ORIGINAL PAPER

Comparison of Changes in Ejection Fraction to Changes in Impedance Cardiography Cardiac Index and Systolic Time Ratio

Ejection fraction (EF) is the most common measure of left ventricular function in patients with heart failure. However, serial measurements of EF are costly and not practical for guiding frequent management decisions. Impedance cardiography (ICG) provides noninvasive hemodynamic measures with proven validity. The purpose of this study was to assess how changes in ICG parameters compared with changes in EF in heart failure subjects enrolled in a comprehensive outpatient management program. Retrospective chart review identified 13 subjects with two sets of paired echocardiography and ICG measurements (before and after treatment in an outpatient heart failure clinic setting). Mean age was 69±11 years, etiology was 54% ischemic heart disease, and mean New York Heart Association class was 2.5±0.5. The mean time between pre- and posttreatment EF measurements was 198±161 days. Changes in cardiac index and systolic time ratio by ICG were compared with changes in EF by echocardiography. From entry to final measurement, mean EF improved 9%±13%. Seven (54%) subjects had >5% improvement in EF, three (23%) had >5% decrease, and three had <5% change. Changes in ICG cardiac index and systolic time ratio were highly correlated with changes in EF (0.85, –0.73). ICG may be a practical, reliable, and cost-effective method of monitoring left ventricular function and guiding management decisions. (CHF. 2004;10(2 suppl 2):11–13) ©2004 CHF, Inc.

Heart failure (HF) is associated with diminished cardiac function and characterized by abnormal hemodynamic parameters. The most common descriptor of ventricular function in patients with HF is the ejection fraction (EF), which is obtained by imaging techniques including echocardiography. Echocardiography is time consuming and costly and EF measurement by this technique is moderately subjective. Therefore, frequent serial studies are not practical in the clinical management of patients with HF.

A simple and cost-effective noninvasive method of monitoring changes in ventricular function would be desirable in the clinical evaluation and management of patients with HF to identify and quantify decompensation or improvements due to pharmacologic or device-related interventions. Impedance cardiography (ICG) is a technology that is gaining acceptance in the evaluation and management of patients with HF.[1] ICG utilizes the changes in thoracic impedance during the cardiac cycle to measure hemodynamic parameters with high reproducibility and strong correlation to invasive measures like thermodilution using a pulmonary artery catheter.[2–4] ICG-measured systolic time intervals have been validated by comparison with reference methods like phonocardiography and have shown significant association with ventricular performance measured at a single point in time by echocardiography and radionuclide ventriculography.[5–7]

The purpose of this study was to determine how changes in ICG hemodynamic parameters compared with changes in EF in patients with chronic HF in a comprehensive outpatient program.

Methods

A retrospective chart review was performed for patients followed in the outpatient HF clinic at our institution between January 1, 2001, and August 31, 2003. Patients were eligible for inclusion in the study if they had two separate sets of paired EF and ICG measurements. A paired measurement was defined as an EF and ICG performed within 45 days of each other. EF was measured by standard echocardiography technique on physician order. The echocardiographic studies were performed and interpreted according to usual clinic protocols. If the echocardiography study produced a range for EF as opposed to a single number, the midpoint of that range was used as the EF for the measurement (i.e., 30%–35%=32.5%). ICG recordings were obtained using commercially available equipment (BioZ ICG Monitor, CardioDynamics, San Diego, CA). No patients who met the paired EF and ICG measurements criteria were excluded.

EF, cardiac index (CI), and systolic time ratio (STR) data were entered into a database (Microsoft Excel, Microsoft Corp, Redmond, WA) and evaluated using the statistical analysis function.

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Table. Patient Characteristics at Entry and Final Measurements (N=13)		
CHARACTERISTIC	ENTRY	FINAL
New York Heart Association class	2.5±0.5	2.2±0.6*
No. taking a β blocker (n [%])	5 (39%)	13 (100%)*
No. taking an ACE inhibitor (n [%])	6 (46%)	12 (92%)*
Ejection fraction (%)	29±13	37±11*
ACE=angiotensin-converting enzyme; *p<0.01		

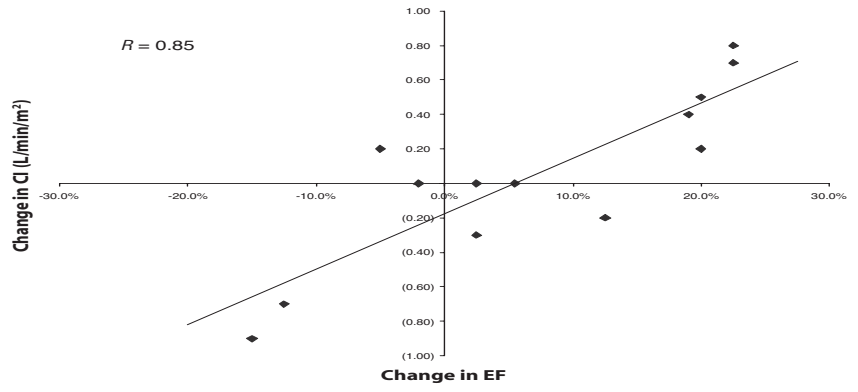

Figure 1. Change in cardiac index (CI) vs. change in ejection fraction (EF)

