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Comparison of bioreactance and echocardiographic non-invasive cardiac output monitoring and myocardial function assessment in primagravida women

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Abstract

Background. Non-invasive cardiac output monitoring (NICOM) using bioreactance (BRT) in pregnancy is gaining interest but lacks validation. We compared simultaneous cardiac output (CO) measurements obtained using the NICOM® (BRT-CO) and echocardiography (echo-CO), and assessed the relationship between maternal characteristics and myocardial performance.
Methods. Paired stroke volume (SV) and CO readings were obtained using NICOM® and echocardiography, in a group of healthy nulliparous women throughout a 15 min period. Agreement between NICOM® and echocardiography was assessed using Bland–Altman analysis and the intraclass correlation coefficient (ICC). Left ventricular (LV) function was assessed using systolic strain and tissue Doppler velocities (S′, E′, and A′ waves).
Results. Thirty-five women with a median [interquartile range] age, weight, and gestation of 29 [26–34] yr, 71 [64–79] kg, and 28 [21–29] weeks, respectively, were enrolled. There was good agreement between NICOM®-measured and echocardiographically measured SV [mean bias 6 ml (limits of agreement −18 to 29); ICC 0.8 (95% confidence interval 0.6–0.9), $P<0.001$] and CO [mean bias 0.2 litres (limits of agreement −1.3–1.7); ICC 0.8 (95% confidence interval 0.7–0.9), $P<0.001$; mean percentage error ±26%; coefficient of error (precision)=3.4%]. The mean (SD) LV S′ was 9.7 (2.3) cm s^{-1}. The mean (SD) LV strain was −18.6 (2.6)%. There was a negative relationship between BMI and LV diastolic function measured using the E′:A′ ratio ($r=-0.51$, $P<0.01$).
Conclusions. Stroke volume and CO measurements obtained using NICOM® were comparable to those obtained using echocardiography, with acceptable limits of agreement. Increased maternal BMI negatively impacts LV diastolic function measured using tissue Doppler imaging.

Key words: cardiac output; echocardiography; myocardial function

Haemodynamic assessment of healthy women in pregnancy has traditionally centred on maternal blood pressure and heart rate (HR). Further assessment of maternal haemodynamic profile has been limited because of the invasive nature of many methods, such as pulmonary artery catheter placement for thermodilution measurement of cardiac output (CO). Even some minimally invasive methods require arterial line placement, which limits elective use in healthy parturients. Early non-invasive methods of CO assessment were limited by poor signal-to-noise ratios and electrical interference in the case of

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Editor's key points

- Non-invasive measurements of cardiac output are potentially useful in obstetric patients but have not been validated in this population.
- The NICOM® bioreactance monitor of cardiac output was compared with standard transthoracic echocardiographic methods in 35 healthy primagravida.
- Stroke volume and cardiac output measurements were comparable between the two methods, validating the utility of non-invasive bioreactance monitoring in pregnant patients.

bioimpedance, or were time consuming and required an expert to perform and read the examination when using echocardiography. However, development of bioreactance has allowed detailed non-invasive assessment of maternal haemodynamics, on an outpatient basis if required, without the need for an expert to operate the device. Bioreactance technology uses the phase shift (or time delay) of an applied alternating current traversing the thoracic area to derive stroke volume (SV).[1]

Recent obstetric studies have used this technology to assess maternal haemodynamics in patients at high risk of pre-eclampsia and intrauterine growth restriction.[2 3] Bioreactance has been validated in many patient populations, against gold-standard techniques for the assessment of CO, and is robust enough to be used at rest and during exercise.[1 4 5] Until recently, however, bioreactance has not been validated in the obstetric population. The obstetric population has a unique and rapidly changing body habitus, particularly during the second and third trimesters. In addition, the impact of the uterus, amniotic fluid, and fetus on the bioreactance properties of the thorax are unknown. Therefore, extrapolating bioreactance validity data from other patient populations for use in the obstetric population is not necessarily justified.[6]

We compared simultaneous CO measurements obtained using the non-invasive cardiac output monitor NICOM® (Cheetah Medical, Newton, MA, USA) by means of bioreactance (BRT-CO) and echocardiography (echo-CO) in a group of healthy primigravid women, and assessed the relationship between maternal characteristics, cardiac output, and myocardial performance.

