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Is the Nexfin finger cuff method for cardiac output measurement reliable during coronary artery bypass grafting? A prospective comparison with the echocardiography and FloTrac/Vigileo methods

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Background/aim: The aim of the current study was to assess the accuracy of cardiac output (CO) measurements obtained by the Nexfin finger cuff method as compared with the FloTrac/Vigileo and echocardiography methods in coronary artery bypass grafting (CABG) patients.

Materials and methods: First-time elective CABG patients were prospectively enrolled in this study and divided into three groups according to CO measurement method. CO measurements were performed simultaneously by three different contributors and were collected by the fourth one 24 h postoperative in the intensive care unit (ICU). Data were statistically analyzed.

Results: Seventeen female and 13 male patients between 42 and 78 years of age (with a mean of 56 ± 4) were the subjects of this study. The mean CO measurements were 5.9 ± 1.4 L/min, 5.8 ± 1.1 L/min, and 6.0 ± 1.1 L/min for the Nexfin, FloTrac/Vigileo, and echocardiography methods, respectively ($P > 0.05$). The correlation values between Nexfin and FloTrac/Vigileo, Nexfin and echocardiography, and FloTrac/Vigileo and echocardiography were $r = 0.445$, $r = 0.377$, and $r = 0.384$, respectively ($P < 0.05$).

Conclusion: Nexfin yielded results comparable to those obtained with FloTrac/Vigileo and echocardiography for the postoperative CO assessment of CABG patients. Nexfin may be used in uncomplicated, hemodynamically stable patients in ICU as a reliable and totally noninvasive method of CO measurement.

Key words: Noninvasive monitoring, echocardiography, pulse contour analysis

1. Introduction

Cardiac output (CO) is the volume of blood pumped by the heart per minute and is the product of heart rate (HR) and stroke volume (SV) (1). Over the past decades, many techniques for CO measurement have been developed and used. CO is considered to be one of the most important physiological parameters as the major determinant of systemic oxygen delivery and cardiac function. Moreover, it is a determinative factor for volume replacement therapy. Its measurement is of great significance since so many efforts in cardiovascular patients are aimed at optimizing CO. The significance of measuring CO is emphasized by studies that have repeatedly shown that clinical evaluation and conventional monitoring alone are inaccurate and unreliable for the evaluation of CO and that adequate resuscitation cannot be based on stabilization of vital signs alone (2–6). An accurate and noninvasive measurement of CO is one of the best methods of cardiovascular assessment. There are a number of clinical methods for CO measurement ranging from noninvasive ones (echocardiography, Doppler) to invasive ones (Swan-Ganz technique, thermodilution technique, and arterial pressure waveform analysis) (2,3). Each method has its unique advantages and disadvantages and this leads practitioners to further search for less invasive and equally effective methods. For a CO measurement method to gain widespread acceptance, obstacles such as physiological limitations, troublesome maintenance, limited reliability, and insufficient precision must be eliminated (7–11).

The aim of our study was to assess the accuracy of CO measurements obtained by the finger cuff method (Nexfin BMEYE B.V, Amsterdam, the Netherlands) (Nexfin) as

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compared with FloTrac/Vigileo (Edward Lifesciences, Irvine, CA, USA) (FTV) and echocardiography (ECO) in coronary artery bypass grafting (CABG) surgery patients.

2. Materials and methods

This prospective study was approved by the ethics committee of the School of Medicine at Acıbadem University in Turkey. Informed consent was obtained from 30 patients who were scheduled to undergo isolated first-time CABG at the Acıbadem Healthcare Group, Kadıköy Hospital.

2.1. Patient selection

The patients included in this study had a sinus rhythm and stable hemodynamic conditions, and required no inotropic or intraaortic balloon pump support. All had CABG and were normothermic and extubated at the time of CO measurement.

2.2. CO measurements

CO measurements by each method were simultaneously obtained in the ICU in the morning of the first postoperative day (20–24 h after admission to the ICU). Measurements of CO were performed by three different contributors for each method and recorded by a fourth one.

The method of Nexfin is based on the development of pulsatile unloading of the finger arterial walls using an inflatable finger cuff with a built-in photoelectric plethysmograph. While continuously measuring arterial blood pressure (ABP), the monitor also calculates CO. The cuffs were placed in the middle phalanx of the second finger of the patient's left hand. ABP-based measurements were performed with the FTV method. The right radial artery was used for waveform analysis in each patient. FTV was attached to the existing arterial cannula and its sensor was attached to a display unit to assess CO.

ECO measurements of CO were performed by a single cardiologist via transthoracic echocardiography evaluating the velocity–time integral of the left ventricular outflow tract (LVOT), HR, and LVOT area.

