A Comparative Study of Bioimpedance and the Thermodilution Method in Cardiac Output Monitoring After Coronary Artery Bypass Grafting

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Background --- Cardiac Output can be reliably monitored noninvasively after Coronary Artery Bypass Grafting Surgery. It is the aim of this study to determine the reliability of cardiobioimpedance in monitoring the cardiac output after coronary artery bypass grafting in comparison with thermodilution method.

Methods --- This is a validation study involving patients who underwent coronary artery bypass grafting who had a pulmonary artery catheter inserted and admitted to the PHC Recovery Room from May to December 2006. Cardiac output, cardiac index and systemic vascular resistance were measured using bioimpedance cardiography and thermodilution method simultaneously in the first, second, fourth and eight hour after Coronary Artery bypass grafting

Results --- A total of 38 patients who underwent Coronary artery bypass grafting were investigated. Mean cardiac output on the 1st, 2nd , 4th and 8th hour by cardioimpedance were 3.22 L/min (r=0.937, p-value 0.0), 3.61 L/min (r=0.963, p-value 0.086), 3.81 L/min (r=0.934, p-value 0.01) and 4.33 L/min (r=0.958, p-value 0.010) compared to thermodiltion results of 3.4 l/min, 3.6 L/min, 3.99 L/min and 4.23 L/min. Mean Cardiac Index on the same monitoring by cardioimpedance were 2.24 (r=0.934, p-value 0.396), 2.35 (r=.969, p value 0.481) 2.82 (r=0.999, p-value 0.231) and 2.91 (r=0.994, p-value 0.458) compared to thermodilution which showed 1.94, 2.17, 3.06 and 3.13 respectively.

Conclusion --- Cardioimpedance reliably measures cardiac output in patients after Coronary artery bypass grafting operation. It enhances the value of the method in continuous monitoring of patients after the said operation. *Phil Heart Center J 2007; 13(2):92-95.*

Key Words: Bioimpedance ■ Thermodilution ■ Cardiac Output ■ Validation ■ Coronary artery bypass graft surgery

The early period after Coronary Artery Bypass Grafting operation provides a crucial opportunity for early assessment and rapid therapeutic interventions that may affect the outcome of the said procedure. After CABG, patients require careful hemodynamic monitoring for at least the first postoperative day, because the patient shows significant hemodynamic instability during this initial intensive care unit period.[1] The primary purpose of circulatory monitoring is to obtain frequent, repetitive or continuous measurement of circulatory functions to allow prompt recognition and early initiation of therapy.

Invasive and noninvasive monitoring systems can provide similar information that identifies episodes of hypotension, low cardiac output and deranged vascular resistance. In practice, a 10 to 15% difference between invasive and noninvasive cardiac estimations would be acceptable when 30% to 50% changes from the normal range are present.[2]

Thermodilution used in conjunction with PA balloon flotation catheter to obtain simultaneous PA opening pressure has become the standard for hemodynamic evaluation particularly in the early stages of acute critical illness and high risk surgical procedures. The use of the invasive method for measuring cardiac output has its controversies from infections to its associated increased morbidity and mortality.[3] Although in a recent study by Chittock et al, the use of pulmonary artery catheter was associated with decreased mortality in the most critically ill patients and with increased mortality in patients with less severe illness. Thermodilution also has an appreciable inaccuracies in both high and low cardiac output ranges and especially when the patient has hypothermia and arrhythmias, which is usually seen in post CABG patients.

Cardiac output can be determined non invasively by impedance measurement. In this method the injecting electrode produce an electrical field across the thorax from the base of the neck to the level of the xiphisternal junction, the electrical signals travel predominantly down the aorta rather than through the alveoli. Clinical evaluation under the worst case scenario of emergency trauma in an inner-city county hospital have shown improved stability of signal and satisfactory agreement with simultaneous thermodilution cardiac output measurements. The correlation of bioimpedance versus thermodilution cardiac output measurement were equivalent to those of pulse oximetry

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compared with the standard blood gas analysis. No instance of spurious impedance values that would have led to incorrect or harmful therapy was observed.[4]

Because of this, it is being considered that non invasive cardiac output monitoring by bioimpedance can be an acceptable cheaper and safer alternative to invasive monitoring in post CABG patients. This study is aimed to compare the cardiac output monitoring measured by thermodilution and bioimpedance in the first eight hours after coronary artery bypass grafting operation as well as to determine if there is a significant difference between thermodilution and bioimpedance cardiac output estimations after coronary artery bypass grafting surgery.

Methods

This is a validation study involving patients who underwent coronary artery bypass grafting who had a pulmonary artery catheter inserted and was admitted to the PHC Recovery Room from May to December 2006. After establishing the patient's eligibility, written informed consent was obtained. Baseline demographic data, co-morbidities, ejection fraction by echocardiography, coronary angiographic findings and drugs used after the operation were also obtained.