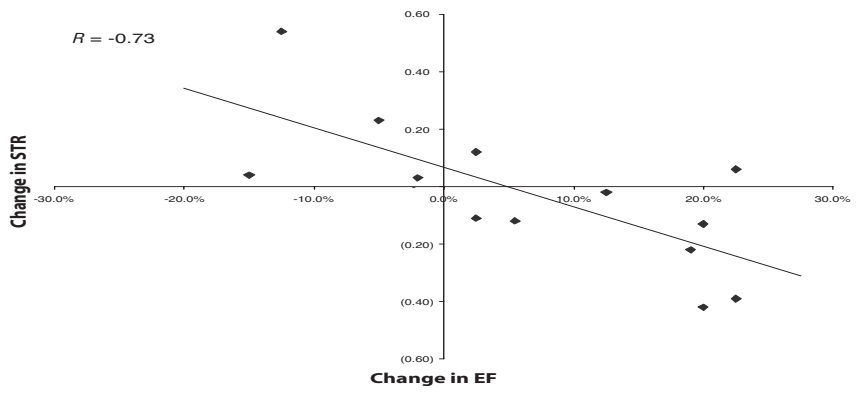

Figure 2. Change in systolic time ratio (STR) vs. change in ejection fraction (EF)

Continuous variables were expressed as mean ± standard deviation. Changes from initial paired measurements to final paired measurements were compared and plotted using a scatter plot format. Correlation coefficient was determined using Pearson's method.

Results

Records from 73 patients followed in the HF clinic were reviewed for possible inclusion. Thirteen patients met the inclusion criteria, resulting in 26 paired measurements of EF and ICG parameters.

The mean age of the patients was 69±11 years. Eight patients were men (62%) and 12 (92%) were white. The etiology of HF was ischemic in seven patients (54%). Ten of 13 patients (77%) had entry EF ≤40%, suggesting primarily systolic dysfunction as the cause of their HF. The average interval between entry EF measurement and final measurement was 198±161 days, and average time between EF and its paired ICG measurements was 20±17 days. The Table shows the entry and final values for representative data elements for the patient group.

EF showed significant improvement (defined as a 5% increase in absolute terms) from entry to final measurement in seven patients (54%). Three patients (23%) had a significant worsening and three patients (23%) had no significant change in EF from entry to final measurement. Of the 10 patients with significant changes in EF (±5%), CI and STR each trended in the same direction as EF in eight patients (80%).

The change in CI as measured by ICG is plotted against change in EF in Figure 1. The correlation coefficient for changes in EF and changes in CI was 0.85. The change in STR from ICG data are plotted against change in EF in Figure 2. The correlation coefficient for the changes in EF and STR was –0.73.

Discussion

EF, the percentage of blood pumped with each heartbeat, is the most commonly cited measure of cardiac function and is routinely reported during an echocardiographic study. EF is used to characterize HF as the result of systolic or diastolic dysfunction and to stratify risk and guide therapy, such as the initiation of various medications. Serial echocardiographic studies are expensive and subject to inter- and intraobserver variation.[8] These factors may limit the usefulness of echocardiography in guiding treatment decisions in patients with significant HF, particularly during short-term drug titration.

ICG measures of STR and CI are hemodynamic parameters that reflect cardiac pump function and contractility. CI is the amount of blood pumped by the heart in liters per minute, corrected for body surface area. Before the availability of ICG, CI could be measured only with a pulmonary artery

catheter in the intensive care unit or catheterization laboratory and was not available in the office setting. STR, calculated as the ratio of the preejection period (time from onset of electrical systole to onset of mechanical systole) to left ventricular ejection time (duration of mechanical systole), negatively correlates with contractility and overall left ventricular performance.[9]

This study demonstrated strong correlations and directional agreement between changes in EF and changes in two ICG hemodynamic measures in patients undergoing treatment in an outpatient HF clinic. It is unclear whether the small differences that did exist occurred because of a change in ventricular function between the time of ICG and EF measurements, EF measurement variability, ICG measurement variability, or truly independent but converse measurements of cardiac function such as CI decreasing with EF increasing.

Because echocardiography evaluation is often prohibitive due to cost and reimbursement constraints, ICG measurements, which can be obtained easily and cost-effectively in an office setting, may serve as a valuable adjunct to and more cost-effective and appropriate means for day-to-day management of patients with HF. In addition to the HF clinic or cardiology setting, ICG is also easily available to general practitioners and internists and thus can help in the care of patients who do not have ready access to specialized cardiology clinics. ICG might help any practitioner recognize changes in a patient's status more promptly, leading to treatment that could prevent clinical decompensation and hospital admission.

Published guidelines for the management of patients with HF stress the importance of β blockers and angiotensin-converting enzyme inhibitors for persons with systolic dysfunction. HF programs have demonstrated improvement via the use of these two medications that have been linked to improved functional class and prognosis.[10] It is noted that patients in this study benefited from a significant increase in the use of these two classes of medications during the course of follow-up, and showed improvement in average EF and New York Heart Association functional class. The mechanisms of β blockers and angiotensin-converting enzyme inhibitor actions are likely due to both neurohormonal and hemodynamic factors. It is not established that the long-term benefits are related to short-term hemodynamic effects. However, in the day-to-day treatment decisions of using these medications, the hemodynamic considerations are clearly important and may limit the ability to initiate or up-titrate dosing regimens. The availability of accurate hemodynamic measures that correlate with EF measures of left ventricular function, such as the ICG-derived changes in CI and STR, can provide clinicians with valuable information with which to make management decisions.

The most significant limitations of this study are the small sample size and its retrospective design. In addition, the paired EF and ICG studies were not performed concurrently, raising the possibility that the patients may have had changes in hemodynamic status between the paired EF and ICG examinations. Added variability in EF measurements also likely occurred due to different technician operators and physician interpreters.

The strong correlation with changes in EF suggests that ICG may be a valuable and cost-effective tool for monitoring ventricular function in patients with HF due to decompensation or therapeutic intervention. Further study, including a larger series of patients enrolled in prospective fashion, is recommended.

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