Measurement of cardiac output using Physio Flow® with different positions of electrode placement

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ABSTRACT

Introduction: Physio Flow is a non-invasive impedance cardiograph device that measures cardiac output. Recommended electrode placements involve six electrodes, including two near the xiphisternum (Z3 and Z4/ECG3/neutral). This study aims to evaluate if changing the positions of these two leads to the left fourth and fifth intercostal spaces along the mid-axillary line results in a change in the cardiac output measurement.

Methods: This was a prospective, controlled, crossover, paired study of 30 patients where electrodes were placed in the recommended positions and cardiac output (CO1) obtained after two minutes. The second cardiac output (CO2) was then obtained with the electrodes Z3 and Z4/ECG3/neutral repositioned at the left mid-axillary line at the fourth and fifth intercostal spaces. The final step involved switching the Z3 and Z4/ECG3/neutral leads back to the recommended position and the cardiac output (CO3) was measured.

Results: The average of the initial and third readings (COave) was compared with the measured CO2 and analysed. The regression equation was: CO at the proposed site (CO2) = COave at the recommended site + 0.058. The paired samples correlation was 0.995. Within the 95 percent limits of agreement, the bias with CO measured at the proposed site of electrode placement was 0.046 L/min with the limits at -0.24 L/min and 0.34 L/min. The mean difference was 0.86% of the average CO.

Conclusion: A small positive bias was demonstrated when Physio Flow measurements were taken with the leads Z3 and Z4/ECG3/neutral placed in the mid-axillary line fourth and fifth intercostal spaces.

Keywords: electrode placements, impedance, non-invasive cardiac output monitoring, Physio Flow®

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INTRODUCTION

The gold standard of cardiac output (CO) measurement in subjects at rest and during exercise is the direct Fick and the dye-dilution methods[1]. Both techniques are invasive but give a reliable determination of CO, and are accurate to within 5% to 10%[2,3]. CO measurement by Physio Flow® (Manatec Biomedical, Paris, France) is based on a formula including heart rate, stroke volume index and body surface area, and does not include the distance between the sensing electrode and blood resistivity. Measurement of the parameters using Physio Flow® involves placing six pre-gelled electrodes on the thorax which are connected to an electronic processing unit, which is in turn connected to a laptop computer running on Microsoft Windows 95/98 for acquisition and analysis of data. The calibration phase is done over 30 heart beats and subsequent continuous measurements can be taken, beat by beat or averaged over several beats.

Recommended electrode placement involves six electrodes, two on the left lateral aspect of the neck (Z1 and Z2), two on the chest (ECG1 and ECG2) and two near the xiphisternum (Z3 and Z4/ECG3/neutral) (Fig. 1). For upper abdominal surgery, the

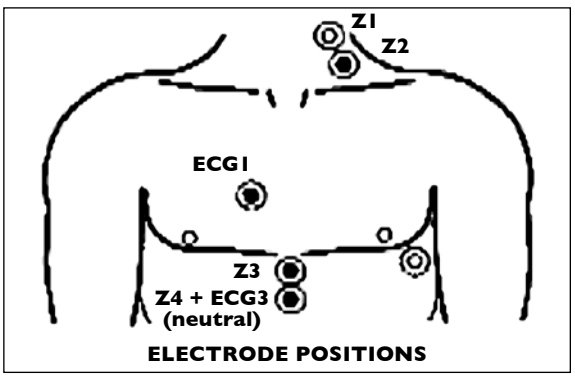

Fig. 1 Figure illustrating the recommended sites of electrode placements.

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placement of Z3 and Z4/ECG3/neutral electrode is impractical. This study aims to evaluate if changing the position of the leads Z3 and Z4/ECG3/neutral to the left fourth and fifth intercostal spaces along the mid-axillary line, where they will not intrude into the surgical field, will affect the CO measurement .

METHODS

This was a non-blinded, prospective, controlled, crossover, paired study. Ethics approval was obtained from the hospital's ethics committee prior to commencement. The study involved 30 patients, who had no contraindications to the placement of the electrodes, such as dermatological conditions or any known hypersensitivity to the electrodes. Written consent was taken from the patients participating in this study and the CO study was performed using Physio Flow®. Their gender, height, weight, age and non-invasive blood pressure readings were documented, prior to commencement of the measurements. The equipment used involved the Physio Flow® Model Lab1 connected to a Hewlett Packard (Hewlett Packard Development Company, Palo Alto, CA, USA) laptop PC Year2000 certified computer running on Windows 98 (Microsoft Corporation, Redmond, WA, USA). Hewlett Packard HP40493E Ag/AgCl pre-gelled electrodes were used.