Data were collected during the first eight hours post-operatively at the recovery room from each patient using thermodilution bolus method and by using bioimpedance monitoring (BioZ System 1.52) simultaneously. The data were collected within the first hour and then every two to four hours (1st hr, 2nd hr, 4th hr and 8th hr) for three determinations. Thermodilution data was obtained using the pulmonary catheter. The position of the pulmonary catheter was verified by waveform analysis, the computation constant was confirmed and the transducer leveled and zeroed. For each patient , cardiac output was measured using a room temperature fluid bolus technique. Exactly 10 ml of normal saline was injected through a cardiac output injection kit connected to the right atrial port of the pulmonary artery catheter. Injection time was less 4 seconds. The cardiac output curve was examined with each injection to ensure that the curve and the injection time were normal. A total of 3 thermodilution measurements were obtained for each patient. Cardiac output, cardiac index, systemic vascular resistance was recorded as indicated by the bioimpedance monitor each time a bolus was injected for the thermodilution measurements.

Statistical Analysis

Data were described as mean, standard deviation, frequency and percent distribution. Paired t-test and Pearson Correlation Analysis were used for comparing results of cardiac output, cardiac index and systemic vascular resistance of bioimpedance and thermodilution method. A p value ≤ 0.05 was considered significant.

Results

A total of 38 patients who underwent Coronary artery bypass grafting were included in the study. Majority (71%) were males and the mean age was 58.3 ± 10.5 years, although about a quarter were less than 50 years-old. Co-morbidities present were hypertension which was seen in 58% of the cases, followed by diabetes (42%). Echocardiographic data showed a mean left ventricular ejection fraction of 58.9 ± 13.9, with 21% of these patients having an ejection fraction lower than 50 percent. A total of 76 % have 3 vessel disease, while 26 % had Left Main involvement. Only 18% had 2 vessel disease. All patients were on inotropics after CABG and 36% were on vasodilator. All of them were on mechanical ventilator (Table 1). Data on hemodynamics on the patients analyzed were shown in Table 2. The said data were collected on the 1st hr, 2nd hr, 4th and 8th hr post CABG. Mean cardiac output on the 1st, 2nd , 4th and 8th hour by cardioimpedance were 3.22 L/min (r=0.937, p-value 0.0), 3.61 L/min (r=0.963, p-value 0.086), 3.81 L/min (r=0.934, p-value0.01) and 4.33 L/min (r=0.958, p-value 0.010) compared to thermodiltion results of 3.4 l/min, 3.6 L/min, 3.99 L/min and 4.23 L/min. Mean Cardiac Index on the same monitoring by cardioimpedance were 2.24 (r=0.934, p-value 0.396) 2.35 (r=.969, p value 0.481) 2.82 (r=0.999, p-value 0.231) and 2.91 (r=0.994, p-value 0.458) compared to thermodilution which showed 1.94, 2.17, 3.06 and 3.13 respectively. Mean SVR on the same monitoring by cardioimpedance were 1973.89 (r=0.920, p-value 0.169) 1834.24 (r=0.969, p value 0.173) 1764.26 (r=0.914, p-value 0.637) and 1708.34 (r=0.967, p-value 0.652) compared to thermodilution which showed 2037.74, 1860, 1749.97 and 1715.60 respectively. The p value on cardiac index and SVR showed a non significant difference between thermodilution and bioimpedance. A non significant difference was noted only on the 2nd hour of cardiac output monitoring. A high Pearson Correlation coefficient was noted on the three hemodynamic parameters.

Discussion

Traditionally, pulmonary artery catheters have been used to monitor and adjust medications to optimize hemodynamic status after coronary artery bypass grafting. Hemodynamic status can be measured intermittently or sequentially using such method. A continuous measurement of cardiac output increased the number of treatment decisions and this will provide a hemodynamically guided care to monitor the course of treatment in post CABG patient since most of them have altered hemodynamics status, on inotropics and on vasodilator therapy.

Impedance cardiography can be an accurate method of measuring cardiac output, cardiac index and other hemodynamic parameters. It is a viable alternative to pulmonary artery catheters in patients who will undergo CABG or hemodynamic study. The measurements of hemodynamic data should be compared with the current method or technique to examine the reliability of a new method. Patients who underwent CABG should have a continuous monitoring for the primary purpose of hemodynamically guided therapy for stabilization of their altered hemodynamics. In our study, cardioimpedance showed no significant difference to thermodilution in measuring cardiac output, cardiac index and SVR. Both methods for the said hemodynamic study were acceptable even though there were conflicting data on cardiac output monitoring which could be affected by stroke volume, heart rate or body surface area. Woltzer et al showed that weight can influence stroke volume in impedance cardiography.[5] Evidence indicates that factors related to clinicians and equipment and intrinsic to patient, may affect the accuracy and reproducibility of thermodilution measurements likewise the accuracy of impedance cardiography may be influenced by factors related to clinician such as sensor placement, the digital; signal processing systems, and the algorithm and equations used to calculate cardiac output. Therefore many human and technological factors would affect the correlation of cardiac output measurements made with clinical standard (thermodilution) and measurements made with impedance cardiography.[6]

