

Prospective Evaluation of Cardiac Decompensation in Patients with Heart Failure by Impedance Cardiography Test: The PREDICT Multicenter Trial

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ABSTRACT

Background: The management of heart failure could be improved if physicians had additional objective measures that could signal disease progression and monitor the efficacy of treatment.

Objectives: This study evaluated noninvasive impedance cardiography (ICG) variables in chronic heart failure (HF) patients to determine if they could predict short term risk defined by the composite end point of all-cause death or hospitalization or emergency department (ED) visit due to HF.

Methods: We prospectively evaluated 212 patients who had a prior episode of HF decompensation within three months. Baseline variables included age, gender, race, HF etiology, ejection fraction, and medications. Every two weeks for 26 weeks, we collected blinded ICG (BioZ® ICG Monitor) and clinical variables including heart rate (HR), systolic and diastolic blood pressure (SBP, DBP), patient self-assessment with visual analog score (VAS), New York Heart Association class (NYHA), and weight.

Results: During the follow-up period, there were 2,316 study visits. Fifty-nine of 212 patients (27.8%) had 104 HF events (16 deaths, 78 hospitalizations, and 10 ED visits). In visits preceding versus not preceding a HF event ≤ 14 days, there were significant differences in HR, SBP, VAS, NYHA, and 14 of 17 ICG variables. The below median ICG stroke index (33.6 ml/m^2) and above median thoracic fluid content (32.1 /kohm) had a 6.46 relative risk (RR) (95% confidence interval [95% CI] 4.48 – 9.04) for a HF event within 14 days versus a patient with an above median stroke index and below median thoracic fluid content. Multivariate regression analysis was performed incorporating all baseline, clinical, and ICG variables as well as changes in clinical variables from the previous visit, and resulted in six independently associated variables to a HF event ≤ 14 days: VAS, NYHA, SBP, and three ICG parameters (velocity index, thoracic fluid content index, left ventricular ejection time). When ICG variables were combined to form a composite ICG score, the ICG score had the strongest association (chi square 13.83, $p < 0.0002$) with the subsequent occurrence of a HF event, followed by VAS, NYHA, and SBP. Patient visits with a high risk ICG score had an 8.4% HF event rate ≤ 14 days and 8.29 RR (95% CI 5.74 - 11.50) for a HF event versus those with a low risk score.

Conclusions: Planned retrospective analysis of the PREDICT study indicates that ICG can identify patients at highest and lowest short term risk for a HF event. When included together with other clinical variables, ICG may improve the short-term predictive power of the clinical assessments currently in routine use.

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BACKGROUND

Most prognostic variables in heart failure (HF) identify patients at high long-term risk. There is a need to identify patients at immediate risk of a major HF event. Current approaches to the identification of short-term risk rely on the evaluation of clinical status. Impedance cardiography (ICG) is a noninvasive method to measure hemodynamic parameters.

OBJECTIVES

This study evaluated ICG variables in chronic HF patients to determine if they could predict short term risk defined by the composite end point of hospitalization or emergency department (ED) visit due to HF, or all-cause death.

METHODS

Inclusion Criteria: 1) Chronic heart failure (HF) > 2 months in duration due to ischemic or nonischemic cardiomyopathy; 2) New York Heart Association (NYHA) functional class II, III or IV; 3) ED visit, unscheduled clinic visit, or hospitalization for HF within 3 months; 4) Receiving medications for HF at doses that are appropriate for the patients' clinical status; 5) No significant change in symptoms, no change in oral medications for HF, and no use of intravenous medications for HF within 7 days.

Data Collection: Baseline variables at enrollment included each patient's age, gender, race, HF etiology, ejection fraction, and medications. Patients were scheduled for outpatient visits every 2 weeks for 26 weeks. Recorded variables included clinical variables of: 1) Vital signs and body weight; 2) Patient assessment with visual analog score; and 3) Functional assessment using NYHA classification. ICG data were collected with the BioZ ICG Monitor (CardioDynamics, San Diego) that were obtained and read blindly. Patient care was unrelated to collection of study data.

