Cardiomyopathies

Evaluation of Right Ventricular Systolic Function in Chagas Disease Using Cardiac Magnetic Resonance Imaging

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Background—Right ventricular (RV) impairment is postulated to be responsible for prominent systemic congestion in Chagas disease. However, occurrence of primary RV dysfunction in Chagas disease remains controversial. We aimed to study RV systolic function in patients with Chagas disease using cardiac magnetic resonance.

Methods and Results—This cross-sectional study included 158 individuals with chronic Chagas disease who underwent cardiac magnetic resonance. RV systolic dysfunction was defined as reduced RV ejection fraction based on predefined cutoffs accounting for age and sex. Multivariable logistic regression was used to verify the relationship of RV systolic dysfunction with age, sex, functional class, use of medications for heart failure, atrial fibrillation, and left ventricular systolic dysfunction. Mean age was 54±13 years, 51.2% men. RV systolic dysfunction was identified in 58 (37%) individuals. Although usually associated with reduced left ventricular ejection fraction, isolated RV systolic dysfunction was found in 7 (4.4%) patients, 2 of them in early stages of Chagas disease. Presence of RV dysfunction was not significantly different in patients with indeterminate/digestive form of Chagas disease (35.7%) compared with those with Chagas cardiomyopathy (36.8%) (P=1.000).

Conclusions—In chronic Chagas disease, RV systolic dysfunction is more commonly associated with left ventricular systolic dysfunction, although isolated and early RV dysfunction can also be identified. (Circ Cardiovasc Imaging. 2017;10:e005571. DOI: 10.1161/CIRCIMAGING.116.005571.)

Key Words: atrial fibrillation ▪ Chagas cardiomyopathy ▪ heart failure ▪ magnetic resonance imaging ▪ systole

Chagas disease is caused by the protozoan parasite Trypanosoma cruzi (T cruzi), usually transmitted to human beings by blood-sucking triatomine bugs or by non-vector-borne transmissions ways, such as blood transfusion, solid organ or bone marrow transplantation, vertically from mother to fetus, and by consumption of contaminated food or drink.1 About 7 million people are infected worldwide, mostly in Latin America.2 However, as a result of migration from endemic countries, Chagas disease has spread to other nonendemic areas. Over 300000 infected individuals are estimated to be living in the United States and another 68 000 to 123 000 in Europe.3,4 The global health and economic burden of the disease is estimated in the range of 30 000 disability-adjusted life years and $7.19 billion per year.5

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fraction. CMR has been previously used to study patients with Chagas disease, but the focus has always been on the LV, with scarce data on the RV functional assessment. The aims of this study were (1) to describe RV impairment patterns and (2) to determine clinical correlates of RV systolic dysfunction in Chagas patients with and without cardiomyopathy using CMR to assess RV systolic function.

Methods

Study Population
This cross-sectional study enrolled 158 individuals with age ≥18 years and chronic Chagas disease, determined by the positivity of at least 2 different serological tests: ELISA, indirect immunofluorescence or indirect hemagglutination. All study participants were consecutively recruited in the outpatient clinics at the Hospital das Clínicas de Ribeirão Preto, University of São Paulo, Brazil, from February 2010 to August 2014. Exclusion criteria were the presence of other cardiomyopathies, obstructive coronary artery disease, cardiac valve disease, or systemic diseases with potential effect on cardiac muscle. RV dysfunction in our study was defined accordingly to another previous research, in which RV measurements did not include RV outflow tract to provide normative reference ranges for RVEF stratified with age and sex, with lower limit of normality ranging from 48% to 59% depending on age and sex (Table II in the Data Supplement shows detailed values according to age and sex).

Reproducibility
Reproducibility of CMR parameters was tested for 20 patients randomly selected. For inter-reader reproducibility, the second reader was blinded to the first reading. For intraobserver reproducibility, the rereading was performed at least 30 days after the original reading.

Statistical Analysis
Normality of data was evaluated by the Shapiro–Wilk test. Comparisons of baseline characteristics between those participants with or without RV systolic dysfunction were assessed by Student t test, Wilcoxon rank-sum test, χ² test, and Fisher exact test as appropriate. Clinical parameters related to reduced RV systolic function in the baseline comparisons were included in a multivariable analysis using logistic regression, including age, sex, and LV systolic dysfunction as covariates, to verify independent association of those variables with RV systolic dysfunction. Intraclass correlation coefficient and Cohen k coefficient were used to test variability of continuous and categorical variables, respectively. P value <0.05 was considered statistically significant. All statistical analyses were performed using STATA 14.0 (StataCorp).

