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LETTER TO THE EDITOR

Response to "Cardiac output by pulse contour analysis does not match the increase measured by rebreathing during human spaceflight"

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TO THE EDITOR: The recently published paper by Hughson et al. (4) described interesting results about an increase in cardiac output (CO) during spaceflight compared with values measured while seated before flight using different methods or inert gas rebreathing and pulse contour analysis (PCA) (1, 2, 6). However, those changes were only detected by inert gas rebreathing but not by the PCA method based on blood pressure measurements on the finger. The authors concluded that the discrepancy may be explained by the inability of the PCA method to detect CO changes caused by a volume shift to the splanchnic area.

With this letter we would like to provide some additional thoughts to explain the found discrepancies and what may have caused them.

First of all, absolute values of PCA derived CO depends on the amplitude of pressure. Obtaining PCA-derived CO without absolute accurate blood pressure would therefore be a possible source of error. Hughson et al. used a device that can calibrate a reconstructed brachial pressure (Finometer Pro) on earth. However, in space, such a calibration was not executed, as the device used there does not offer that functionality. Moreover, proper cuff application is required for measuring blood pressure adequately. On earth, cuffs must be applied by trained staff. During flight experiments onboard the International Space Station, the cuff must be applied by astronauts, and without the above mentioned calibration an error introduced by a wrong or not ideal application of the cuff could be missed.

A second source of error relates to the use of a mathematical model of aortic impedance in PCA methods, frequently being the Langewouters model (7). This model computation will likely introduce a bias in CO if not calibrated properly (6, 10). This bias should not matter when assuming a constant aortic impedance, as each astronaut is his/her own control in the reported experiments. However, the long stay in space under altered vascular loading conditions may change vascular properties as described recently by the same authors (5). Those changes may also occur in the thoracic and abdominal aorta and lead to aortic impedance changes. This is supported by the observation of reduced 24 h blood pressure in space (8, 9).

A third possible source of error is inherent to all PCA methods. These methods are based on arterial pressure only and therefore do not take into account central venous pressure. However, it was shown that central venous pressure decreases under microgravity conditions (3, 11). As a consequence, in such conditions the estimation of SVR will actually become more accurate, contributing to an improved accuracy of PCA derived CO.

The method of rebreathing itself can increase CO (3), at which point it becomes important to obtain PCA-derived CO and rebreathing-derived CO during the same interval. Indeed, inflight measurement of CO was done simultaneously. In contrast, the preflight PCA-derived CO measurements were done in supine and seated position and at rest, whereas the preflight rebreathing technique derived CO was done in only a seated position. Posture and exercise are two determinants of CO and may therefore have undermined the conclusion by the authors.

Considering the above, the conclusion made by the authors that pulse contour analysis method-derived CO should be used with caution in space may be right, but possible limitations of the used protocol and PCA method like the lack of calibration, needed user training, and control for cuff placement, as well as blood volume shifts and atrial filling changes, could have been discussed in more detail.

The important point that needs to be made is that each method has its strengths and should be carefully selected to fit the research question at hand. Using them simultaneously may even provide new information on the human circulation in space.

DISCLOSURES

Both authors are employed by Finapres Medical Systems, the legal manufacturer of Modelflow.

AUTHOR CONTRIBUTIONS

M.J.v.H. drafted manuscript; M.J.v.H. and G.J.L. edited and revised manuscript; M.J.v.H. and G.J.L. approved final version of manuscript.

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