Prognostic Implications of Right Ventricular Free Wall Strain in Recipients of Cardiac Resynchronization Therapy

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Right ventricular (RV) function is an important prognostic marker in cardiac resynchronization therapy (CRT) recipients. Measuring RV systolic function with echocardiography, however, remains challenging due to the complexity of right heart morphology. Evaluation of RV function with RV free wall strain (FWS) may improve risk stratification in recipients of CRT compared with conventional RV function parameters. In 871 recipients of CRT (mean age 65 ± 11 years, 75% were men), RV function was assessed by RV fractional area change (FAC), tricuspid annular plane systolic excursion (TAPSE), and RV FWS measured by speckle tracking echocardiography. RV dysfunction was defined as RV FWS <23%, RV FAC <35%, and TAPSE <17 mm according to present guidelines. Patients were followed up for the primary end point of all-cause mortality. RV FWS identified a higher percentage of patients with RV systolic dysfunction (80.6%) in comparison with RV FAC (44.1%) and TAPSE (60.6%). During a median follow-up of 97 (53 to 145) months, 521 patients (59.8%) died. Recipients of CRT with RV FWS <23% had higher event rates than those with RV FWS ≥23% (p <0.001). On multivariable analysis, RV FWS <23% was independently associated with all-cause mortality (hazard ratio 1.618; 95% confidence interval 1.252 to 2.092; p <0.001) and demonstrated incremental prognostic value over baseline clinical parameters as well as conventional RV function parameters. In conclusion, RV FWS is more sensitive than conventional echocardiographic markers of RV function in detecting impaired RV function. RV FWS is independently associated with all-cause mortality and demonstrates incremental prognostic value over conventional RV function parameters in recipients of CRT. **(Am J Cardiol 2022;171:151−158)**

Cardiac resynchronization therapy (CRT) is an established treatment for patients with heart failure (HF) who remain symptomatic despite optimal medical therapy, with a broad QRS complex (≥130 ms) and reduced left ventricular ejection fraction (LVEF ≤35%).[1] Despite favorable results, long-term mortality rates remain high,[2] and identification of prognostic markers in recipients of CRT remains an active area of research. In this regard, right ventricular (RV) function has been shown to be a major determinant of outcomes in patients with HF and reduced LVEF,[3] including recipients of CRT.[4,5] Measuring RV systolic function in patients with HF being considered for CRT, however, remains challenging due to the complexity of right heart morphology. RV free wall strain (FWS), measured by 2-dimensional speckle tracking echocardiography, may be superior to conventional measures of RV function (such as RV fractional area change [FAC] and tricuspid annular plane systolic excursion [TAPSE]) because it is less angle- and load-dependent, is less hampered by high inter- and intraobserver variability, and does not extrapolate ventricular function from 1 single point to the entire ventricle. Therefore, the aim of the present study was to examine the prevalence and incremental prognostic value of impaired RV systolic function measured by RV FWS in a large cohort of recipients of CRT compared with conventional echocardiographic indexes (RV FAC and TAPSE).

Symptomatic patients with HF who underwent CRT implantation according to contemporary guidelines,[1] were included from an ongoing registry at the Leiden University Medical Center, The Netherlands. All patients underwent complete clinical and echocardiographic evaluation before CRT implantation. Patient information was prospectively collected in the departmental cardiology information system (EPD-Vision; Leiden University Medical Center, Leiden, The Netherlands) and retrospectively analyzed. Clinical data collected for the purpose of the present analysis included demographic characteristics, cardiovascular risk factors, and co-morbidities. An ischemic etiology of

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HF was diagnosed by the presence of significant coronary artery disease on invasive coronary angiography. Quality of life was evaluated with the Minnesota Living with Heart Failure Questionnaire and, if feasible, a 6-minute walk test was performed. Renal function was quantified by estimating the glomerular filtration rate with the Modification of Diet in Renal Disease Study equation. The study complies with the Declaration of Helsinki and was approved by the institutional review board. Due to the retrospective study design, the Medical Ethical Committee waived the need for written informed consent.