Study Outcomes: Reportable events included all deaths, hospitalizations, and ED visits. A HF event was defined as a composite endpoint of all-cause death, hospitalization due to worsening HF, or ED visit due to worsening HF.

Statistical Analysis: Patient visits were categorized into those preceding versus not preceding a HF event within specified time periods from a study visit. Differences in variable values between those visits preceding versus not preceding a HF event were determined by t-test. Values for clinical and ICG variables were grouped by quartile. Heart failure event rates were calculated by dividing the number of visits in a group that preceded a HF event by the total number of visits in that group. Heart failure events rates were converted to relative risk (RR) by dividing the reference HF event rate by the comparison HF event rate and are reported with 95% confidence intervals (95% CI). Differences in HF event rate and RR between groups were calculated by Fisher exact tests. Multivariate backwards and forwards stepping regression analysis identified independent predictor variables, which were ranked according to their Chi-Square and corresponding p values. To assess the joint ability of multiple significant ICG variables to predict a HF event, independently associated ICG variables from the multivariate analysis were combined into a single regression equation with fixed variables and weighting coefficients. The regression equation generated a value for each patient visit that was translated into log of odds and then converted to numeric score between zero and ten, with a higher score denoting higher risk. The multivariate ICG score values were placed into three distinct groupings indicating low, average, and high risk.

RESULTS

Study Sample. During the follow-up period, 212 patients were enrolled and evaluated over 2,316 study visits.

Table 1. Baseline Patient Characteristics

| Characteristic | Value |
|--|--------------|
| Total number of patients | 212 |
| Age (years) | 58.5 ±14.7 |
| Gender (% male) | 145 (68.4) |
| Race (% white) | 132 (62.3) |
| Ischemic etiology | 98 (46.2) |
| Ejection fraction (%) | 27.1 ± 13.5 |
| New York Heart Association class | 2.7 ± 0.5 |
| Class II | 67 (31.6) |
| Class III | 139 (65.6) |
| Class IV | 6 (2.8) |
| ACEI or ARB | 177 (83.5) |
| Beta blocker | 152 (71.7) |
| Diuretic | 203 (96.2) |
| Values are expressed as mean ± SD or by frequency (%). ACEI = angiotensin converting enzyme inhibitor; ARB = angiotensin II receptor blocker | |

Events and Visit Categorization. There were 131 hospitalizations, 45 ED visits, and 16 deaths. A total of 59 (27.8%) patients had 104 HF events including the 16 deaths, 50 patients with 78 HF hospitalizations, and ten patients with ten HF ED visits. There were 77 visits that preceded a HF event ≤ 14 days and 155 that preceded a HF event ≤ 30 days, equating to 14 and 30 day HF event rates of 3.3% and 6.7%, respectively.

Visit Differences For patients with or without a HF event during the study, there were no significant differences in baseline patient characteristics, clinical variables, or ICG variables measured in the initial visit. In visits preceding versus not preceding a HF event ≤ 14 days, there were significant differences in the clinical variables of visual analog score, NYHA class, heart rate, systolic blood pressure, and 14 of 17 ICG variables (Table 2).

Table 2. Clinical and Impedance Cardiography Variables in Visits Preceding Versus Not Preceding a Heart Failure Event (Values expressed as mean \pm standard deviation)

