2] and, more importantly, is an improvement relative to calculation of EE by predictive equations from the patient's anthropometric data. The equation used by Stapel et al. incorporated a cohort respiratory quotient (RQ) of 0.86.

In his commentary, Pierre Singer [3] questions the usability of VCO_2 for assessing EE in critically ill patients for three reasons: 1) the concept involves complicated mathematics; 2) calculation of RQ from the patient's nutrition is complicated and uncertain; and 3) this invalidates the use of VCO_2 calorimetry in the critically ill patient. We disagree with the first reason. Multiplying VCO_2 by 8.19 is not complicated. We agree with the second reason. We unexpectedly saw significantly lower RQs in patients on a glucose-only diet compared with patients on enteral nutrition, such that individual RQ estimates calculated from the nutrition would have been inaccurate [4]. This does not imply that we agree with the third reason. In our sensitivity analysis we showed that changing our mean cohort RQ of 0.81 to 0.76, which is the lower end of the published range, only increased the VCO_2 calorimetry estimates of EE by 6 %, while increasing RQ to the upper end of the published range, RQ = 0.89, reduced estimated EE by 8 %.

We recommended choosing a value of RQ = 0.85. With that choice, VCO_2 calorimetry on average underestimated EE by 4 %, with an SD of 3 %, relative to EE estimated by IC [4], well within the ±10 % limits of acceptance. Our findings agree well with those by Stapel et al. and our conclusion is that VCO_2 calorimetry is both easy and usable as a method for assessing EE for any cohort RQ within the published range (0.76–0.89).

The question remains whether VCO_2 measured by built-in capnographs in various ventilators is sufficiently accurate. Stapel et al. found a 6.6 % systematic overestimation of VCO_2 with their ventilator (SERVO-i; Maquet), compared to the gold standard (Deltatrac II; Datex). This is promising, but data are needed for other built-in capnographs.

Author's response

Sandra N. Stapel and Heleen M. Oudemans-van Straaten

We would like to thank Pielmeier and Andreassen for their valuable arguments in response to Pierre Singer's commentary on our study about VCO_2-derived measurement of EE.

In this study we concluded that EE can be accurately assessed at the bedside by multiplying ventilator-derived VCO_2 by 8.19, especially when taking the mean 24-h value [1]. To calculate EE from ventilator-derived VCO_2, we had to estimate the RQ in order to transform VCO_2 into VO_2. For study purpose, we used the RQ of nutritional intake, knowing there would be inaccuracy [5].

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We actually found that measured RQ (0.859 ± 0.047) was quite similar to nutritional RQ (0.864 ± 0.015), but the two were not related at all ($p = 0.485$). In addition, the SD of the measured RQ was much larger. Thus, we share the opinion of both Pielmeier and Singer that calculating RQ from the administered nutrition is inaccurate. Nutritional RQ does not account for endogenous metabolism, which is unpredictable during critical illness. This was reported previously by McClave et al. [5] and is confirmed by the study of Rousing et al. [4], to which Pielmeier and Andreassen contributed.

Nevertheless, as we outlined, RQ only accounts for 15 % of the total bias of VCO_2-derived EE. Since the mean RQ of our cohort and the RQ of most nutritional formulae are both 0.86, we proposed the simplified equation based on a fixed RQ of 0.86: $EE = 8.19 \times VCO_2$ (ml/min). In their interesting study, Rousing et al. [4] showed that, for any chosen RQ within the range of cohort values of 0.76 to 0.89, VCO_2-based calorimetry performed significantly better than equations, thereby confirming our findings. They recommend using an RQ of 0.85, surprisingly similar to our conclusion.

Of note, IC remains the gold standard for assessment of EE in ventilated critically ill patients. However, the best-validated system, the Deltatrac, is no longer on the market and new indirect calorimeters have not yet proven to be accurate [6]. More importantly, predictive equations are inaccurate and their use should be avoided. VCO_2-based EE provides the best alternative.

We agree with Pielmeier and Andreassen that we cannot extrapolate the results of our capnograph to other built-in capnographs. Their accuracy should first be validated, especially during irregular breathing. Furthermore, since we found a systematic error of 6.6 % for the VCO_2 measurement, accuracy of the Maquet measurement should also be improved. The use of VCO_2 measurements per second (instead of per minute) is currently under investigation.

Abbreviations

EE, energy expenditure; IC, indirect calorimetry; RQ, respiratory quotient; SD, standard deviation; VCO_2, carbon dioxide production

Authors' contributions

UP and SA drafted the manuscript. Both authors approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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