The agreement between thermodilution method and impedance cardiography is similar to reported comparisons between invasive methods in analogous setting.[7] Drazner et al found that Pearson Correlations between impedance cardiography and thermodilution were 0.76 for cardiac output and 0.64 for cardiac index, much less than we found in our study (0.96 and 0.93) respectively. A high Pearson correlation coefficient may mean high agreement between methods of measuring cardiac output. Despite differences in methods, these studies both indicate that impedance cardiography provides results that are comparable to results of accepted invasive techniques. Cardioimpedance reliably measures cardiac output in patients after CABG. The excellent repeatability of bioimpedance enhances the value of this method in continuous monitoring of patients after CABG.

Since all our patients were on mechanical ventilation and can have a possible influence on accuracy of cardioimpedance. Our study showed that comparable results were obtained using thermodilution and cardioimpedance in our patients. The present study indicates that cardioimpedance can be reliable in mechanically ventilated patients similar to other researches who have reported positive clinical results with impedance cardiography in patients receiving mechanical ventilation.[8]

Impedance cardiography is a useful monitoring technique in a critical care unit[9] and could decrease hospital costs associated with invasive and hemodynamic monitoring.[10] In a small study[11] in which the investigators evaluated whether the availability of impedance cardiography could reduce the need for pulmonary artery catheterization, patients who were first determined to need invasive monitoring were subsequently monitored with impedance cardiography. In 71% of patients, use of impedance cardiography eliminated the need for a pulmonary artery catheter.

Conclusions

Bioimpedance is a noninvasive technology use to measure cardiac output and can provide other hemodynamic measurements. Our study provided evidence that hemodynamic measurement done using this method is almost in agreement when compared with bolus thermodilution method. Cardiac output is easier to measure by impedance cardiography than by thermodilution. It can be applied quickly and does not pose a risk of infection and other complications associated with arterial catheters. Our findings provided further validation of the use of cardioimpedance for continuous monitoring post CABG patients. In addition the increased frequency of cardiac output data available with impedance cardiography might lead to more timely interventions.

Table 1. Clinico-demographic Characteristics of post-CABG patients

Variable	N (%) N=38
Age (yrs) Mean ± SD	58.3 ± 10.6
Sex Male	27 (71%)
Female	11 (29%)
Co-morbidity	
Hypertension	22 (58%)
Diabetes Mellitus	16 (42%)
Smoking history	11 (29%)
Dyslipidemia	3 (8%)
Renal insufficiency	1 (2%)
PAOD	1 (2%)
Echocardiography (EF) (mean,SD)	58.9 ± 13.9
Coronary Angiogram	
1 vessel disease	2 (5%)
2 vessel disease	7 (18%)
3 vessel disease	29 (76%)
Left main involvement	10 (26%)
Drugs used after bypass	
IV inotropic	38 (100%)
IV vasodilator	10 (26%)
IV inodilator	1 (5%)

Table 2. Comparison of hemodynamic parameters obtained using Bioimpedance with Thermodilution Method

	BIOIMPEDANCE		THERMODILUTION		CORRELATION	P
	Mean	SD	Mean	SD	(r)	Value
CARDIAC OUTPUT						
1st hr	3.22	0.70	3.40	0.71	0.937	0.000
2nd hr	3.61	0.73	3.66	0.70	0.963	0.086
difference	0.38		0.27			
p-value	0.000		0.000			
4th hr	3.81	0.80	3.99	0.65	0.934	0.001
difference	0.59		0.59			
p-value	0.000		0.000			
8th hr	4.33	0.75	4.23	0.68	0.958	0.010
difference	1.11		0.84			
p-value	0.000		0.000			
CARDIAC INDEX						
1st hr	2.24	2.23	1.94	0.44	0.934	0.396
2nd hr	2.35	1.67	2.17	0.50	0.969	0.481
difference	0.11		0.23			
p-value	0.277		0.000			
4th hr	2.82	3.86	3.06	5.06	0.999	0.231
difference	0.58		1.12			
p-value	0.039		0.177			
8th hr	2.91	2.30	3.13	4.07	0.994	0.458
difference	0.67		1.19			
p-value	0.000		0.078			
SVR						
1st hr	1973.9	706.91	2037.74	697.87	0.920	0.169
2nd hr	1834.2	586.34	1860.00	614.54	0.983	0.173
difference	139.66		177.74			
p-value	0.108		0.044			
4th hr	1764.3	438.29	1749.97	452.80	0.914	0.637
difference	209.63		287.76			
p-value	0.033		0.001			
8th hr	1708.3	386.52	1715.60	380.63	0.967	0.652
difference	265.55		322.13			
p-value	0.006		0.001			

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