| Variable | Visits Not Preceding a HF Event \leq 14 Days (N = 2239) | Visits Preceding a HF Event \leq 14 Days (N = 77) | p Value |
|--|---|---|---------|
| <i>Clinical</i> | | | |
| New York Heart Association class | 2.6 \pm 0.6 | 3.0 \pm 0.5 | <0.0001 |
| Heart rate (bpm) | 71.0 \pm 13.5 | 80.0 \pm 17.1 | <0.0001 |
| Patient visual analog score | 73.0 \pm 19.8 | 60.2 \pm 21.6 | <0.0001 |
| Systolic blood pressure (mm Hg) | 123.9 \pm 22.5 | 116.0 \pm 20.7 | 0.0023 |
| Diastolic blood pressure (mm Hg) | 73.1 \pm 13.7 | 72.1 \pm 12.9 | 0.5025 |
| <i>Impedance cardiography</i> | | | |
| Stroke index (mL/m ²) | 33.0 \pm 9.7 | 27.4 \pm 10.5 | <0.0001 |
| Stroke volume (mL) | 66.2 \pm 21.8 | 54.6 \pm 22.9 | <0.0001 |
| Left stroke work index (g x m /m ²) | 35.7 \pm 12.7 | 29.2 \pm 13.2 | <0.0001 |
| Left ventricular ejection time (msec) | 265 \pm 38 | 248 \pm 39 | 0.0002 |
| Velocity index (/1000 /sec) | 35.0 \pm 15.2 | 28.7 \pm 13.9 | 0.0003 |
| Systolic time ratio index (/sec) | 0.68 \pm 0.31 | 0.80 \pm 0.33 | 0.0017 |
| Thoracic fluid content (/kOhm) | 33.1 \pm 9.2 | 37.4 \pm 11.8 | 0.0020 |
| Thoracic fluid content index (/kOhm /m ²) | 16.4 \pm 5.2 | 18.7 \pm 6.5 | 0.0029 |
| Stroke systemic resistance index (dyne x cm ⁻⁵ x m ²) | 234 \pm 135 | 300 \pm 202 | 0.0055 |
| Left cardiac work index (kg x m /m ²) | 2.6 \pm 0.85 | 2.4 \pm 0.88 | 0.0094 |
| Cardiac output (L/min) | 4.6 \pm 1.36 | 4.2 \pm 1.5 | 0.0096 |
| Acceleration index (/100 /sec ²) | 67.0 \pm 30.2 | 59.1 \pm 26.7 | 0.0230 |
| Cardiac index (L/min/m ²) | 2.3 \pm 0.6 | 2.1 \pm 0.7 | 0.0243 |
| Systemic vascular resistance (dyne x sec x cm ⁻⁵) | 1664 \pm 880 | 1870 \pm 989 | 0.0440 |
| Pre ejection period (msec) | 141 \pm 33 | 135 \pm 27 | 0.0545 |
| Systemic vascular resistance index (dyne x sec x cm ⁻⁵ x m ²) | 3266 \pm 1604 | 3658 \pm 1876 | 0.0739 |
| Systolic time ratio (no units) | 0.56 \pm 0.19 | 0.58 \pm 0.17 | 0.3235 |
| Values are expressed as mean \pm standard deviation. | | | |

Variable Risk Stratification. Table 3 lists the independently associated clinical variables. NYHA class IV visits had an 11.4% HF event rate \leq 14 days with a 3.43 RR (95% CI 1.52 - 6.38) versus the average risk, but accounted for only 3.0% of visits and 10.0% of HF events. The highest risk quartiles for patient visual analog score and systolic blood pressure had a 1.87 (95% CI 1.32 - 2.57) and 1.30 (95% CI 0.85 - 1.9) RR versus the average risk, respectively. Table 4 characterizes the risk stratification of ICG variables by their highest to lowest risk quartile.

Table 3. Risk Stratification for a Heart Failure Event \leq 14 Days with Independently Associated Clinical Variables