Methods

This was a cross-sectional study conducted in the Rotunda Hospital, Dublin, with Institutional Research Ethics Board approval. Informed consent was obtained from all participants. Subjects were recruited from those participating in a large prospective study assessing the ability of NICOM® to predict the evolution of pre-eclampsia and intrauterine growth restriction (the HANDLE study). All low-risk primagravida patients attending the Rotunda Hospital for antenatal care of a singleton pregnancy were considered for inclusion. Those patients with multiple gestations, known fetal abnormality, pre-existing medical conditions, or hypertension at the first antenatal visit were excluded. Eligible subjects who were enrolled in the HANDLE study were then approached for consent to conduct simultaneous echocardiography assessments during NICOM assessments. Study participants underwent simultaneous echocardiography and NICOM assessment of cardiac output throughout a 15 min period. The echocardiographer was blinded at all times to the NICOM readings. None of the participants underwent multiple assessments. Maternal weight and height were noted at the time of the assessments to derive BMI.

NICOM® measurements

Cardiac output and SV measurements using bioreactance (BRT-CO and BRT-SV) were performed using the NICOM® monitor (Cheetah Medical). Bioreactance is a technique that uses four dual electrodes, each with a current-emitting and -sensing component. Electrodes are placed on the right and left shoulders and the posterolateral aspect of the left and right thorax, below the level of the heart. In this way, they 'box' the heart. An AC current, of known frequency, is then passed from the outer emitting electrodes and detected by the inner sensing electrodes. The phase shift in the sensed signal is proportional to the pulsatile blood flow in the thorax and is highly correlated with aortic blood volume.[1] The derivative of this signal over time provides information on aortic flow (i.e. SV). Stroke volume is calculated using the following formula: $SV = dX/dt \times VET$, where SV is the stroke volume, dX/dt the maximal flow, and VET the ventricular ejection time. Heart rate is obtained from an ECG signal sensed from the electrodes, and CO is then calculated as follows: $CO = SV \times HR$. The NICOM® display of haemodynamic measurements was shielded from view during echocardiographic assessment.

Echocardiographic measurements

Echocardiographic measurements of CO were performed at the same time as NICOM® using a Vivid S6 echocardiography machine and a 4 MHz multifrequency probe (General Electric, Milwaukee, WI, USA) using a standardized protocol adapted from recently published guidelines.[7] All patients were in a semi-recumbent position elevated at a 45° angle and placed in a slightly left lateral position. Cine loops were obtained at end expiration in raw DICOM format by two investigators (A.E.-K. and C.B.) and stored in an archiving system for later analysis (EchoPac, version 112 revision 1.3; General Electric). Offline analysis was conducted at the end of the study by a single investigator (A.E.-K.) who was blinded to the NICOM® values. Stroke volume and CO were measured as follows. The long axis parasternal view of the left ventricle was used to obtain the aortic root diameter to derive the aortic cross-sectional area (AoCSA) as follows: $AoCSA = \pi \times (\text{aortic root radius})^2$. The apical five-chamber view was used to obtain a pulsed-wave Doppler measurement of aortic blood flow at the aortic root to derive the velocity–time index (VTI). Heart rate was obtained using the RR interval from the ECG. Stroke volume was calculated using the following formula: $SV = AoCSA \times VTI$. Cardiac output was derived using the following formula: $CO = SV \times HR$.

Left ventricular (LV) function was measured using tissue Doppler imaging to derive mitral valve annular systolic velocity (S′) and early (E′) and late (A′) diastolic velocities of the LV lateral wall. Diastolic E′ and A′ waves were expressed as a ratio (E′:A′) to assess diastolic function. Speckle tracking echocardiography was used to derive LV strain. Tissue Doppler imaging values were obtained from the apical four-chamber view using a pulsed-wave Doppler sample gate of 2–4 mm at the level of the mitral valve annulus. The cursor was aligned with the longitudinal plane of LV motion to maintain an angle of insonation $<20°$. Left ventricular S′ was obtained from averaging three consecutive waves. For longitudinal strain analysis, grey-scale