All patients underwent transthoracic echocardiography before CRT implantation in the left lateral decubitus position with commercially available ultrasound equipment (Vivid 7 and E9, GE-Vingmed, Milwaukee, Wisconsin). ECG-triggered echocardiographic data were stored digitally in a cine-loop format for offline analysis using EchoPAC version 203 (GE Medical Systems, Horten, Norway). Left ventricle (LV) volumes, LVEF, and left atrial volumes were measured using the Simpson's biplane method.[6] RV end-systolic area and end-diastolic area were traced in a focused RV apical view according to present recommendations.[6] Peak systolic pulmonary artery pressure was derived from the peak velocity of the tricuspid regurgitant jet according to the Bernoulli's equation, adding the right atrial pressure (estimated by the inspiratory collapse and diameter of the inferior vena cava).[6] The severity of mitral and tricuspid regurgitation was graded using a multiparametric approach, as recommended by present guidelines.[7] Speckle tracking LV global longitudinal strain was averaged from 17 LV segments and measured from 2-dimensional apical views (2-, 3-, and 4-chamber).[8] The region of interest was automatically generated and manually adjusted to the myocardial thickness. The methods to evaluate RV systolic function have been previously described by our study group.[9] In summary, RV FAC was calculated by the following formula: FAC = ([RV end-diastolic area - RV end-systolic area]/RV end-diastolic area) × 100%.[6] TAPSE was measured on M-mode recordings of the lateral tricuspid annulus in an RV-focused view.[6] Impaired RV systolic function was defined as FAC <35% or TAPSE <17 mm, according to contemporary guidelines.[6] RV FWS was measured on the RV-focused apical view by applying a speckle tracking technique. The RV was divided into 6 segments (basal, mid, and apical segments of the RV free wall and septum), whereas the region of interest was automatically drawn by the software and manually adjusted to encompass the RV free wall. RV FWS was subsequently calculated as the mean of the RV lateral basal, mid, and apical segments, with exclusion of the septal segments.[6,10] Impaired RV FWS was defined as <23%, according to present echocardiographic recommendations.[11] Both LV global longitudinal strain and RV FWS are represented as absolute (i.e., positive) values.

CRT implantation was performed according to a standard approach, that is, insertion of the right atrial and ventricular leads through the subclavian or cephalic veins. Before insertion of the LV lead, coronary sinus venography was performed. The LV pacing lead was then introduced into the coronary sinus through an 8 Fr guiding catheter and positioned in a posterior or posterolateral vein, if possible. All leads were connected to a dual-chamber, biventricular CRT device. Defibrillator functionality was included in most of the implanted devices (96%). Recipients of CRT were followed up at regular intervals at the HF outpatient clinic, each time with a device interrogation. Atrioventricular and interventricular delays were empirically set at 120 to 140 ms and 0 ms, respectively. CRT optimization was performed during follow-up visits at the discretion of the treating physician.

Patients were followed up for the occurrence of all-cause mortality. Data on mortality were obtained from the departmental cardiology information system (EPD-Vision, Leiden University Medical Center, Leiden, The Netherlands), which is linked to the governmental death registry database. Follow-up data were complete for all patients.

Continuous data are presented as mean ± SD when normally distributed and as median and interquartile range when not normally distributed. Categoric data are presented as frequencies and percentages. Continuous variables were compared using the independent samples t test when normally distributed, whereas the Mann-Whitney U test was used to compare continuous variables that did not adhere to a normal distribution. Categoric variables were compared using the chi-square test. Event-free survival curves were generated using the Kaplan-Meier method and differences between groups were analyzed using the log-rank test. To assess the association of impaired RV function and all-cause mortality, uni- and multivariable Cox proportional hazard models were constructed with each parameter of RV function (i.e., RV FAC, TAPSE, and RV FWS) individually as a continuous and as a categoric variable. The following covariates were included in the multivariable model: age, gender, arterial hypertension, dyslipidemia, diabetes mellitus, body mass index, sinus rhythm, ischemic etiology of HF, estimated glomerular filtration rate, New York Heart Association (NYHA) class III to IV, β-blocker, angiotensin-converting enzyme inhibitor/angiotensin receptor blocker, mineralocorticoid receptor antagonist, diuretics, LV end-diastolic volume, LVEF, left atrium indexed volume, and RV end-diastolic area. For both uni- and multivariable analysis, hazard ratios (HRs) with 95% confidence intervals (CIs) were calculated. To investigate the incremental value of RV FWS over clinical and conventional echocardiographic parameters to predict outcome, a likelihood ratio test was performed. The change in global chi-square values was calculated and reported. A 2-sided p value of <0.05 was considered statistically significant. Statistical analysis was performed using SPSS for Windows, version 25.0 (IBM, Armonk, New York).

A total of 871 patients (mean age 65 ± 11 years, 75% were men) were analyzed. Baseline characteristics of the overall population are shown in Table 1, whereas Table 2 summarizes the echocardiographic data for the overall population. Patients were subsequently divided into 2 groups: preserved (≥23%) and impaired (<23%) RV FWS, according to thresholds recommended by present guidelines.[11] Individuals with impaired RV FWS were less likely to have sinus rhythm, had more impaired renal function, and were less frequently treated with β-blockers and angiotensin-converting enzyme inhibitors/angiotensin receptor blockers compared with patients with preserved RV FWS (Table 1).

