

Accuracy of impedance cardiography for evaluating trends in cardiac output

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Editor—We read with interest the paper by Lorne and colleagues¹ who report the use of a new cardiac output monitor based on the principle of impedance cardiography (ICG), the Niccomo (Medis Medizinische GmbH, Ilmenau, Germany), and wish to raise several important points.

Lorne and colleagues use a number of statistical methods to support their assertion that, 'ICG appears to be a reliable method for the non-invasive monitoring of cardiac output'. Firstly, they quote a Pearson's co-efficient of 0.84. More than 30 years ago, Bland and Altman described why regression analysis is not an appropriate tool for comparing cardiac output monitors,² highlighting that correlation measures the strength of a relationship between two variables, not the agreement between them, and that correlation does not take into account the measurement scale. This means that a close correlation would be seen between variables if one monitor reliably gave a reading 50% of that of another. They also demonstrated that correlation is affected by the range of the samples, so that apparently close correlation may be caused by a wide spread of samples where agreement is actually poor.

Bland and Altman's own method of analysis has become widely accepted as more appropriate, with accepted limits of agreement defined in the literature as a percentage error of 28%.^{3,4} In this present study Lorne and colleagues demonstrate a small bias, but wide limits of agreement, with a 45% error clearly someway outside the established boundaries of acceptability. They reduced this error to 35% by excluding patients with chronic obstructive pulmonary disease. This is clinically relevant, as it is patients with such major comorbidities in whom it may be most useful to measure cardiac output.

The authors therefore appear to demonstrate relatively poor agreement in cardiac output values between the Niccomo monitor and the Oesophageal Doppler Monitor (ODM). Moreover, ODM itself approximates only moderately well to a thermodilution technique, with a meta-analysis demonstrating a bias of 0.19 litre min⁻¹ and limits of agreement of -0.69–2.0 litre min⁻¹.⁵ Although considered the de-facto gold standard for cardiac output measurement in anaesthesia, thermodilution is less accurate than measurement using the Fick principle, the technique regarded by most as the most accurate measure of cardiac output.⁶ We are therefore left with a monitor (ICG), which approximates only moderately well to another monitor (ODM), which is itself an approximation (Thermodilution) of an approximation (Fick).

Additionally, Lorne and colleagues contend that perioperative cardiac output monitoring has been shown to reduce morbidity and length of stay. Notwithstanding that it is not the presence of the monitor which makes the difference, but the way in which the data from the monitor are interpreted and used to direct treatment, in our opinion, the assertion that cardiac output monitoring may be used to reduced morbidity associated with major surgery remains unproven. Recently studies and reviews have failed to demonstrate a clear benefit from the use of cardiac output

monitoring to guide fluid therapy.^{7,8} Indeed as the current generation of minimally-invasive cardiac output monitors are all validated, either directly or indirectly, against a thermodilution technique using a pulmonary artery flotation catheter well established to confer minimal advantage to patient care,^{9,10} it would be surprising if less accurate monitors proved to be more useful.

Whilst written in the context of the Niccomo monitor, the above observations apply to any new, minimally invasive cardiac output monitor, particularly those which, for pragmatic reasons, are validated against other minimally invasive cardiac output monitors, rather than a true gold-standard. Before incorporating new devices in our practice, we need to question exactly how valid the measurements we use to guide us are - bad measurement will lead to bad treatment.

Declaration of interest

None declared.

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Reply from the authors

In a perfect world, we would have used a perfect method for cardiac output monitoring

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Editor—We thank Dr Heinink and colleagues for their valuable comments on our study.¹

There is neither perfect statistical method nor perfect cardiac output measurement tool.

Pearson's correlation is questionable; we have already performed Bland and Altman analysis in our paper. In the last decade, a question has been raised that has not been solved by methodologists: which method to be used when there is a wide range of sampling? Critchley and Critchley percentage of error and Bland and Altman methods are not exempt from methodological problems in case of wide range of sampling. Interchangeability is defined currently by a ratio between limits of agreements and mean of the population.² If a single value is far from the average of the whole population, the absolute value of the variability at this range may be very different from that defined by the average in the population. In that case, there is a high risk of false classification of values far from the average.

As we have stated in the text, we have not used the pulmonary artery catheter (PAC) as a reference method for cardiac output. Because monitoring with PAC is associated with complications³ and a single bolus cannot be used easily to assess trends; we have chosen oesophageal Doppler instead of PAC to evaluate ICG trends. We agree with Dr Heinink and colleagues that ODM is not the best way to assess absolute values of cardiac output. However, the assertion that the Fick method is the best way to measure cardiac output is not strongly supported by the cited review article. The calculation of pulmonary blood flow and therefore total cardiac output is done by taking measurements of oxygen consumption and carbon dioxide production along with the pulmonary arterial and venous concentrations of these gases. This method does not take into account the value of the pulmonary shunt fraction. In addition, pulmonary blood gases analysis is not a minimally invasive method that can be used for all patients. Derived from the Fick principle, partial carbon dioxide re-breathing technique was associated with controversial results. The accuracy of this technique is affected by increased carbon dioxide production,⁴ reduced minute ventilation or spontaneous ventilation,⁵ and high cardiac output states⁶ or high pulmonary shunt fraction.⁷

However, our main goal was to study trends. As we have already discussed in our paper, the ability of oesophageal Doppler to detect changes in cardiac output has been already demonstrated.^{8–10} The validation of the clinical relevance of OD was

mainly conducted by using relative changes of stroke volume in high-risk surgical patients including colorectal, femur and hip surgery.^{11–16} The OD was used for this type of interventions to guide fluid administration with a protocolised goal-directed fluid administration. In these studies, authors used trending of stroke volume rather than absolute values. In fact, the purpose of this type of protocol is a submaximal optimization of SV (OD makes a good follow-up, even if the absolute accuracy is questionable) and its maintenance during the intervention by the administration of liquids or catecholamines.^{11–17} Basing clinical decisions on trends rather than absolute values is relevant clinically and has the advantage of avoiding the problems of the measurement of the true stroke volume value.

Even though recent studies might have shown no benefit of GDT guided by using ODM monitoring; these are difficult to compare with other studies because therapies used to achieve the goal are heterogeneous (dopexamine, crystalloids, colloids, or both). However, a recent meta-analysis of 38 studies suggests that the intervention is associated with fewer complications and mortality at long-term follow-up.¹⁸

Declaration of interest

None declared.

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