2.3. Data collection and statistical analysis

Prospectively collected demographic and hemodynamic data (age, sex, mean arterial pressure, heart rate, central venous pressure) and CO measurements were retrospectively analyzed. Paired measurements of SVR, SV, and CO were compared using Pearson's correlation coefficients; in addition, a Bland–Altman plot (12) was used to graphically compare the agreement of pairs of measurements of SVR, SV, and CO, using GraphPad Prism v5.0. Data were reported as percentages or as means ± SD. Statistical analysis was performed with SPSS and $P < 0.05$ was considered significant.

3. Results

Demographic data and hemodynamic parameters are given in Table 1. Hemodynamic measurement results are given in Table 2. The mean values of CO obtained with Nexfin, FTV, and ECO techniques were 5.9 ± 1.4, 5.9 ± 1.1, and 6.0 ± 1.1 L/min, respectively, and the mean values of SV were 65 ± 15, 66 ± 11, and 70 ± 12 mL, respectively. The mean systemic vascular resistance values were measured as 1244 ± 468, 1102 ± 232, and 1042 ± 235 dyn s cm^{-5}, respectively. No significant differences were found among the different techniques regarding CO, SV, and SVR ($P > 0.05$).

Figure 1a shows a Bland–Altman plot representing the difference between the SVR measurements of FTV and ECO (y-axis) against their means (x-axis) for all patients. The mean difference (bias) between the two measurements was –0.3376, with a 95% limit of agreement (–2.844, 2.169).

Figure 1b shows a Bland–Altman plot representing the difference between the SVR measurements of Nexfin and FTV (y-axis) against their means (x-axis) for all patients. The mean difference (bias) between the two measurements was 0.1041, with a 95% limit of agreement (–2.593, 2.802).

Figure 1c shows a Bland–Altman plot representing the difference between the SVR measurements of Nexfin and ECO (y-axis) against their means (x-axis) for all patients. The mean difference (bias) between the two measurements was –0.2335, with a 95% limit of agreement (–3.087, 2.620).

Table 1. Demographic data and hemodynamic parameters.

Age	Nexfin	FloTrac/Vigileo	Echocardiography
	58 ± 4	56 ± 5	53 ± 5
Sex (male/female)	04/06/15	5/5	4/6
Mean arterial pressure (mmHg)	73 ± 8	70 ± 12	72 ± 9
Heart rate (beats/min)	91 ± 7	89 ± 8	93 ± 6
Central venous pressure (mmHg)	9 ± 4	8 ± 3	9 ± 5

Table 2. Mean values for all variables.

Nexfin	CO (L/min)	SV (mL)	SVR (dyn s cm^{-5})
	5.85 ± 1.4	65 ± 15	1244 ± 468
FTV	5.75 ± 1.1	66 ± 11	1102 ± 232
ECO	6.0 ± 1.1	70 ± 12	1042 ± 235

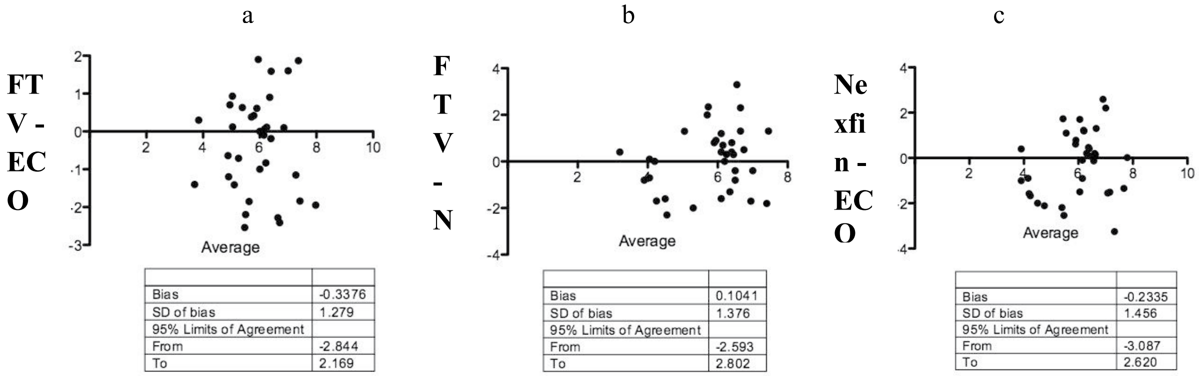

Figure 1. Bland–Altman plot between Nexfin, FTV, and ECO for CO (L): a) FVT–ECO, b) FTV–Nexfin, c) Nexfin–Eco.