Table 1
Baseline clinical characteristics

Variable	Overall population (n=871)	RV FWS <23% (n=702)	RV FWS ≥23% (n=169)	p- value
Age (years)	64.9 (±10.7)	64.8 (±10.8)	64.9 (±10.4)	0.976
Men	649 (74.5%)	531 (75.6%)	118 (69.8%)	0.119
Systemic hypertension	398 (45.9%)	318 (45.5%)	80 (47.3%)	0.666
Diabetes mellitus	186 (21.4%)	155 (22.1%)	31 (18.3%)	0.287
Dyslipidemia	367 (42.4%)	293 (42.0%)	74 (43.8%)	0.680
Current smoker	141 (16.3%)	111 (15.9%)	30 (18.0%)	0.806
BMI (kg/m^2)	26.3 (±4.3)	26.3 (±4.4)	26.3 (±4.0)	0.975
Ischemic etiology	495 (56.8%)	389 (55.4%)	106 (62.7%)	0.085
QoL score	31.9 (±19.6)	33.0 (±19.8)	27.7 (±17.8)	0.004
6MWT (meters)	334.0 (±118.5)	327.2 (±117.3)	360.6 (±120.2)	0.003
NYHA III-IV	565 (66.2%)	463 (66.9%)	102 (63.0%)	0.340
Sinus rhythm	637 (73.1%)	492 (70.1%)	145 (85.8%)	<0.001
QRS duration (ms)	154 (±35)	155 (±35)	150 (±34)	0.073
Beta-blocker	658 (75.5%)	518 (73.8%)	140 (82.8%)	0.014
ACE-i/ARB	770 (88.4%)	613 (87.3%)	157 (92.9%)	0.042
MRA	370 (42.5%)	310 (44.2%)	60 (35.5%)	0.041
Diuretics	684 (78.5%)	563 (80.2%)	121 (71.6%)	0.014
Statin	540 (62.0%)	430 (61.3%)	110 (65.1%)	0.356
eGFR (ml/min/1.73m^2)	68.4 (±24.7)	67.2 (±24.7)	73.3 (±24.3)	0.004
Hemoglobin (g/dl)	13.4 (± 1.6)	13.4 (±1.6)	13.4 (±1.6)	0.674

Values are presented as mean ± SD, median (IQR), or n (%).

ACE-i = angiotensin-converting enzyme inhibitor; ARB =angiotensin receptor blocker; BMI = body mass index; eGFR = estimated glomerular filtration rate; MRA = mineralocorticoid receptor antagonist; MWT = minute walking test; NYHA = New York Heart Association; QoL = quality of life.

Those with an impaired RV FWS also had lower LVEF, larger indexed left atrium volume, and greater RV area (Table 2). Figure 1 shows the percentages of preserved and impaired RV function in the population at baseline, stratified according to conventional (RV FAC and TAPSE) and deformation (RV FWS) parameters. RV FWS identified a higher percentage of patients with abnormal RV function (81%) in the study cohort in comparison with RV FAC (44%) and TAPSE (61%).

After a median follow-up of 97 (53 to 145) months, 521 patients (60%) died. Significantly worse survival rates were noted among patients with impaired RV systolic function, whether defined by RV FAC, TAPSE, or RV FWS (Figure 2). When dividing recipients of CRT according to RV FWS, survival rates at 1, 3, and 5 years were 94%, 82%, and 68%, respectively, in patients with impaired RV FWS versus 99%, 94%, and 85% in those with preserved RV FWS (p <0.001) (Figure 3). When assessed as a continuous variable, more preserved RV FWS at baseline was independently associated with a lower risk of all-cause mortality (HR 0.944; 95% CI 0.929 to 0.959; p <0.001) compared with the risks represented by preserved RV FAC (HR 0.984; 95% CI 0.977 to 0.992; p <0.001) and preserved TAPSE (HR 0.965; 95% CI 0.946 to 0.984; p <0.001)

Table 2
Baseline echocardiographic characteristics

Variable	Overall population (n=871)	RV FWS <23% (n=702)	RV FWS ≥23% (n=169)	p-value
LVEDV (ml)	190 (149 - 244)	193 (150 - 246)	182 (141 - 237)	0.192
LVESV (ml)	138 (102 - 181)	143 (103 - 185)	133 (97 - 171)	0.073
LVEF (%)	27.5 (±8.1)	27.1 (±8.2)	29.0 (±7.7)	0.007
LV GLS (%)	7.5 (±3.4)	7.3 (±3.4)	8.1 (±3.3)	0.006
LAVi (ml/m^2)	43 (±20)	45 (±21)	37 (±13)	<0.001
Moderate or severe MR	329 (37.8%)	274 (39.0%)	55 (32.5%)	0.029
RVEDA (cm^2)	22.1 (±6.9)	22.7 (±7.0)	19.7 (±5.8)	<0.001
RVESA (cm^2)	14.2 (±6.1)	15.0 (±6.2)	11.1 (±4.4)	<0.001
RV FAC (%)	37.0 (±12.9)	35.2 (±12.7)	44.6 (±10.7)	<0.001
TAPSE (mm)	16.2 (±4.8)	15.7 (±4.8)	18.5 (±3.8)	<0.001
RV FWS (%)	17.7 (±6.1)	15.5 (±4.6)	26.5 (±2.9)	<0.001
RA area (cm^2)	17.8 (13.9 − 22.6)	18.5 (14.4 − 23.6)	15.5 (12.6 − 18.6)	<0.001
TR velocity (m/s)	2.6 (±0.6)	2.6 (±0.6)	2.5 (±0.5)	0.002
PASP (mmHg)	35.5 (±14.0)	36.2 (±14.3)	32.0 (±11.8)	0.003
Moderate or severe TR	186 (21.4%)	167 (23.8%)	19 (11.2%)	<0.001