| Quartile | Value \pm SD | Visits (%) | Events (%) | HF Event Rate (%) (95% CI) | RR vs. Average Risk (95% CI) | RR vs. Quartile 1 (95% CI) |
|--|------------------|------------|------------|----------------------------|------------------------------|----------------------------|
| New York Heart Association class | | | | | | |
| 1 | I | 48 (2) | 0 (0) | 0.0 (0 - 7.4) | - | - |
| 2 | II | 815 (35) | 11 (14) | 1.4 (0.7 - 2.4) | 0.40 (0.20 - 0.72) | - |
| 3 | III | 1375 (60) | 58 (75) | 4.2 (3.2 - 5.4) | 1.26 (0.96 - 1.62) | - |
| 4 | IV | 70 (3) | 8 (10) | 11.4 (5.1 - 21.3) | 3.43 (1.52 - 6.38) | - |
| Systolic blood pressure (mm Hg) | | | | | | |
| 1 | 154.3 \pm 15.7 | 579 (25) | 11 (14) | 1.9 (1.0 - 3.4) | 0.57 (0.29 - 1.01) | - |
| 2 | 127.8 \pm 4.5 | 579 (25) | 13 (17) | 2.3 (1.2 - 3.8) | 0.68 (0.36 - 1.15) | 1.18 (1.13 - 1.26) |
| 3 | 114.1 \pm 3.7 | 579 (25) | 28 (36) | 4.8 (3.2 - 6.9) | 1.45 (0.97 - 2.08) | 2.55 (2.05 - 3.41) |
| 4 | 98.3 \pm 7.2 | 579 (25) | 25 (32) | 4.3 (2.8 - 6.3) | 1.30 (0.85 - 1.9) | 2.27 (1.87 - 2.96) |
| Patient visual analog score | | | | | | |
| 1 | 94.1 \pm 4.1 | 579 (25) | 6 (8) | 1.0 (0.4 - 2.2) | 0.31 (0.11 - 0.67) | - |
| 2 | 81.7 \pm 3.3 | 579 (25) | 9 (12) | 1.6 (0.7 - 2.9) | 0.46 (0.21 - 0.88) | 1.50 (0.69 - 2.83) |
| 3 | 69.7 \pm 4.9 | 579 (25) | 26 (34) | 4.5 (3.0 - 6.5) | 1.35 (0.9 - 1.96) | 4.33 (2.85 - 6.28) |
| 4 | 44.3 \pm 14.2 | 579 (25) | 36 (47) | 6.2 (4.4 - 8.5) | 1.87 (1.32 - 2.57) | 5.98 (4.24 - 8.21) |
| Average risk for HF event \leq 14 days = 3.3%; CI = confidence interval; RR = relative risk; SD = standard deviation; NYHA Class IV to I comparison was not calculable because the HF event rate for NYHA Class I was 0.0%; Significance of models was as follows: NYHA (p<0.0001), systolic blood pressure (p<0.01) | | | | | | |

Table 4. Risk Stratification for Heart Failure Event \leq 14 Days with ICG Variables

| Parameter | High Risk Quartile Mean \pm SD | Low Risk Quartile Mean \pm SD | RR, High vs. Low Risk Quartile (95% CI) | p Value |
|--|----------------------------------|---------------------------------|---|---------|
| Stroke index (mL/m ²) | 19.7 \pm 5.3 | 44.4 \pm 4.3 | 3.50 (2.46 - 4.80) | <0.001 |
| Stroke volume (mL) | 38.2 \pm 9.7 | 94.1 \pm 11.5 | 3.40 (2.37 - 4.69) | <0.001 |
| Stroke systemic resistance index (dyne x cm ⁻⁵ x m ²) | 403.7 \pm 185.9 | 136.8 \pm 17.6 | 3.27 (2.31 - 4.47) | <0.001 |
| Thoracic fluid content (/kOhm) | 45.0 \pm 9.6 | 23.7 \pm 2.3 | 3.00 (2.08 - 4.16) | <0.001 |
| Left ventricular ejection time (msec) | 216 \pm 17 | 314 \pm 19 | 2.46 (1.69 - 3.43) | <0.01 |
| Left stroke work index (g x m /m ²) | 21.2 \pm 5.4 | 55.1 \pm 9.2 | 2.62 (1.82 - 3.62) | <0.01 |
| Velocity index (/1000 /sec) | 17.7 \pm 4.4 | 55.1 \pm 11.6 | 2.42 (1.63 - 3.43) | 0.01 |
| Acceleration index (/100 /sec ²) | 35.2 \pm 7.7 | 107.2 \pm 26.2 | 2.50 (1.62 - 3.65) | 0.02 |
| Thoracic fluid content index (/kOhm /m ²) | 23.3 \pm 4.9 | 11.0 \pm 1.3 | 2.14 (1.46 - 3.03) | 0.02 |
| Systolic time ratio index (/sec) | 1.11 \pm 0.24 | 0.36 \pm 0.07 | 2.07 (1.40 - 2.94) | 0.03 |
| Cardiac output (L/min) | 2.8 \pm 0.6 | 5.0 \pm 0.3 | 2.00 (1.29 - 2.95) | 0.06 |
| Left cardiac work index (kg x m /m ²) | 1.6 \pm 0.4 | 3.7 \pm 0.6 | 1.69 (1.12 - 2.43) | 0.12 |
| Systemic vascular resistance (dyne x sec x cm ⁻⁵) | 2774 \pm 1123 | 984 \pm 126 | 1.63 (1.07 - 2.36) | 0.16 |
| Systolic time ratio (no units) | 0.80 \pm 0.12 | 0.34 \pm 0.07 | 1.64 (1.05 - 2.44) | 0.18 |
| Systemic vascular resistance index (dyne x sec x cm ⁻⁵ x m ²) | 5250 \pm 2110 | 2047 \pm 239 | 1.56 (1.02 - 2.29) | 0.21 |
| Pre ejection period (msec) | 101 \pm 16 | 183 \pm 23 | 1.67 (1.02 - 2.55) | 0.21 |
| Cardiac index (L/min/m ²) | 1.5 \pm 0.3 | 3.0 \pm 0.3 | 1.39 (0.90 - 2.03) | 0.35 |
| SD = Standard deviation | | | | |

