Comparison of New Impedance Cardiography versus Ventricular Angiography in Measuring Hemodynamic Variables

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Background: Hemodynamic variables provide crucial information to a critical care clinician. Non-invasive, safe, easily reproducible continuous hemodynamic monitoring is helpful in diagnosing and guiding treatment in critically ill patients. This study determined the correlation and agreement of measuring stroke volume (SV) and left ventricular ejection fraction (LVEF) using new generation impedance cardiography (ICG) and ventricular angiography (Cath).

Methods: Biplanar left ventriculograms were done to calculate SV and LVEF among patients who underwent cardiac catheterization from October 2004 to December 2004. ICG was performed to obtain concurrent SV and LVEF. Thirty-six comparative measurements were obtained. Pearson's r correlation coefficients and Bland-Altman comparisons were calculated.

Results: Thirty-six patients (30 acute coronary syndromes, 3 congestive heart failure and 3 valvular heart disease; mean New York Heart Association Class 2 +/- 1) were examined using the 2 methods. The average age of the patients was 53 +/- 15 years. The correlation coefficient between the values of SV_{ICG} and SV_{cath} was r = 0.50 (p<0.01; n = 36; bias = -1 ml; standard deviation = 19.6 ml). The correlation coefficient between the values of EF_{ICG} and EF_{cath} was r = 0.67 (p<0.01; n = 36; bias = -2.5%; standard deviation = 12.3%). The limits of agreement between SV_{ICG} and SV_{cath} were -40.2 ml to 38.2 ml; the limits of agreement between EF_{ICG} and EF_{cath} were -27.1% to 22.1%.

Conclusions: In our study, the limits of agreement between the new generation ICG and the left ventricular angiogram were wide. We concluded that the new generation ICG should not replace the standard methodology at a single time point. ***(Thorac Med 2008; 23: 73-80)***

Key words: impedance cardiograph, thoracic electrical bioimpedance, ventricular angiography, thermodilution, pulmonary artery catheter, cardiac output, stroke volume

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Introduction

Cardiac output is a primary determinant of global oxygen transport from the heart to the rest of the body, so it is the most important hemodynamic measurement for assessing perfusion status. While augmenting cardiac output to high levels (i.e., > 3.5l/min/m^2) has been shown not to improve survival rates in septic shock [1-2], a very low cardiac output is detrimental and associated with high mortality rates [1]. Reliable hemodynamic measurements help clinicians make appropriate decisions regarding the diagnosis and treatment of critically ill patients.

Over the past 30 years, pulmonary artery catheterization (PAC) has been widely used to measure hemodynamic variables in critically ill patients; however, controversy still exists regarding the use of PAC in these patients. A number of studies were not able to show that measuring PAC had any benefit in determining the prognosis for such patients [3-5]. In addition, the thermodilution method through PAC requires central venous access, which is more invasive and is associated with insertion and infection risks. Hence, hemodynamic variables have been monitored in only the sickest patients during the past decades.

However, hemodynamic measurement is important in many other clinical conditions, including diagnosis of acute dyspnea and shock, as a prognosis predictor and treatment guide for heart failure, in hemodialysis, and in weaning from the mechanical ventilator. Therefore, a simple, reliable, noninvasive, and continuous monitoring of circulatory dysfunction has become indispensable to enable the application of hemodynamic measurement throughout the hospital, and for diverse patients with different degrees of medical severity. The monitoring of continuous real-time hemodynamic variables allows prompt recognition of circulatory abnormalities and early therapeutic intervention.

The impedance cardiograph (ICG) provides such information, but its practicality remains unclear. In the past, the accuracy of ICG was typically validated by Doppler echocardiography and the thermodilutional method [6-10]. However, left ventricular ejection fraction (LVEF) and stroke volume (SV), as measured by ventricular angiography (Cath), is more precise and objective, and is the standard method in patients without pulmonary artery catheter insertion [11-12]. The purpose of this study was to determine the agreement between the LVEF and SV as measured by ICG compared to those values as obtained by Cath.

Materials and Methods

After receiving approval of the protocol, including the consent form, by the institutional ethics committee, patients undergoing elective Cath were considered for enrollment into the study from October 2004 to December 2004. A total of 36 patients were enrolled.

Left ventricular angiograms were performed in our cardiac catheterization laboratory. Biplanar left ventriculograms in 30-degree right anterior oblique (RAO) and 60-degree left anterior oblique (LAO) projections were performed to estimate left ventricular end-systolic and end-diastolic volume, using the standard area-length ellipsoid formula [12]. Afterward, the SV and LVEF were calculated.

