Short Communication

Cardiac Output Assessment by Transthoracic Electrical Bio-impedance in Patients of Acute Myocardial Infarction: Comparative Analysis with Echocardiography

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Abstract

Objectives: Transthoracic electrical bio-impedance (TEB) has been proposed as a non-invasive and continuous method of cardiac output (CO) measurement, but it still has not found wide usages in clinics. The present study measured CO, using a new instrument NICOMON, and compared it with Echocardiography (ECHO) in acute myocardial infarction (AMI) patients.

Methods: In the present study 100 patients of AMI were assessed by both ECHO and NICOMON for cardiac output and ECHO is considered as a reference method for comparison. TEB CO was measured by passing an alternating current and measuring the bio-impedance across the thorax. End diastolic volume (EDV), End systolic volume (ESV) & Left ventricular outflow tract (LVOT) diameter, measured by ECHO were used to calculate CO. Various statistical methods like “t”-test & correlation coefficient (r) were used where found suitable.

Results: Mean TEB-CO (4.03±1.11 l/min) was significantly higher (p<0.001) than mean ECHO-CO (3.80±1.28 l/min) with a mean difference of 0.25±1.02 l/min.

Conclusions: NICOMON measures CO non-invasively but, it needs more elaborative studies on a larger sample to establish it as an alternative method of ECHO for cardiac output measurement on regular basis.

Introduction

Cardiac output is a measure of blood flows to all tissues of the body, (1) so it is one of the most important factors in relation to the circulation. Hemodynamic instability early during intensive care increases the risk of morbidity and mortality so the development of an accurate, simple, cost-effective, noninvasive technique of measuring cardiac output (CO) can be important for clinical decision making and research in many inpatient and outpatient clinical settings. The recent emphasis on the uncertain risk-benefit ratio of invasive CO monitoring by pulmonary...
artery catheterization (PAC) further necessitates for the development of noninvasive alternatives.

A number of noninvasive methods of assessing CO have been studied in the past, with transesophageal Doppler echocardiography, impedance cardiography, and carbon dioxide breath analysis currently available. Thoracic bio-impedance was the first and currently the most widely used noninvasive method for CO monitoring.

David B Northridge et al (2), in a study found that echocardiography & electrical bio-impedance provide reliable result in most of the acute myocardial infarction patients. Doppler echocardiography takes more time and need technical expertise in comparison to electrical bio-impedance which was simple to use and provides continuous monitoring. In a study, Julija Braždžionyte et al (3) found significant correlation between hemodynamic parameters (stroke volume, cardiac output) obtained by impedance cardiography and echocardiography.

In contrast to the above reports, Jukka Takala, et al (4) in a study found that there was no role of minimally-invasive cardiac output monitoring techniques in ICU in early hemodynamic stabilization of patients and also it does not affect the outcome. Sandeep A. Kamath, et al (5) in a study found that in patients of advanced heart failure, impedance cardiography does not provide much advantage. When compared with other methods of CO monitoring, TEB has shown satisfactory (Bougault V et al (6), Hirschl MM et al (7)) agreement.

This study was undertaken to compare the accuracy and precision of measurement of cardiac output by transthoracic electrical bioimpedance (TEB) using a novel instrument (NICOMON, Larsen & Toubro Ltd., India) in comparison with echocardiography method.

Material And Methods

This cross-sectional study was performed between July 2012 and August 2013 after obtaining approval from the institutional review board of KGMU, Lucknow and written, informed consent from the patients. The study was undertaken in 100 patients of acute myocardial infarction, admitted to cardiology emergency of Gandhi Memorial & Associated Hospital and their cardiac output were measured with ECHO and then with NICOMON. Exclusion criteria were: Patients having cardiac conditions which affect cardiac output like anaemia, valvular heart disease, myocarditis, cardiac tamponade, cardiac metabolic derangements, endocrinal disorders like thyroid dysfunction, arteriovenous fistula (shunt), vitamin deficiency like vitamin B_1 deficiency, pericardial effusion & Patients having conditions which interfere with bio-impedance signal like obesity or pleural effusion.

TEB CO was measured using the NICOMON instrument (Larsen and Toubro Ltd., India). NICOMON works on the principle of impedance plethysmography. In impedance cardiography four pairs of electrodes measure haemodynamic parameters. Each pair of electrodes comprises of a transmitting and sensing electrodes. Two pairs are applied to the base of the neck on directly opposite sides and two pairs are placed at the level of the sternal-xiphoid process junction, again directly opposite from each other. The electrodes define the upper and lower limits of the thorax and the distance between them is measured to obtain the thoracic length (L). A high frequency, low amplitude alternating current is introduced through the transmitting thoracic electrodes and the sensing thoracic electrodes measure impedance associated with the pulsatile blood flow in the aorta which occurs during the cardiac cycle. By measuring the impedance change generated by the pulsatile flow and the time intervals between the changes, stroke volume (SV) can be calculated. The change in impedance is measured from the baseline impedance (Z_0) (overall thoracic resistance to flow of electrical current). It predominantly reflects total thoracic fluid volume. The magnitude and rate of the impedance change is a direct reflection of left ventricular contractility. This change in impedance related to time (dZ/dt) generates a waveform that is similar to the aortic flow curve. During systole, a volume of blood leaves the thorax via the large arteries. The SV can be determined from the impedance curve by extrapolating to the impedance change (dZ) that would result if no blood
were to flow out of the thorax during systole. The SV is calculated using the formula,

\[ \text{Stroke Volume} = \rho \frac{L^2}{Z_0} \times (dZ/dt)_{\text{max}} \times \text{VET} \]

where \( \rho \) - resistivity of blood, \( L \) - mean distance between the inner electrodes (the thoracic length), \( \text{VET} \) - ventricular ejection time, \( (dZ/dt)_{\text{max}} \) - the absolute of the maximum value of the first derivative during systole and \( Z_0 \) - basal thoracic impedance. VET is obtained from the dZ/dt versus time curve \(^8\).