Pearson's rank correlation coefficients for the CO levels measured with the different techniques are given in Table 3. The CO levels measured with Nexfin and FTV were correlated (r = 0.445, $P < 0.05$), and so were the CO levels measured with Nexfin and ECO (r = 0.377, $P < 0.05$) and the CO levels measured with FTV and ECO (r = 0.384, $P < 0.05$).

4. Discussion

During postoperative follow-up of patients who have undergone cardiac surgery in which the pressure–volume relationship has deteriorated, routinely used parameters such as ABP and central venous pressure are insufficient to assess the accuracy of tissue perfusion. In this subset of patients advanced monitoring methods such as CO, mixed venous oxygen saturation, and blood lactate level measurements are suggested to assess the efficiency of tissue perfusion (7).

Table 3. Pearson correlation values between methods of cardiac output measurement.

	Correlation coefficients	P-values
Nexfin–FTV	r = 0.445	P < 0.05
Nexfin–ECO	r = 0.377	P < 0.05
FTV–ECO	r = 0.384	P < 0.05

There are a number of clinical methods for CO measurement ranging from direct pulmonary artery catheterization to noninvasive measurements of arterial pulse. Each of these invasive and noninvasive methods has unique limitations, advantages, and disadvantages, and the relative comparison is limited by the clinical evaluation and hemodynamic stability of the patients concerned (4–7). The effectiveness of a clinical monitoring method involves many factors other than its absolute accuracy, and includes safety, accessibility, adaptability, and cost. In clinical care settings, many extensive research studies were done in order to introduce new methods for CO measurement with as few disadvantages as possible (13–18). These techniques do not exclude or replace the others as their advantages and limitations are quite different. These noninvasive methods are not intended to replace the pulmonary artery catheter, which is quite unique in measuring the right atrium, pulmonary artery and pulmonary wedge pressures, and the mixed venous oxygen saturation, in addition to CO.

A comparison of arterial pressure waveform analysis with thermodilution and ECO assessment was previously conducted by Lorsomradee et al. (17). An overall agreement has already been demonstrated for arterial pressure waveform analysis and thermodilution techniques (14,18). However, ECO assessment, especially during the early postoperative period, may lead to overestimation of CO.

Hence, ECO for CO measurement in the early postoperative period may be questionable (19). CO measurement with arterial waveform analysis may provide reliable results with a less invasive technique and may increase the use of CO analysis, thus improving perioperative patient care (18). This knowledge encouraged us to compare Nexfin, which is a relatively new method, with a well-known and reliable method like FTV and a noninvasive method like ECO.

De Wilde et al. (15) studied 13 CABG surgery patients within 2 h of arrival to the ICU following cardiac surgery. In that study the FTV Modelflow method and the transesophageal ultrasonic HemoSonic system were compared with an accurately performed thermodilution method. The authors concluded that only the Modelflow method was shown to be an acceptable alternative to the thermodilution method for CO measurement. In another recent study performed by Stover et al. (16), a standard cardiac monitoring system (pulmonary artery catheter and arterial catheter) was compared with Nexfin. The authors noted that Nexfin, which is quick to install and easy to use, could offer a quick initial hemodynamic overview and save time until a longer-lasting invasive monitoring can be installed in case of a deterioration in the patient cardiac status. Nexfin, which is a relatively new, unique, and totally noninvasive method (13), was shown to be reliable for CO measurement either in critically ill patients (20) or in cardiac surgery patients (21,22). The results of our study also support the reliability of this noninvasive method for CO measurement.

The ideal technique for CO monitoring would be noninvasive, easily applied, accurate, reliable, consistent, and compatible in postoperative cardiac patients in ICU. Today, no single technique meets all these expectations. With a Bland–Altman plot, we had the data of the correlations between Nexfin, FTV, and ECO confirm that, being correlated with the results of FTV and ECO, Nexfin can be used reliably for patients in ICU after cardiac surgery for the evaluation of patient tissue perfusion deterioration despite the fact that patient arterial and central venous pressures may remain normal.

In our study, all of the patients had preoperative ejection fraction >35% and pulmonary capillary wedge pressure <15 mmHg, and there was no postoperative hemodynamic instability. Each patient was normothermic and free from inotropes and vasopressors. The measurements of CO were performed in uncomplicated conditions. These are the limitations of our study.

In conclusion, the ability to accurately measure CO is important in clinical medicine as it provides improved diagnosis of abnormalities and can be used to guide appropriate management of care, helping the clinician in evaluating the problem and treating it before it affects the patient's hemodynamic stability. As Nexfin is a totally noninvasive blood pressure and CO monitoring method, it can be used for this purpose in uncomplicated hemodynamically stable patients. However, further studies should be conducted to confirm our preliminary data, especially in hemodynamically unstable patients. The widespread use of Nexfin would help avoid complications associated with the invasive methods of CO measurement.

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