A new generation impedance cardiograph (Physio Flow PF-05; Manatec Biomedical; Macheren, France) was used to obtain the bioimpedance data. SV measured by impedance cardiography (SV_{ICG}) was based on changes in transthoracic impedance (Z) during cardiac ejection. The device we used emits an alternating electrical current of 1.8 mA and 75 kHz via electrodes (Ag/AgCl, Blue Sensor VL; Medicotest; Oelstykke, Denmark). Two sets of 2 electrodes, 1 transmitting and 1 sensing, were applied above the supraclavicular fossa at the left base of the neck and along the xiphoid, respectively. Another set of 2 electrodes was used to monitor a single ECG signal. With the Physio Flow device, there is no need to measure baseline Z.

The Physio Flow System provides a continuous measure of cardiac output and LVEF by measuring the stroke volume of each heart beat and averaging that over a period (chosen by the user). For this study, the recording interval was set at beat to beat, and the Physio Flow device was left connected during the entire process of the Cath examination. We marked the time of starting to measure the left ventricle volume as a vertical line on the screen. Finally, we averaged the measurements over the 10 minutes around the mark. The final value was compared with that obtained from the left ventricular angiogram.

A statistical analysis of the ICG and Cath data (SV and LVEF) were done using Pearson's r correlation coefficients with $p<0.05$ considered significant. In addition, Bland-Altman comparisons with bias (mean difference) and precision (standard deviation [SD] of difference) were carried out to evaluate the agreement between the 2 methods.

Results

A total of 36 patients were enrolled in this study (mean age, 53 years old; 25 males, 11 females; mean New York Heart Association Class 2 +/- 1). Thirty-six comparative measurements were taken using ICG and cardiac ventriculography. The SV range was 43-115 ml in the ICG group and 47-158 ml in the ventriculography group. The regression analysis and Bland-Altman representations are presented in Figure 1. The correlation coefficient between the values of SV_{ICG} and SV_{cath} was r = 0.50 ($p<0.01$; n = 36; bias = -1 ml; standard deviation = 19.6 ml). The limits of agreement between SV_{ICG} and SV_{cath} were -40.2 ml to 38.2 ml. EF range was 25% to 78% in the ICG group and 22% to 84% in the ventriculography group. This data is presented in Figure 2. The correlation coefficient between the values of EF_{ICG} and EF_{cath} was r = 0.67 ($p<0.01$; n = 36; bias = -2.5%; standard deviation = 12.3%), and the limits of agreement between EF_{ICG} and EF_{cath} were -27.1% to 22.1%.

Discussion

After a new generation of ICG became available, a number of studies showed strong correlation and clinically acceptable agreement between cardiac output as measured by bioimpedance and thermodilution, and concluded that the new generation of ICG provided an acceptable alternative for hemodynamic monitoring [8-9,13]. Nevertheless, the thermodilution method via PAC is an inherently inaccurate estimate of cardiac output, with 22% variability reported in the measurement of thermodilution from 1 injection to the next [14], although the pulmonary artery catheter has been used almost exclusively as the method of following cardiac output. SV and LVEF measured by Cath are more precise and objective in patients without pulmonary artery catheter

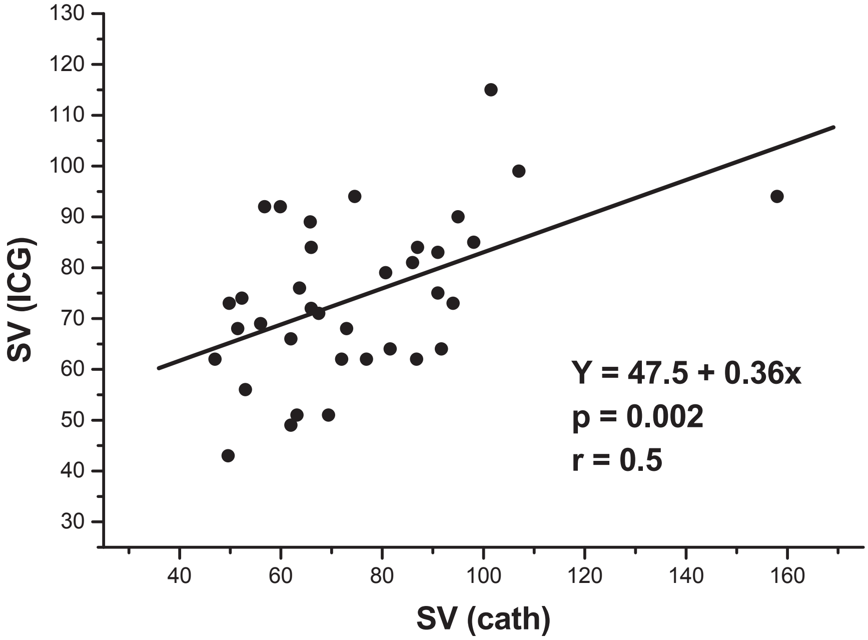

Fig. 1A. Stroke volume comparison using regression analysis. The correlation coefficient was r = 0.50; $p<0.01$.