Values are presented as mean ± SD, median (IQR) or n (%).

EDA = end-diastolic area; EDV = end-diastolic volume; EF = ejection fraction; ESA = end-systolic area; ESV = end-systolic volume; FAC = fractional area change; FWS = free wall strain; GLS = global longitudinal strain; LA = left atrium; LAVi = left atrial volume index; LV = left ventricle; PASP = pulmonary artery systolic pressure; RA = right atrium; RV = right ventricle; TAPSE = tricuspid annular plane systolic excursion; TR = tricuspid regurgitation.

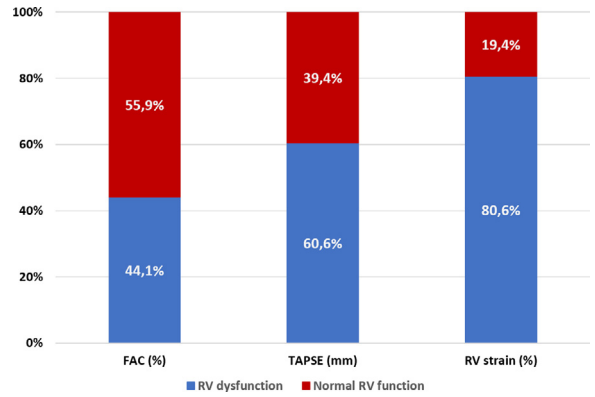

Figure 1. Distribution of RV dysfunction according to different echocardiographic parameters. Using prespecified cutoffs for RV dysfunction (RV FAC <35%, TAPSE <17 mm and RV FWS <23%), the distribution for RV dysfunction and normal RV function are shown for the overall population.

(Table 3). Similarly, when assessed as a categoric variable, impaired RV FWS remained independently associated with the highest risk of all-cause mortality (HR 1.618; 95% CI 1.252 to 2.092; p <0.001) compared to the risks represented by RV FAC (HR 1.405; 95% CI 1.167 to 1.691; p <0.001) and impaired TAPSE (HR 1.243; 95% CI 1.023 to 1.510; p = 0.029).

To investigate the incremental prognostic value of RV FWS over conventional measures of RV function (RV FAC and TAPSE) and clinical parameters, the likelihood ratio testing was performed. The baseline model comprised all covariates that were included in the multivariable regression analysis, that is, age, gender, arterial hypertension, dyslipidemia, diabetes mellitus, body mass index, sinus rhythm, ischemic etiology of HF, estimated glomerular filtration rate, NYHA functional class III to IV, β-blocker, angiotensin-converting enzyme inhibitor/angiotensin receptor blocker, mineralocorticoid receptor antagonist, diuretics, LV end-diastolic volume, LVEF, left atrium indexed volume, and RV end-diastolic area. RV FWS provided incremental prognostic value when added to the baseline model and conventional echocardiographic parameters to assess RV function (RV FAC and TAPSE) (Figures 4 and 5).

Of the 871 patients included, follow-up RV FWS was available in 629 patients at 6 months follow-up. RV FWS did not improve in the overall population (18.1% at baseline vs 18.5% at 6 months follow-up, p = 0.076). A multivariable linear regression analysis was performed (adjusting for age, etiology of HF, diabetes mellitus, NYHA functional Class III to IV, QRS duration before implantation, β-blocker, angiotensin-converting enzyme inhibitor/angiotensin receptor blocker, mineralocorticoid receptor antagonist, estimated glomerular filtration rate, baseline LVEF, and baseline RV FWS) to investigate which variables were significantly associated with improvement of RV FWS (as a continuous variable) at 6 months follow-up. Nonischemic HF (coefficient [B] 0.075; 95% CI 0.023 to 1.795; p = 0.044) and RV FWS at baseline (coefficient [B] 0.523; 95% CI 0.452 to 0.595; p <0.001) were independently associated with improvement of RV FWS at follow-up, whereas diabetes mellitus (coefficient [B] −0.102; 95% CI −2.570 to −0.494; p = 0.004) and NYHA class III-IV (coefficient [B] −0.140; 95% CI −2.674 to −0.880; p <0.001) were independently associated with worsening of RV FWS at follow-up.