The measurements were taken in the operating theatre induction room prior to conduct of anaesthesia. The electrodes were placed in the positions recommended by the manufacturers. The machine was calibrated after obtaining a stable signal. After allowing the patient to rest for two minutes, the first CO measurement (CO1) was obtained. For the second CO (CO2) reading, the Z3 and Z4/ECG3/neutral leads were placed along the left mid-axillary line at the fourth and fifth intercostal spaces, respectively. Re-calibration was done and after achieving a stable signal, CO2 reading was obtained after two minutes. The third CO (CO3) reading involved switching the leads back to the recommended placement and obtained after two minutes of stabilisation. This was done as a control to check if the CO had significantly changed within this time frame. It serves to compensate for the possible changes in CO within the short interval between the sets of CO readings.

RESULTS

30 patients were recruited, of which 23 were males and seven were females. The demographics of the study population are summarised in Table I. All of them had their CO measured three times as described, prior to commencement of surgery. An average (COave) was obtained for CO1 and CO3 measurements to minimise the difference in CO, which may be due to autonomic fluctuations with time. This COave is compared with CO2 measured using the proposed position of electrode placement. An analysis of the first and third readings of the CO revealed that the change in CO during the time interval is minimal. The mean for both are 5.36 L/min and paired samples correlation was 0.99. A paired sample t-test of the paired difference between CO1 and CO3 showed a mean of 0 with a standard deviation of 0.16 and standard error of mean to be 0.03 (Table II). The 95% confidence interval of the difference was -0.62 to 0.62.

Table I. Descriptive statistics of the study population.

	N	Mean	Standard deviation
Age (years)	30	47.33	18.909
Height (m)	30	1.6960	0.07262
Weight (kg)	30	63.8767	11.25785
BMI (kg/m^2)	30	22.0767	2.86346

Table II. Paired samples statistics comparing the initial (CO1) and third (CO3) cardiac output measurements with the electrodes at the recommended sites of placement.

	Mean	N	Std. deviation	Std. error mean
CO1 (L/min)	5.362	30	1.5189	0.2773
CO3 (L/min)	5.362	30	1.5462	0.2823

Comparison of the CO measured from the two different placements of electrodes (COave and CO2) with the Bland and Altman method is presented in Fig. 2. The average of the first and third readings (COave) was then compared with the measured and analysed. The regression equation was CO2 at the proposed site = COave at the recommended site + 0.058. The paired samples correlation between COave and CO2 was 0.995. Bias with the proposed electrode placement was +0.046 L/min, with the 95% limits of agreement at -0.24 L/min and 0.34 L/min. The mean difference of CO2 was 0.86% of the COave.

DISCUSSION

Danish-born scientist Nyboer first introduced thoracic electrical bioimpedance in the late 1950s. The classical equations for bioimpedance use two

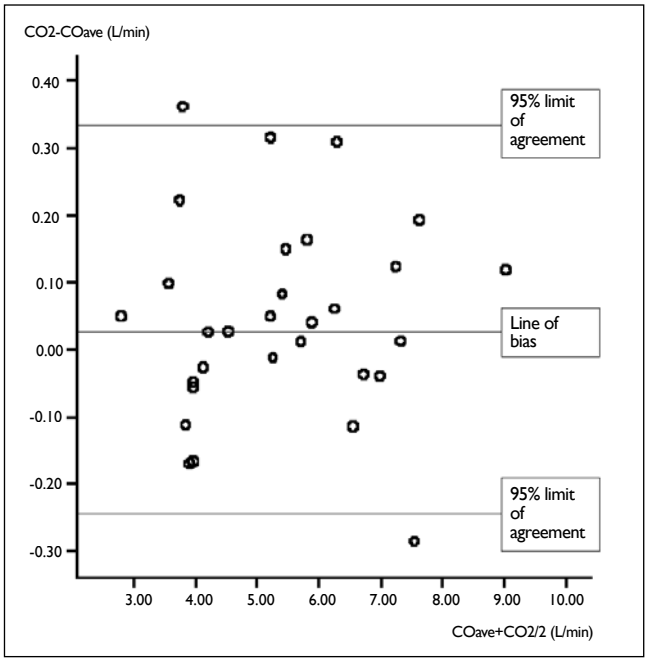

Fig. 2 Bland and Altman plot of CO2-COave versus CO2+COave/2 (L/min) with the line of bias and 95% limits of agreement. (n=30).