| | | | |
|--|-------------|---|---|
| <p style="text-align: center;">High to Low Risk Profile RR 6.46 (4.48 – 9.04) P<0.0001</p> | | Thoracic Fluid Content (/kOhm) | |
| | | ≤ 32.1 | > 32.1 |
| Stroke Index (mL/m²) | > 33.6 | Low Risk HF Events / Visits: 5 / 541 HF Event Rate 0.92 (0.30 - 2.14)% | Average Risk HF Events / Visits: 17 / 617 HF Event Rate 2.76 (1.61 - 4.37)% |
| | ≤ 33.6 | Average Risk HF Events / Visits: 23 / 622 HF Event Rate 3.70 (2.36 - 5.50)% | High Risk HF Events / Visits: 32 / 536 HF Event Rate 5.97 (4.12 - 8.32)% |

Figure 1. All patient visits were categorized by four hemodynamic profiles according to median values of stroke index and thoracic fluid content. Each profile is displayed with its 14 day heart failure event rate and 95% CI, the number of visits preceding a heart failure event, and the total number of visits.

Figure 1 depicts the combined ability of stroke index and thoracic fluid content to profile risk for a HF event ≤ 14 days. Compared to a patient with an above median stroke index (33.6 ml/m²) and below median thoracic fluid content (32.1 /kOhm), a patient with a below median ICG stroke index and above median thoracic fluid content had a 6.46 RR (95% CI 4.48 – 9.04) for a HF event within 14 days (6.0 vs. 0.9%), a 3.33 RR (95% CI 2.54 – 4.25) within 30 days (10.4 vs. 3.1%), as shown in Figure 2. Risk stratification beyond 30 days with a 2.60 RR (95% CI 2.11 – 3.15) within 60 days (15.9 vs. 6.1%), and a 2.27 RR (95% CI 1.88 – 2.69) within 90 days (18.8 vs. 8.3%).