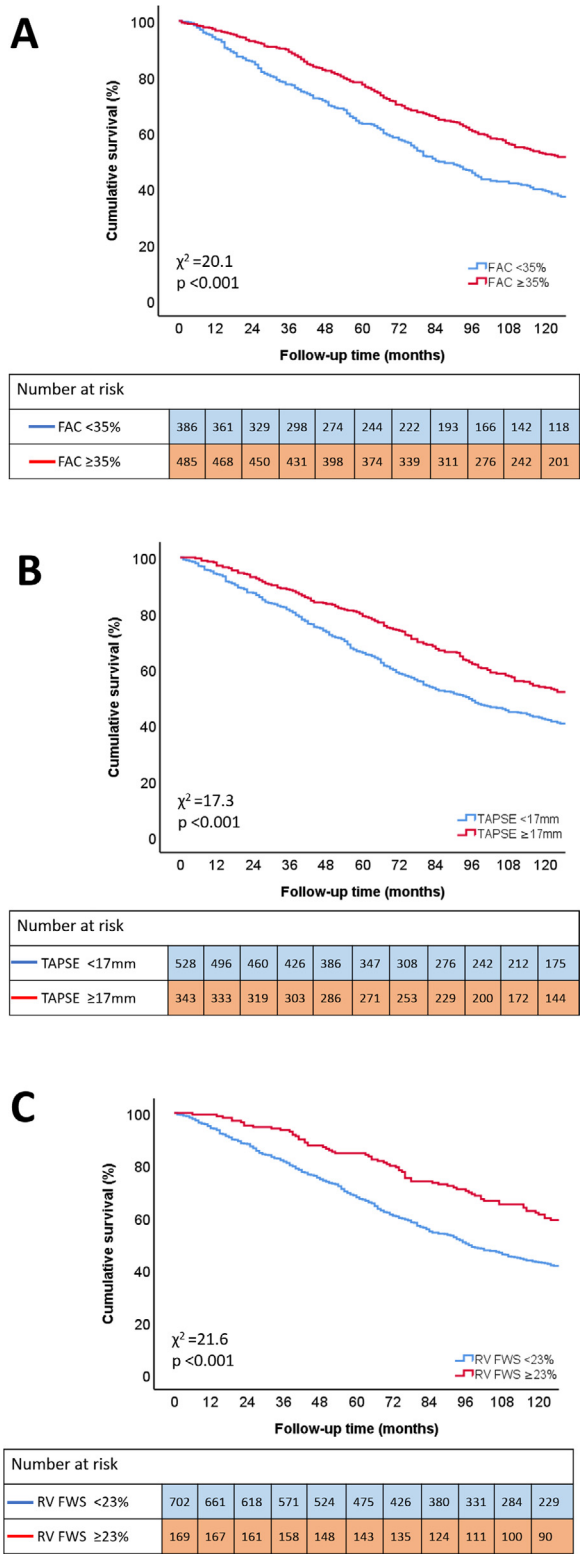

Figure 2. Kaplan-Meier curves for time to cumulative survival, according to RV FAC, TAPSE and RV FWS.

The main findings of the present study can be summarized as follows: (1) in recipients of CRT, assessment of RV FWS by speckle tracking echocardiography identifies a

