

tance characteristics in normal volunteers and patients with coronary disease (many with concomitant respiratory disease). Though the bioimpedance technique has undoubted potential for non-invasive cardiac output determination in humans, the NCCOM3 technique is not a satisfactory implementation of this method.

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- 1 Keim HJ, Wallace JM, Thurston H, Case DB, Drayer JIM, Laragh JH. Impedance cardiography for determination of stroke index. *J Appl Physiol* 1976;41:797-800.
- 2 Silke B, Permenkil R, Maitra S, Verma SP, Taylor SH. A new transthoracic bioimpedance (TEI) method of cardiac output determination. *Br J Clin Pharmacol* 1989;28:738P.
- 3 Taylor SH, Silke B. Is the measurement of cardiac output useful in clinical practice? *Br J Anaesth* 1988;60:90S-8S.
- 4 Silke B, Zezulka AV, Verma SP, Taylor SH. Hemodynamic assessment of nicardipine alone and with atenolol in coronary artery disease using a modified echo-doppler device. *Am J Cardiol* 1989;64:28H-34H.
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These letters were shown to the authors, who reply as follows:

SIR,—We are grateful for the opportunity to reply to the points raised in these two letters.

We agree entirely with Dr Shoemaker's comments. The bioimpedance stroke volume equation used in the BoMed NCCOM3 was

first described by Dr Sramek. The contribution of Dr Bernstein, which we would not wish to underestimate, was an improved method for calculating VEPT (one variable in the Sramek equation) rather than a modification of the equation itself. As stated in our paper, VEPT was determined from both body height and weight—the Bernstein method.

We take issue with many of the points raised by Dr Silke. The thermodilution results were taken simultaneously with electrical bioimpedance by two blinded observers. As we stated, the bioimpedance estimate was taken as an average of 120 heart beats, not 10. This was compared with three averaged thermodilution estimates because these require a similar length of time. Each thermodilution estimate is in itself an average over a number of cardiac beats. We disagree with Dr Silke's assertion that averaging generates spurious accuracy. In fact we deliberately made only one estimate of cardiac output with each method per patient to avoid the spurious correlations that can be generated when multiple measurements are made in the same patient.

We do not follow Dr Silke's reasoning regarding the haemodynamic status of our patients. They were not chosen for their haemodynamic stability—unlike the patients included in the drug studies cited. Since we made the thermodilution and bioimpedance measurements simultaneously, any haemodynamic instability would not bias our results.

Dr Silke suggests that we did not study a wide enough range of cardiac outputs. In fact the thermodilution results ranged from 2 l/min to over 6 l/min which covers most values commonly encountered in clinical practice. He also suggests that the three patients in whom there was considerable disagreement

between electrical bioimpedance and thermodilution might have been those with the highest cardiac outputs. Inspection of figure 3 of our original paper clearly shows that this was not the case. There was no relation between the size of the errors and the mean of the two estimates of cardiac output.

There are several possible reasons to explain the poorer results obtained by Dr Silke with electrical bioimpedance. However, it is difficult to compare our methods because his study has not been published in full. The most obvious difference between the studies is that our measurements were not made during exercise. A previous report concluded that the BoMed NCCOM3 was inaccurate during exercise.¹ Another problem with Dr Silke's study is that electrical bioimpedance is compared with thermodilution—a technique that may be unreliable during exercise because of the development of tricuspid incompetence.² Therefore the lack of agreement between bioimpedance and thermodilution during exercise should not discourage physicians from using this device in patients at rest, especially to monitor changes in cardiac output.

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- 2 Lipkin DP, Poole-Wilson PA. Measurement of cardiac output during exercise by the thermodilution and direct Fick techniques in patients with chronic congestive heart failure. *Am J Cardiol* 1985;56:321-4.