Ejection fraction, end diastolic volume, end systolic volume and left ventricular outflow tract diameter determined stroke volume (SV) by Echo method and then CO has been obtained by multiplying SV by heart rate.

Statistical analysis of data obtained was done by paired “t”-test to compare the TEB-CO & ECHO-CO. The changes in CO were compared using correlation analysis. A “p” value of less than 0.05 was considered to be statistically significant.

Results

The study was conducted on a cross-sectional design. A total of 100 subjects were enrolled and data from all the 100 patients were used for analysis. The cardiac output and cardiac index of acute myocardial infarction patients were measured by NICOMON & ECHO and were compared.

For the parameter CI mean value in NICOMON was found to be significantly higher as compared to that of ECHO \( (p<0.001) \). A weak positive correlation (“r” value=0.18) for CI value was found. TEB-CO values

<table>
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<tr>
<th>TABLE I: Comparison of Cardiac Index (CI) and Cardiac Output between NICOMON and ECHO.</th>
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<td>CI (Lt/min/m²)</td>
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<td>CO (Lt/min)</td>
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Chart 1: Bar diagram showing comparison of Cardiac Index between NICOMON and ECHO.

Bar diagram showing association between mean values of Cardiac Index obtained by NICOMON (2.77) and ECHO (2.25) with standard deviation of 0.73 & 0.80 respectively.
ranged from 2.5 to 8.3 Lt/min with a mean of 4.03±1.11 Lt/min, whereas ECHO-CO values ranged from 1.71 to 9.0 Lt/min with a mean of 3.80±1.28 Lt/min. The average correlation (r) was 0.16 (p<0.001).

Discussion

Impedance cardiography provides information about haemodynamic status without the risk, cost and skill associated with the other invasive or minimally invasive techniques. NICOMON is a cost-effective, portable, bed-side and a non-invasive method of estimating cardiac output and other cardiovascular parameters. So the clinical validation of new techniques is necessary to convince that these new tools provide reliable measurements.

Recently, the use of pulmonary artery catheters for invasive hemodynamic monitoring has been increasingly criticized on account of its unclear risk/benefit ratio. Hence, a new technique that could provide a fair estimation of cardiac output in a less invasive and less expensive way is clearly desirable. Minimally invasive and non-invasive methods of estimation of cardiac output (CO) were developed to overcome the limitations of invasive nature of pulmonary artery catheterization (PAC). Transthoracic electrical bio-impedance (TEB), a non-invasive technique to measure CO, has been increasingly explored for its use in post-cardiac surgical patients over the last four decades. With the TEB method, CO is calculated by detecting changes in the body’s impedance to small electrical currents.

Since its introduction in the mid 1960s by the National Aeronautical and Space Administration researchers and William Kubicek, impedance cardiography using the TEB has been increasingly explored for its ability to measure CO and other hemodynamic parameters. The present study has been done to evaluate non-invasive method to measure CO by TEB technology and to compare it with ECHO-CO method in acute myocardial infarction patients.

In the present study it has been found that the cardiac index (CI) recorded in patients of acute myocardial infarction by NICOMON (2.77 Lt/min/m²) was more than that recorded by ECHO (2.25 Lt/min/m²) and a weak positive correlation ("r" value=0.18) was found. The mean value in NICOMON was found to be significantly higher (p<0.001) than that recorded by ECHO. The TEB-CO (4.03 Lt/min) was more than
ECHO-CO (3.80Lt/min) and a weak positive correlation ($r^2$ value=0.16) (p<0.001) between the two was found. The above results showed that to establish NICOMON as an alternative method for measuring cardiac index and cardiac output needs more elaborate studies on a larger sample before drawing out a conclusive statement.

There are some studies which support findings of the present study. In a study Yolanda Ballestero, et al (9) found that in paediatric patients, it not a suitable method for evaluation of the CI in children weighing<20 kg with the currently available software and electrodes. Sandeep A. Kamath, et al (5) in a study found that in advanced heart failure patients, impedance cardiology is not much useful. Above results are also supported by studies done by Bougault V et al (6), Hirschl MM et al (7).

However David B Northridge et al (2) in a study found that Doppler echocardiography needs expertise while electrical bio-impedance was simple to use and provide immediate results. Julija Braždžionyte et al (3) found in a study that hemodynamic parameters (stroke volume, cardiac output) measured by impedance cardiology and echocardiography were significantly correlated.

To conclude, we can say that data obtained from 100 patients of acute myocardial infarction measured by NICOMON & ECHO shows weak positive correlation and difference between mean values of cardiac output and Cardiac Index is significant statistically. The results of our study do not exclude the possibility that NICOMON, when combined with a specific care protocol or used in other circumstances, could have an impact on relevant outcomes. So we can say that a bigger sample size might give some favorable results to establish NICOMON as a cost-effective, portable, bed-side and a non-invasive method of estimating cardiac output and other cardiovascular parameters.

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References