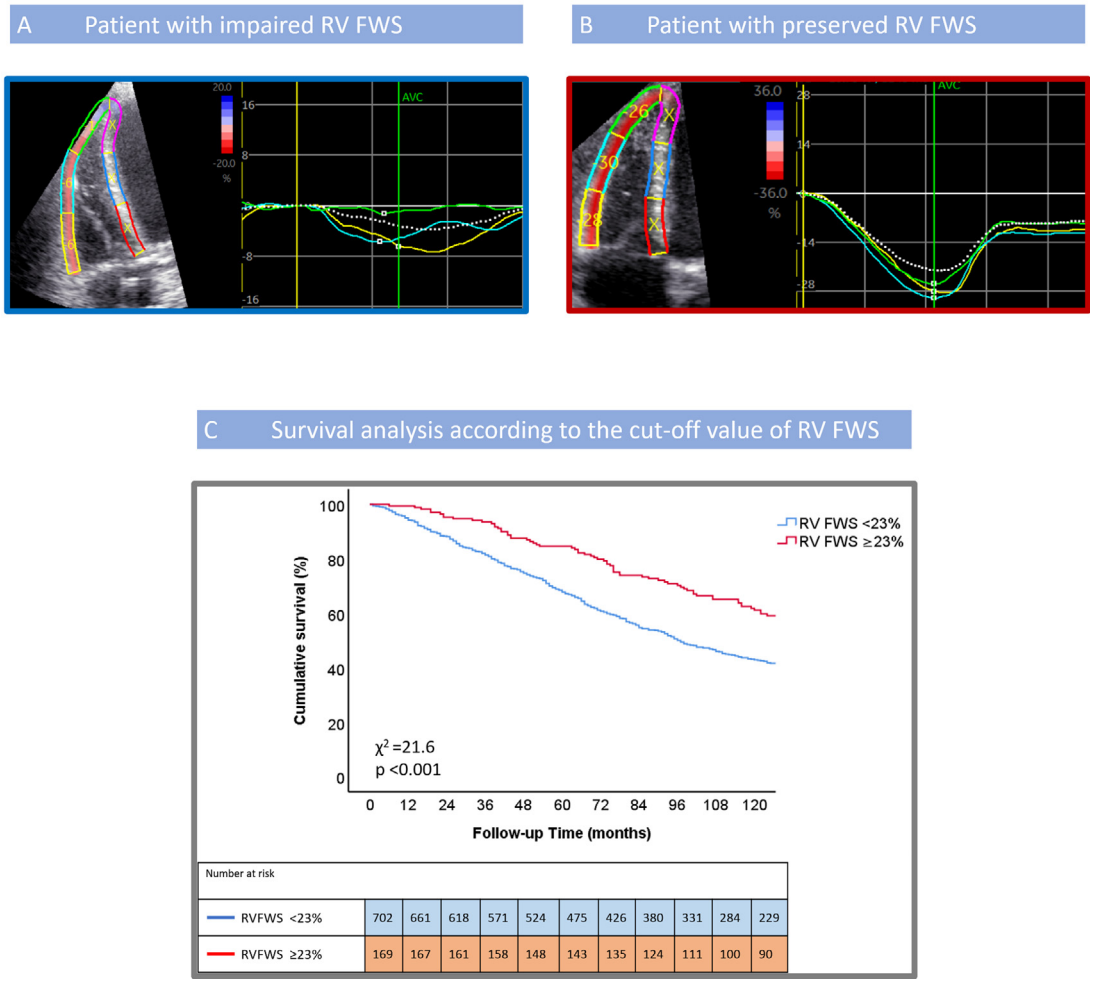

Figure 3. Association of right ventricular free wall strain and mortality in recipients of CRT. Example of 2 patients having similar RV dimensions, but different values for RV FWS: RV FWS 4.3% (*A*) and RV FWS 28% (*B*). Survival curves for all-cause mortality according to the cut-off value of RV FWS (23%) show that patients with RV FWS <23% have higher mortality rates compared with patients with RV FWS ≥23% (*C*).

Table 3
Uni -and multivariable Cox regression analysis to assess association between RV systolic functional parameters and all-cause mortality

	Univariable analysis		Multivariable analysis*	
Variable	HR (95% CI)	P value	HR (95% CI)	P value
RV FAC (%) (continuous)	0.979 (0.973 − 0.986)	<0.001	0.984 (0.977 − 0.992)	<0.001
RV FAC <35% (categorical)	1.477 (1.243 − 1.754)	<0.001	1.405 (1.167 − 1.691)	<0.001
RV TAPSE (mm) (continuous)	0.943 (0.926 − 0.961)	<0.001	0.965 (0.946 − 0.984)	<0.001
RV TAPSE <17mm (categorical)	1.464 (1.221 − 1.754)	<0.001	1.243 (1.023 − 1.510)	0.029
RV FWS (%) (continuous)	0.963 (0.923 − 0.950)	<0.001	0.944 (0.929 − 0.959)	<0.001
RV FWS <23% (categorical)	1.757 (1.380 − 2.237)	<0.001	1.618 (1.252 − 2.092)	<0.001

* Adjusted for age, gender, arterial hypertension, dyslipidemia, diabetes mellitus, body mass index, sinus rhythm, ischemic etiology for heart failure, estimated glomerular filtration rate, New York Heart Association functional class III to IV, β-blocker, angiotensin-converting enzyme inhibitor/angiotensin receptor blocker, mineralocorticoid receptor antagonist, diuretics, left ventricular end-diastolic volume, left ventricular ejection fraction, left atrial volume index, and right ventricular end-diastolic area.

FAC = fractional area change; FWS=free wall strain; RV = right ventricle; TAPSE = tricuspid annular plane systolic excursion.