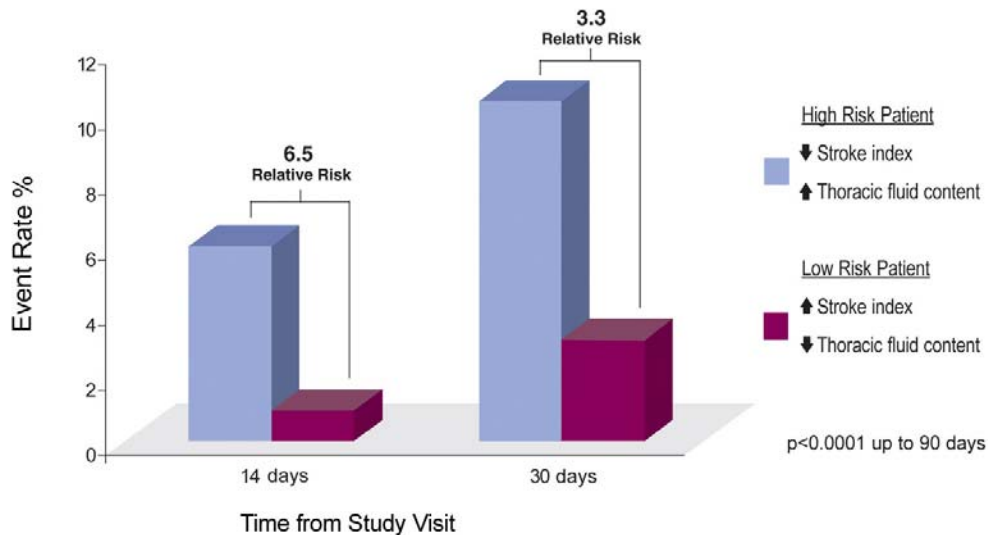


Figure 2. High and low risk hemodynamic profiles according to median values of stroke index and thoracic fluid content with their 14 and 30 day heart failure event rate are displayed, with their corresponding RR.

Multivariate Analysis of Variables. Multivariate regression analysis was performed to determine independent association to a HF event ≤ 14 days. Analysis included all baseline patient characteristics, clinical variables, ICG variables, and changes in clinical variables from the previous visit. Three clinical variables (visual analog score, NYHA, and systolic blood pressure) and three ICG variables (thoracic fluid content index, velocity index, left ventricular ejection time) were independently associated to a HF event ≤ 14 days (Table 5).

Table 5. Multivariate Analysis of Baseline Patient Characteristics, Clinical, and ICG Variables for Independent Association to Heart Failure Event ≤ 14 Days

| Variable | Chi-Square | p Value |
|---|------------|---------|
| Patient visual analog score | 11.76 | 0.0006 |
| Thoracic fluid content index (/kOhm /m ²) | 8.57 | 0.0034 |
| New York Heart Association class | 8.37 | 0.0038 |
| Velocity index (/1000 /sec) | 7.32 | 0.0068 |
| Systolic blood pressure (mm Hg) | 5.56 | 0.0184 |
| Left ventricular ejection time (msec) | 3.85 | 0.0496 |

ICG Composite Score. The three independently associated ICG variables were combined into a single ICG composite score ranging from zero to ten, with a higher score indicating higher risk for a HF event. A higher score could be related to a higher thoracic fluid content index, lower velocity index, and/or shorter left ventricular ejection time. Repeat multivariate analysis with the ICG score showed that the ICG score had the strongest association to a HF event ≤ 14 days, followed by patient visual analog score, NYHA class, and systolic blood pressure (Table 6).

Table 6. Multivariate Analysis of Baseline, Clinical, and ICG score for Independent Association to a Heart Failure Event ≤ 14 Days

| Variable | Chi-Square | p Value |
|----------------------------------|------------|---------|
| ICG score | 13.83 | 0.0002 |
| Patient visual analog score | 10.98 | 0.0009 |
| New York Heart Association class | 9.22 | 0.0024 |
| Systolic blood pressure (mm Hg) | 4.94 | 0.0263 |

ICG Score Risk Stratification. Table 7 characterizes the ICG score groupings by their HF event rate and RR. Patient visits with a high risk ICG score had an 8.4 % HF event rate ≤ 14 days; such high scores were present in 16.5% of visits and predicted 41.6% of HF events. In contrast, patient visits with a low risk ICG score had only a 1.0% HF event rate ≤ 14 days; such low scores were present in 38.6% of visits and only accounted for 11.7% of HF events. Patients with a high risk ICG score were 8.29 (95% CI 5.74 - 11.50) times more likely to experience a HF event ≤ 14 days than those with a low risk score and 2.51 (95% CI 1.74 - 3.49) times more likely than the average visit.

