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COMPARISON OF NON-INVASIVE CARDIAC OUTPUT MEASUREMENT USING INDIGENOUS IMPEDANCE CARDIOGRAPHY WITH INVASIVE FICK METHOD

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ABSTRACT

Background: Cardiac output (CO) is a functional tool to evaluate the cardiovascular performance. To estimate CO, several invasive methods like the Fick method and thermodilution method are available which require cardiac catheterization. Impedance cardiography (ICG) is well-established noninvasive technique for measurement of cardiac output. The cardiac output monitor based on ICG has been indigenously designed and developed by Bhabha Atomic Research Center, Mumbai. For validation of this indigenous equipment, we compared measurement of cardiac output using noninvasive ICG with conventional invasive Fick method.

Materials and methods: We simultaneously measured cardiac output in 10 patients (mean age 40 years, range 21-54 years, 6 males and 4 females) using impedance cardiography with that derived after utilization of Fick's principle in cardiac catheterization laboratory patients undergoing cardiac catheterization. We compared the cardiac indices obtained by two methods.

Results: There is a very good correlation (r=0.9, for n=10) between the cardiac index obtained by impedance cardiography and that derived invasively after cardiac catheterization using the Fick method. The mean values of cardiac indices by ICG method and the Fick method were 3.8±0.6 l/min/m^2 and 2.9±0.5 l/min/m^2 respectively. The average bias from the ICG to Fick is 0.8 l/min/m^2 whereas individual variability is 0.3 l/min/m^2.

Conclusion: These results support use of this indigenous ICG equipment in patient care for monitoring cardiac output measurement with the further validation by comparing it with other noninvasive technique like thermodilution.

Keywords: Impedance cardiography, Fick method, Cardiac output, Noninvasive

1. Introduction:

Measurement of cardiac output is important in diagnosis and management of various conditions affecting cardiovascular performance in adults and pediatric population[1]. Most patients however are managed without measurement of cardiac output by relying on clinical signs and investigations, which indirectly assess the myocardial function and this may be misleading in many groups of patients. For example; hypertension can be viewed fundamentally as a hemodynamic disorder, can be associated with either a high cardiac output or high systemic vascular resistance[2, 3]. In these patients, measurement of cardiac output with arterial pressure measurement, allows systemic vascular resistance estimation and guide for appropriate management.

To estimate CO in clinical practice, several invasive methods are available, like dye-dilution, thermo-dilution techniques, Ficks principle etc. These have been extensively used worldwide as methods to measure cardiac output in intensive care units and operation theatres All these require catheterization of the patient which itself adds to morbidity and mortality of patient [4,5]. Further, most of them give only intermittent measurement of cardiac output of the patient. Invasive techniques are most suitable for intensive care unit or operating room situation when a patient is unstable with some complication and medical decision-making justifies the risk, expense, and time needed to perform the measurement accurately. With the advent of reliable non-invasive techniques, the indications for invasive Cardiac Output monitoring are becoming less and less.[6, 7] There are noninvasive methods like echocardiography which requires costly setup with skilled personnel to perform it and are time consuming.

Alternatively, the method of Impedance Cardiography with its several advantages is a promising method to measure cardiac output.

The existing impedance based cardiac output monitors operate by emitting a very low voltage (2.5 to 4 mA), high frequency (50 to 100 kHz), and alternating electrical current through the thorax using standard ECG electrodes. The electrical impedance changes according to changes in the volume and velocity of the blood flow, in the thoracic aorta within the thorax are detected by sensing electrode as pulsatile decreases in impedance (dZ), which can be further expressed as its derivative (dZ/dt). This derivative has been shown to proportional to stroke volume. The waveform shows two prominent waves namely, C-wave (ventricular systole) and O-wave (ventricular diastole). The onset of C-wave is marked by point-B, which corresponds to the opening of aortic valve [8]. It is marked in successive ten cycles, which then averaged and gives stroke volume. The stroke volume multiplied by heart rate gives CO of the patient. The Bhabha Atomic Research Center (BARC) is India's premier nuclear research facility and a multi-disciplinary research centre with extensive infrastructure for advanced research and development covering the entire spectrum of nuclear science, engineering and related areas. BARC has designed and developed indigenous Cardiac Output Monitor based on impedance cardiography [9, 10]. This study was carried out to validate this non-invasive equipment based on ICG by comparing it with invasive Fick`s method for determination of cardiac output by ICG.

The above study was approved by medical ethics committee of All India Institute of Medical Sciences, New Delhi-110029

2. Materials and Methods

We performed simultaneous assessment of cardiac output in 10 patients with normal sinus rhythm (mean age 40 years, range 21-54 years, 6 males, and 4 females). The recordings were carried out in the Catheterization Laboratory, on the patients from the Department of Cardiology of AIIMS who are routinely undergoing catheterization for cardiac output measurement by the Fick method for various diagnostic and prognostic indications. The patients excluded from the study were the patients with congenital heart diseases, cardiomyopathies, pleural effusion, significant generalized edema and unstable patients. Patients selected for cardiac catheterization were called to catheterization laboratory on the day of scheduled procedure. After adequate preparation and local anesthesia and introduction of suitable arterial and venous sheath, continuous arterial BP was monitored. Swan Ganz catheter was introduced through venous sheath and pressure waveforms were recorded from right atrium (RA), right ventricle (RV), pulmonary artery (PA). Blood samples were drawn from PA and femoral artery (FA) and saturation were estimated. A pigtail catheter was inserted from arterial sheath to aorta and left ventricle (LV) and pressures recorded appropriately. Simultaneous wedge and LV pressures were recorded in appropriate cases. Other parameters like heart rate (HR), body weight, height, body surface area (BSA), hemoglobin (Hb) were recorded. Vo_2 (oxygen consumption) was assessed from nomograms depending on age, heart rate and BSA. Cardiac output (CO) was calculated using Fick's principle. When sample was being taken from pulmonary artery for the Fick method, simultaneously cardiac output measurement was done using horizontal electrode placement by ICG; details about this electrode placement method are mentioned elsewhere.[11]