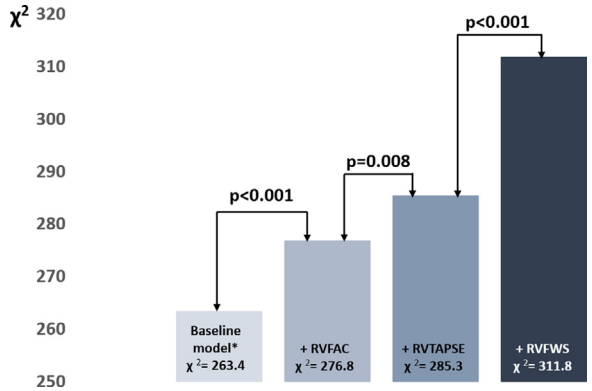

Figure 4. Likelihood ratio test for the incremental prognostic value of RV FWS as a continuous variable. The addition of RV FAC, TAPSE and RV FWS as continuous variables to a baseline clinical model is associated with significant increases in the chi-square value. *The baseline model includes age, gender, arterial hypertension, dyslipidemia, diabetes mellitus, body mass index, sinus rhythm, ischemic etiology for heart failure, estimated glomerular filtration rate, NYHA functional class 3 to 4, β-blocker, angiotensin-converting enzyme inhibitor/angiotensin receptor blocker, mineralocorticoid receptor antagonist, diuretics, left ventricular end-diastolic volume, LVEF, left atrial volume index, right ventricular end-diastolic area.

larger proportion of patients with impaired baseline RV systolic function than conventional echocardiographic indexes; (2) more impaired RV FWS is independently associated with worse outcome in patients undergoing CRT; and (3) RV FWS provides incremental prognostic value over conventional echocardiographic indices of RV dysfunction.

A number of different mechanisms have been proposed to explain RV dysfunction in patients with HF, the most common of which is chronic (mostly ischemic) LV dysfunction.[12] RV function in patients with HF may also be impaired because of other mechanisms, including primary myocardial involvement (e.g., ischemic or idiopathic cardiomyopathies), ventricular interdependence associated with septal dysfunction and pericardial constraint, neurohormonal interactions, volume overload due to secondary tricuspid regurgitation, and reduced RV coronary perfusion as a result of decreased systolic driving pressure.[12] Although the presence of impaired RV systolic function is strongly associated with poor prognosis, detection of RV dysfunction by conventional echocardiography remains challenging because of the complex RV anatomy. TAPSE measures only the displacement of the lateral annulus, thereby extrapolating the motion of a single point to the entire RV. Regional differences in RV function therefore cannot be identified by this technique. RV FAC is hampered by high inter- and intraobserver variability, most likely due to the suboptimal endocardial delineation which is often present with transthoracic echocardiography. RV FWS is less angle- and load-dependent than TAPSE and more reproducible than RV FAC, but its greatest advantage relates to the high sensitivity for detecting subtle systolic RV dysfunction.[13] Because longitudinal subendocardial fibers account for most of RV