Table 7. ICG Score by Low, Average, and High Risk Groups for Association to Heart Failure Event ≤ 14 Days

| Risk Group | ICG Score Range | Average Score | Visits (%) | HF Events (%) | Event rate (95% CI) | RR vs. Average Risk (95% CI) | RR vs. Low Risk Group (95% CI) |
|--------------|-----------------|---------------|-------------|---------------|---------------------|------------------------------|--------------------------------|
| Low risk | 0 – 3 | 2.5 | 893 (38.6) | 9 (11.7) | 1.0 (0.5 - 1.9) | 0.30 (0.14 - 0.57) | - |
| Average risk | 4 – 6 | 4.9 | 1040 (44.9) | 36 (46.8) | 3.5 (2.4 - 4.8) | 1.04 (0.73 - 1.43) | 3.43 (2.42 - 4.72) |
| High risk | 7 – 10 | 7.7 | 383 (16.5) | 32 (41.6) | 8.4 (5.8 - 11.6) | 2.51 (1.74 - 3.49) | 8.29 (5.74 - 11.50) |

RR = relative risk; P <0.001 for differences between average vs. low risk and average vs. high risk; P <0.0001 for difference between high vs. low risk

When the ICG score was applied to estimate risk of HF events >14 days from a study visit, HF event rates for each group increased over time and the ICG score groups maintained significant differences at 30, 60, and 90 days from a study visit (Figure 3). Risk stratification decreased over time but remained significant at 30, 60, and 90 days from a study visit (Figure 4).

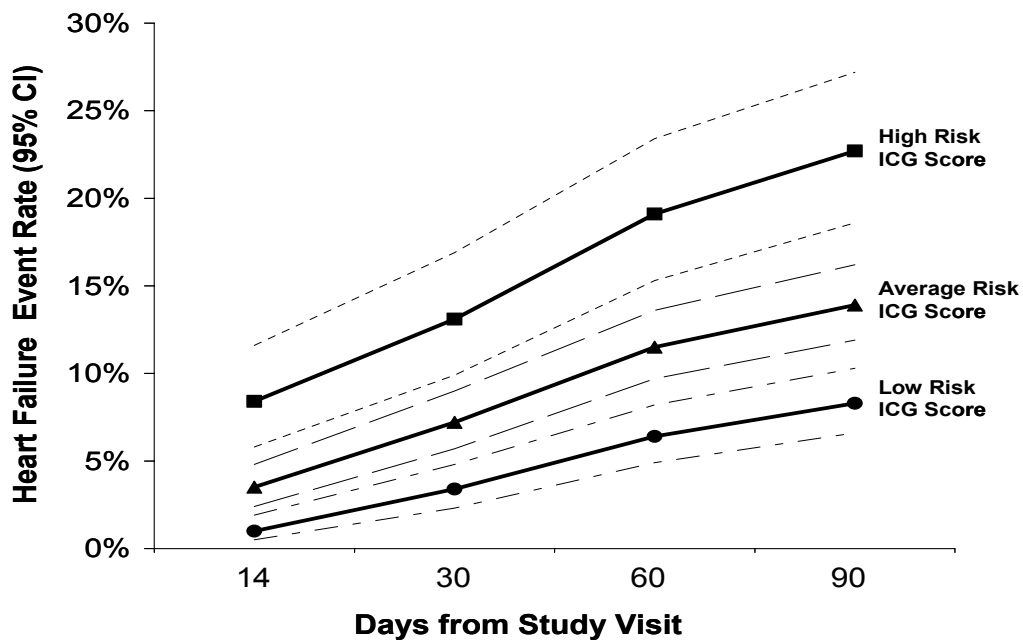


Figure 3. Heart failure event rate \pm 95% CI by days from study visit for high, average, and low risk ICG score groups. Significance for all time periods: P < 0.0001 for high risk vs. low risk groups, P < 0.001 for average vs. low risk, P < 0.01 for high vs. average risk group.