components: the basal thoracic impedance (Z0), which represents the steady-state mean thoracic impedance, and the pulsate variations of impedance (ΔZ), which represents the variations in the volume and velocity of aortic blood flow[4]. This method measures and analyses transthoracic impedance signal that varies according to instantaneous thoracic fluid variations. The accuracy of the measurement can be altered by perspiration, subcutaneous adiposity and poor electrical contact[5]. Moreover, this method relies on the baseline Z0 value. Factors such as a "wet" chest due to pulmonary oedema or effusion will have a reduced baseline as fluid is an excellent conductor of electricity and a "dry" chest will have a higher electrical impedance. Hence, for devices dependent on Z0, large amounts of thoracic fluid may interfere with impedance signal, making haemodynamic data unattainable or unreliable.

Physio Flow® is a non-invasive impedance cardiograph device that is used to monitor CO. Research work began in the 1980s when an extensive patient database with widely different physiopathology, haemodynamic parameters, and varying impedance signal patterns was collected. The database was categorised according to signal patterns and a model based on signal morphology analysis, independent of baseline impedance (Z0) was found[6-10]. It provides continuous trend monitoring of heart rate and stroke volume, and derive CO and index parameters. It uses stroke waveform morphology analysis to determine stroke volume and calculate all the derived parameters. Studies have shown that it provides a clinically acceptable evaluation of CO measurements when compared to "direct" Fick method both at rest and during a mild steady state exercise[11] with the mean difference of +0.04 L/min at rest (limits of agreement at -1.34, +1.41 L/min) and 0.29 L/min (limits of agreement at -2.34 and +2.92 L/min) during exercise. A maximal progressive exercise test[11] showed a mean difference of -2.78% (95% confidence interval of -27.44% and 21.78%)

Since the measurement of cardiac output with Physio Flow® is not dependent on baseline impedance, it is particularly useful in patients where measurement of CO intraoperatively is imperative, such as patients with arrhythmia, pulmonary oedema or pleural effusion. It is also useful in patients undergoing abdominal surgery requiring intermittent positive pressure ventilation when thoracic impedance is likely to change with respiration. However, the recommended lead placement renders it unsuitable. During surgery, measurement of CO should ideally be non-invasive and reliable. Physio Flow® provides a continuous measurement (beat-to-beat) and is simple to perform. It does not require an experienced operator and can be used over a long period. However, whether the use of this continuous CO measurement intraoperatively leads to improved outcome requires further evaluation.

The aim of our study was to determine if alternative positions of electrode placement would affect the cardiac output measurement using Physio Flow®. The proposed placement by the manufacturers, placing leads Z3 and Z4/ECG3/ neutral, at the xiphisternum, precluded this device from being used where the surgical field included the xiphisternum. The proposed position of left mid-axillary line at the fourth and fifth intercostal spaces will render it suitable for most surgeries including laparotomies and right thoracotomies. Our study showed that there is minimal difference between the CO measurements at the two different sites of electrode placements. Our results showed a bias of +0.046 L/min between the CO measurements at two different sites of electrode placement. We have not compared this measurement against the Fick method of CO measurement. However, we can keep in mind that when compared with the Fick method, Physio Flow® has a bias of +0.04 L/min at rest. This should be taken into consideration during the interpretation of the measured CO values.

Hence, Physio Flow® can be used to evaluate the CO of patients even if leads Z3 and Z4/ECG3/neutral were to be placed in the mid-axillary line at the left

fourth and fifth intercostals space, as this correlates well with the measurements obtained from the recommended site of placements at the xiphisternum. Our study may widen its application especially when the proposed new site of lead placements allows its use in abdominal or right-sided thoracic surgery.

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