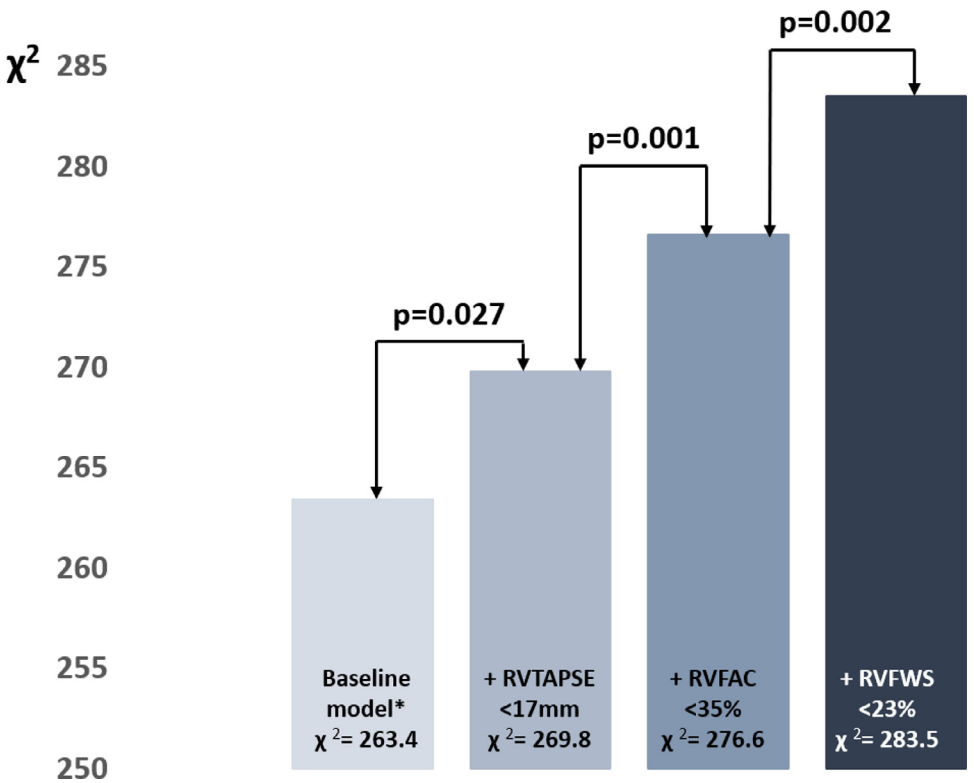

Figure 5. Likelihood ratio test for the incremental prognostic value of RV FWS as a categoric variable. The addition of RV FAC <35%, TAPSE <17 mm and RV FWS <23% as categoric variables to a baseline clinical model is associated with significant increases in the chi-square value. *The baseline model includes age, gender, arterial hypertension, hyperlipidemia, diabetes mellitus, body mass index, sinus rhythm, ischemic etiology for HF, estimated glomerular filtration rate, NYHA functional class 3 to 4, β-blocker, angiotensin-converting enzyme inhibitor/angiotensin receptor blocker, mineralocorticoid receptor antagonist, diuretics, left ventricular end-diastolic volume, LVEF, left atrium volume index, right ventricular end-diastolic area.

contraction, RV FWS (which is measured in the longitudinal direction) is an accurate reflection of global RV function.[14] In a study of 880 patients, RV longitudinal strain was more sensitive than TAPSE and RV FAC in detecting abnormalities in RV systolic function.[15] RV FWS outperformed TAPSE and FAC compared with RVEF measured with cardiac magnetic resonance imaging.[16,17] The present observation that RV FWS is more sensitive for the detection of RV dysfunction in recipients of CRT is in line with these observations. Leong et al demonstrated that impaired TAPSE is an independent predictor of all-cause mortality in 845 recipients of CRT.[4] Similarly, Damy et al[18] reported on the prognostic implications of TAPSE in 345 recipients of CRT. The prognostic impact of RV dysfunction, measured with echocardiographic speckle tracking strain imaging, has not been extensively evaluated in patients undergoing CRT. In a study of 93 recipients of CRT, Nagy et al[19] demonstrated that RV FWS was independently associated with mortality. Similarly, Sade et al[20] showed an independent association between RV FWS and the combined end point of cardiac transplantation, LV assist device implantation, and death in 120 patients. The present data demonstrate a strong, independent link between preserved RV FWS and outcomes in a large population receiving CRT. Importantly, using a guideline-recommended threshold for preserved RV FWS (≥23%),[11] the incremental value of RV FWS to predict outcomes was superior over conventional echocardiographic parameters of RV function. Although RV dysfunction is a predictor of morbidity and mortality in patients with HF, the underlying mechanisms linking RV dysfunction and outcomes remain incompletely understood.[12] An impaired RVEF may further reduce LV output by limiting the RVs ability to deliver an adequate LV preload, thereby enhancing neurohormonal activation.[21] Because of ventricular interdependence, a significantly dilated RV competes with the LV within the confines of the pericardium and reduces LV output. A low LV stroke volume leads to end-organ hypoperfusion, which portends a worse outcome.[22] Because RV FWS is a sensitive biomarker for RV dysfunction in patients with HF, it permits earlier detection of impaired RV function and may permit timely institution of management approaches to prevent or attenuate deterioration in RV function after CRT. Reducing excessive RV preload with diuretic therapy could reduce RV dilatation and wall tension, which in turn lessens RV ischemia and improves RV contractility. Furthermore, in appropriately selected patients, selective pulmonary vasodilators may have a clinical role in decreasing RV afterload.[23] More recently introduced HF treatments, such as sodium-glucose co-transport 2 inhibitors and angiotensin-neprilysin inhibitors, may prove to have beneficial effects on RV remodeling and function.[24,25] Finally, CRT itself reduces pulmonary artery pressures and has the potential to improve RV function. Campbell et al published data showing that RV function improved in parallel with LV function after CRT, with those patients gaining RV function at 1-year after implant, improving their prognosis.[26]

This study is subject to the limitations of a retrospective, observational design. Given the retrospective nature of the study, medical treatment of HF was not standardized between both groups. In addition, due to the retrospective design, there may be confounders that we could not adjust for in the statistical analysis. Echocardiographic assessment of RV FWS is vendor-dependent, and values cannot be compared directly across different ultrasound platforms. In addition, because cardiac magnetic resonance and 3-dimensional echocardiography were not performed for assessment of RV function, comparison between RV FWS and these imaging techniques could not be performed. Also, echocardiographic data after CRT implantation were not available. Finally, granular data were not available to differentiate between cardiac and noncardiac causes of mortality.

In conclusion, baseline RV FWS identifies a larger proportion of recipients of CRT with impaired RV function compared with conventional echocardiographic parameters (TAPSE and FAC) and has incremental prognostic value compared with these conventional echocardiographic parameters.

Disclosures

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