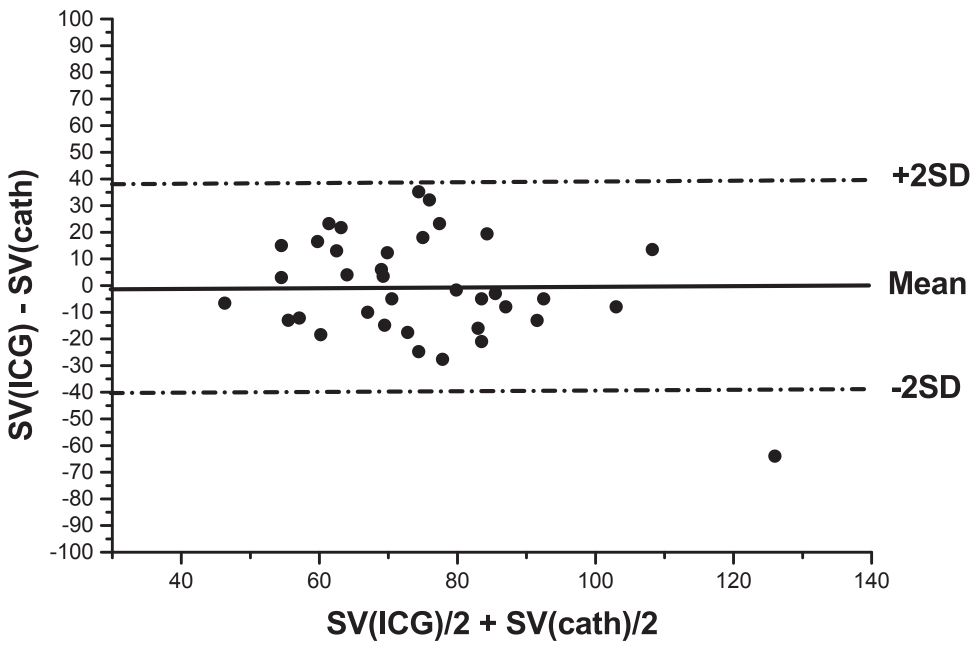

Fig. 1B. Stroke volume comparison using Bland-Altman representation (n = 36). The bias was -1 ml and the standard deviation was 19.6 ml.

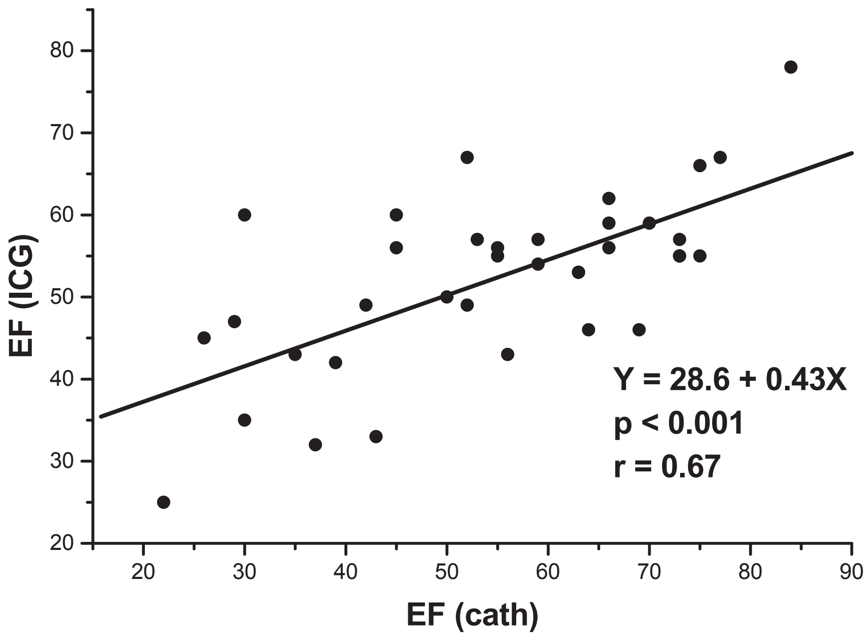

Fig. 2A. Left ventricular ejection fraction comparison using regression analysis. The correlation coefficient was r = 0.67; *p*<0.01.