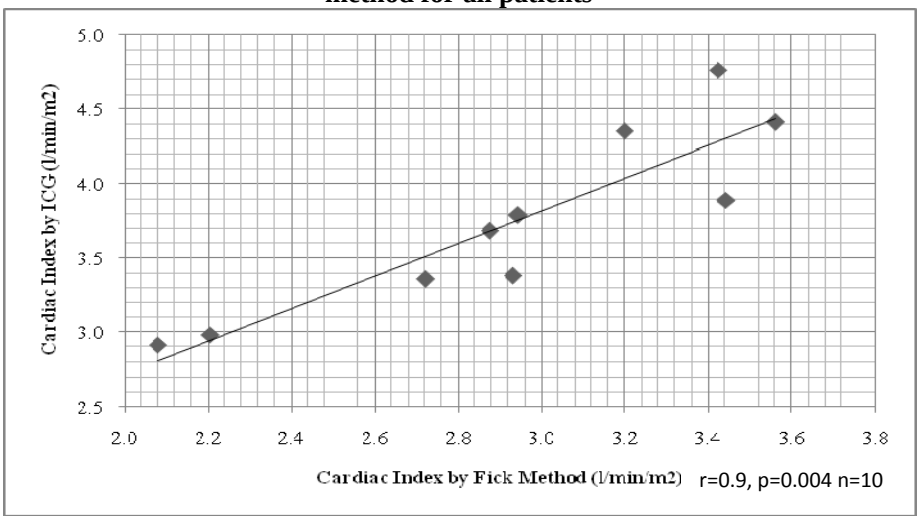
3. Results

There is a good correlation (r=0.9, p=0.004 for n=10) between the cardiac index obtained by impedance cardiography and that derived invasively after cardiac catheterization. The mean values of cardiac indices by ICG method and the Fick method were 3.8±0.6 l/min/m^2 and 2.9±0.5 l/min/m^2 respectively(Table-I). The average bias from the ICG to Fick is 0.8 l/min whereas individual variability is 0.3 l/min/m^2. The cardiac index derived by ICG methods consistently showed higher value than that estimated by Fick Technique.

Table: I Shows cardiac indices (CI) l/min/m^2 by Fick Method (F-CI) and ICG (I-CI) (n = 10)

Sr. No.	1	2	3	4	5	6	7	8	9	10	Mean±SD
F-CI	2.9	2.9	3.4	3.6	2.7	2.2	2.9	2.1	3.4	3.2	2.9 ± 0.5
I-CI	3.7	3.4	4.8	4.4	3.4	3.0	3.8	2.9	3.9	4.3	3.8 ± 0.6

Graph I: shows correlation of values of cardiac index for the Fick method with that of ICG method for all patients



4. Discusssion

We found a good correlation between the Fick method and indigenous ICG. This supports use of this technique in cardiac output measurement with further substantiation of its validity by comparing its performance with other invasive techniques such as thermodilution.[12] PA catheterization is a complicated and invasive ICU procedure commonly used to measure intra-cardiac pressures and derive cardiac Output. The basic data acquisition by invasive methods requires utmost attention for specific positioning of the catheter, pressure, and temperature transducers calibration. Another important fact is that it assumes patient heart rate was stable; the pressures were recorded accurately with confirming accuracy of transducer calibration. For the Fick method, calculated oxygen consumption using nomograms vs. actual oxygen consumption using actual online gas analyzer can be different. In addition, the serial values over a period of time are more important than the absolute value in case of routine management of the patient. They give us the information about the evolution or progress of the disease in response to treatment. Contrary to these limitations of invasive methods, presently, non-invasive cardiac output monitoring intends to monitor parameters continuously and to follow trends in therapy and interventions. These have become more relevant and accurate and have also been reported to be of value in areas not previously been considered appropriate for Cardiac output determination such as emergency rooms, general hospital wards as well as exercise testing setup. [13, 14] Non-invasive techniques allow for the patients to be completely awake, and cardiac output monitoring can be started immediately. [15] These non-invasive techniques can be used in simple set ups, which are less well staffed and cannot afford the risks, expense, and time needed to perform the invasive technique. The utility of ICG in various settings is increasing which include; emergency room triage of patients[16], outpatient management of hypertension and heart failure patients[17, 18], optimization of atrioventricular interval of AV sequential cardiac pacemakers[19], dialysis[20] and liver cirrhosis[21] etc.

Limitation: Study would have been better, with homogenous groups of more number of subjects. Availability of online blood gas analyzer would have been more objective for calculation of actual oxygen consumption rather than use of nomograms.

Conclusion: The Indigenous equipment based on non-invasive Impedance cardiography showed a good correlation with the invasive Fick method for the cardiac output measurement. This study thus supports the use of this equipment for cardiac output measurement with need of further studies having large sample size and different clinical conditions.

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