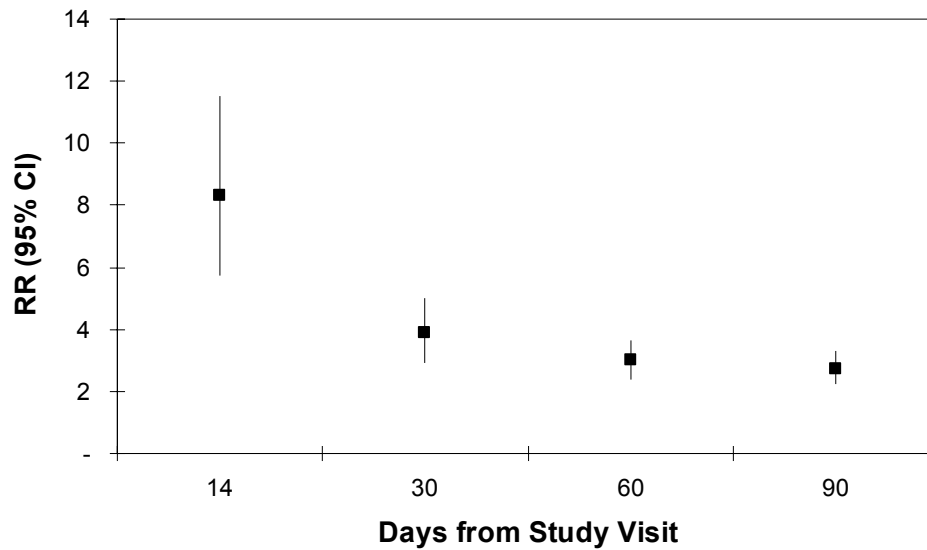


Figure 4. Relative risk (RR) \pm 95% CI of a heart failure event for high versus low risk ICG scores by days from study visit ($P < 0.0001$ for all time periods).

CONCLUSIONS

Planned retrospective analysis of the PREDICT study indicates that ICG can identify patients at highest and lowest short term risk for a HF event. When included together with other clinical variables, ICG may improve the short-term predictive power of the clinical assessments currently in routine use. Such a conclusion requires confirmation in a prospective trial.

Appendix. Impedance Cardiography Variables

| Impedance Cardiography Variable | | Units | Measurement / Calculation |
|--|------------------------------------|--|---|
| <i>Blood Flow</i> | | | |
| SV | Stroke volume | mL | VI x LVET x VEPT (Z MARC® algorithm) |
| SI | Stroke index | mL/m ² | SV / BSA |
| CO | Cardiac output | L/min | SV x HR |
| CI | Cardiac index | L/min/m ² | CO / BSA |
| <i>Resistance</i> | | | |
| SVR | Systemic vascular resistance | dyne x sec x cm ⁻⁵ | [(MAP – CVP) / CO] x 80 |
| SVRI | Systemic vascular resistance index | dyne x sec x cm ⁻⁵ x m ² | [(MAP – CVP) / CI] x 80 |
| SSRI | Stroke systemic resistance index | dyne x cm ⁻⁵ x m ² | [(MAP – CVP) / SI] x 80 |
| <i>Contractility</i> | | | |
| VI | Velocity index | /1000 /sec | 1000 x First time derivative of ΔZ_{max} / baseline impedance |
| ACI | Acceleration index | /100 /sec ² | 100 x Second time derivative of ΔZ_{max} / baseline impedance |
| PEP | Pre ejection period | msec | ECG Q wave to aortic valve opening |
| LVET | Left ventricular ejection time | msec | Aortic valve opening to closing |
| STR | Systolic time ratio | - | PEP / LVET |
| STRI | Systolic time ratio index | /sec | STR / R to R interval |
| <i>Cardiac Work</i> | | | |
| LSWI | Left stroke work index | g x m / m ² | (MAP – PCWP) x SI x 0.0136 |
| LCWI | Left cardiac work index | kg x m / m ² | (MAP – PCWP) x CI x 0.0144 |
| <i>Fluid Status</i> | | | |
| TFC | Thoracic fluid content | /kOhm | 1000 x 1/baseline impedance |
| TFCI | Thoracic fluid content index | /kOhm /m ² | 1000 x 1/ baseline impedance /BSA |
| BSA = body surface area; cm = centimeter; CVP = central venous pressure (estimated value of 6 mmHg); ECG = electrocardiography; g = gram; HR = heart rate; ICG = impedance cardiography; kg = kilogram; kOhm = kilo Ohm; L = liter; MAP = mean arterial pressure; m = meter; min = minute; mL = milliliter; msec = millisecond; sec = seconds; PCWP = pulmonary capillary wedge pressure (estimated value of 10 mmHg); R to R interval = 60 / heart rate; VEPT = volume of electrically participating tissue; Z MARC = impedance modulating aortic compliance. | | | |



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