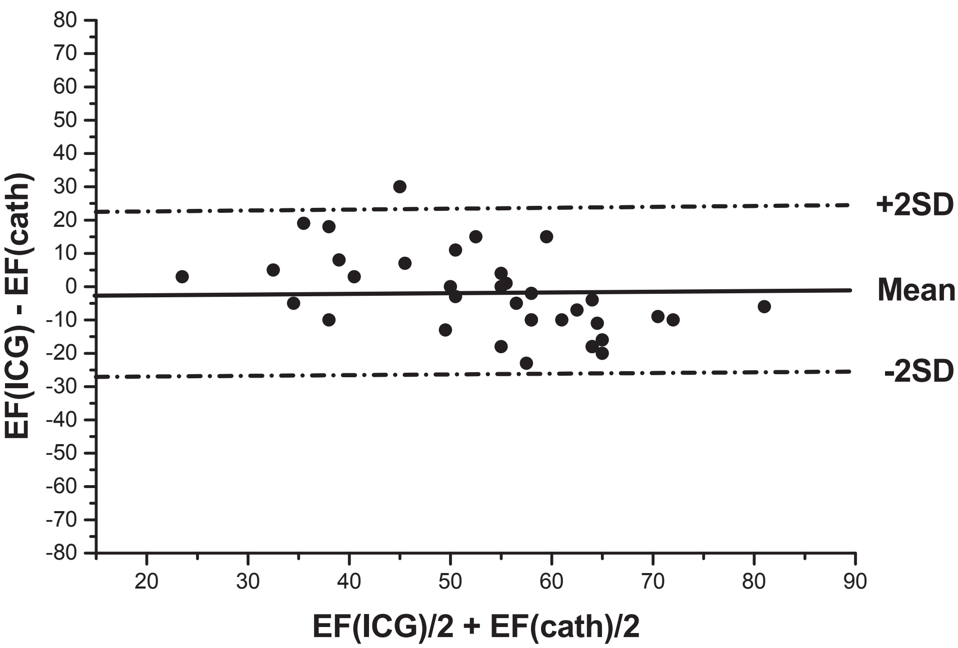

Fig. 2B. Left ventricular ejection fraction comparison using Bland-Altman representation (n = 36). The bias was -2.5% and the standard deviation was 12.3%.

insertion.

Marik *et al*. compared left ventricular ejection fraction and end-diastolic volume estimated by first-generation ICG with measurements determined from left ventricular angiography [15]. The limits of agreement between the ejection fraction estimated by ICG and ventriculography were -35% to 37%; the limits of agreement between the left ventricular end-diastolic volume estimated by ICG and ventriculography were -139 to 113 mL. They concluded that ICG should not replace invasive hemodynamic monitoring.

In our study, the new generation ICG measured beat-to-beat changes of thoracic bioimpedance via sensors applied to the neck and thorax. It used relative values of the impedance signal exclusively, and not absolute values to reduce the influence of lung water [16-18]. But the study results showed wide limits of agreement between the new generation ICG and Cath, in both SV and LVEF, so it is not clinically acceptable to use ICG in place of invasive hemodynamic measurement. It could be argued that changes or trending of SV and LVEF is more important than the absolute value of these variables when making clinical decisions. Further study to determine the longitudinal correlation and agreement would answer this question.

Conclusions

In conclusion, our study showed that the PhysioFlow, a new generation ICG, is an advance over the first-generation system, but does not have sufficient correlation and agreement compared to standard Cath. For the absolute value of hemodynamic variables, it cannot replace the standard method. For monitoring the capabilities and trending of these variables, further investigation is necessary.

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新一代電阻抗心電圖（impedance cardiography）與心導管左心室攝影（left ventriculargraphy）在血流動力學監測上之比較

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背景：新一代電阻抗心電圖（impedance cardiography）（ICG）可以非侵襲性的方法監測血流動力學參數。此研究目的在於比較新一代電阻抗心電圖（impedance cardiography）與心導管左心室攝影（left ventriculargraphy）（Cath）在血流動力學監測上之相關性（correlation）以及一致性（agreement）。

方法：36位接受心導管檢查的病人，於接受左心室攝影時同時利用新一代ICG記錄病人之SV以及LVEF。利用Pearson's r correlation coefficients以及Bland-Altman comparisons計算兩種方法之相關性及一致性。

結果：SVICG與SVcath的相關性為r = 0.50 (p<0.01; n = 36; bias = -1 ml; standard deviation = 19.6 ml)。EF_{ICG}與EF_{cath}的相關性為r = 0.67 (p<0.01; n = 36; bias = -2.5 %; standard deviation = 12.3%)。

結論：新一代ICG所測量的SV及LVEF值仍不能取代左心室攝影（left ventriculargraphy）。***(胸腔醫學 2008; 23: 73-80)***

關鍵詞：電阻抗心電圖（impedance cardiography），左心室攝影（left ventriculargraphy）

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