Results

Cardiac Magnetic Resonance
CMR images were obtained using a 1.5-T scanner Achieva (Phillips, The Netherlands), with a predefined protocol. Cine imaging was acquired by steady-state–free precession pulse sequence gated by ECG. Short-axis slices of both LV and RV were performed, with thickness of 8 mm and gap between slices of 2 mm. For myocardial late enhancement evaluation, the participants received 0.2 mmol of gadolinium-based contrast (Omniscan; GE Healthcare) by intravenous infusion. T1-weighted inversion recovery fast gradient echo pulse sequence was applied 10 minutes after the contrast injection. Ventricular slices with 10 mm of thickness and no gap between them were assessed to identify late gadolinium enhancement in both ventricles. Steady-state–free precession and inversion recovery fast gradient echo protocol parameters are reported in Table I in the Data Supplement. All exams were stored in Digital Imaging and Communication in Medicine pattern and analyzed by a single experienced reader, blinded to all other clinical and laboratory data, using MASS software (Leiden University, Leiden, The Netherlands). RV ejection fraction (RVEF) and LV ejection fraction (LVEF) were determined in cine steady-state–free precession images accordingly to Simpson disk summation technique (Figure 1). For this purpose, the first basal slice was defined as the one immediately adjacent to the atrioventricular junction. RV outflow tract was not included in the RV analysis. End-diastolic and end-systolic volumes were considered as the largest and the smallest volumes during the cardiac cycle, respectively. Endocardial borders were manually delineated. Papillary muscles and trabeculae were considered as part of each ventricular cavity.

LV and RV Systolic Dysfunction
LV systolic dysfunction was defined as LVEF < 57% for males with age ≤35 years and females of all ages, and LVEF < 59% for males with age ≥35 years, as previously described. Although reference ranges for RV parameters were also provided by that study, RV outflow tract was included to determine RV volumes and RVEF. Thus, RV dysfunction in our study was defined accordingly to another previous research, in which RV measurements did not include RV outflow tract to provide normative reference ranges for RVEF stratified by age and sex, with lower limit of normality ranging from 48% to 59% depending on age and sex (Table II in the Data Supplement shows detailed values according to age and sex).

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Results

Cardiac Magnetic Resonance
Clinical and demographic characteristics of all 158 participants are described in Table I. Mean age was 54±13 years, 81 (51.2%) men. Most individuals were in New York Heart Association functional class I (120 [76%]). Hypertension was the most prevalent comorbidity, present in 65 (41%) individuals. According to the traditional criteria for Chagas disease forms, most patients (144 [91.1%]) were in the group II (with cardiomyopathy), whereas 14 (8.9%) individuals were in the group I (without cardiomyopathy). Clinical and demographic characteristics of groups I and II are shown in Table 2. Digestive form was found in 26 (16.4%) patients, 23 of them had evidence of cardiomyopathy, whereas 3 of them had no cardiovascular symptoms and normal both ECG and chest radiography. Indeterminate form was found in 11 subjects.

LV systolic dysfunction was detected in 106 (67%) participants. RV systolic dysfunction was identified in 58 (36.7%) individuals (Figure 2). Reduced RV systolic function in the presence of depressed LVEF was found in 51 (34.8%) patients, whereas isolated RV dysfunction was demonstrated in 7 (4.4%) patients. Among those individuals with indeterminate form, with no cardiac or digestive form, of Chagas disease, 2 (14.3%) of them presented isolated RV dysfunction. Of these 2 subjects, none of them had overweight or obesity, history of hypertension, dyslipidemia, or diabetes mellitus, whereas only 1 subject had history of smoking (45 pack-years). The percentage of participants with RV dysfunction did not differ significantly between the group I (35.7%) and group II (36.8%). Fisher exact test P=1.000. Of note, half of the participants of the group I (n=7) showed left and right systolic dysfunction.
Discussion

RV Involvement in Chagas Disease

This investigation is the largest using CMR to study patients with Chagas disease and the first to describe a systematic evaluation of the RV function using the method that can be considered the gold standard in this context. Although more frequently associated to the impairment of LV systolic function, RV systolic dysfunction was found in 37% of the participants. Also, confirming previous reports using other methods, this study found reduced RVEF in patients with less advanced stages of Chagas disease, including asymptomatic individuals and patients with the indeterminate and isolated digestive form of the disease. Moreover, RV systolic dysfunction was identified in the absence of LV myocardial fibrosis and dysfunction.

Taken together, these data confirm previous investigations that used other methods such as radionuclide angiography, describing isolated involvement of the RV in some patients with Chagas disease. Thus, in face of an incidental finding of isolated RV dysfunction, Chagas disease should be considered in the clinical differential diagnosis, especially in an individual from an endemic region.

Our findings are also in agreement with other previous studies using distinct methods to evaluate the RV in Chagas disease. Prominent inflammation, fibrosis, and vasculitis in the right chambers were shown in experimental models of mice infected with T. cruzi, even during the acute infection phase. In humans, endomyocardial biopsies on the right side of the interventricular septum revealed histopathologic abnormalities in most patients with chronic Chagas disease even at early stages of the disease. Also, in the indeterminate form of Chagas disease, invasive hemodynamic evaluation showed increased RV end-diastolic pressure in comparison with healthy subjects.

In contrast to those findings, recent studies using echocardiography have suggested that RV systolic dysfunction in Chagas disease is exclusively dependent on LV increased afterload. These apparently discordant results might be explained, at least in part, on account of inherent differences in the population samples and techniques used. For example, a study of individuals with chronic Chagas cardiomyopathy found LV involvement in 58% of the participants, whereas the remaining 42% showed involvement of both LV and RV. However, in that investigation, the presence of LV dilation or LV systolic dysfunction was a strict inclusion criteria, and RV systolic function was subjectively estimated.

Inter-reader reproducibility assessed by intraclass correlation coefficient for LV end-diastolic volume, LV end-systolic volume, and LV ejection was 0.98, 0.97, and 0.86, respectively. For RV end-diastolic volume, RV end-systolic volume, and RVEF, intraclass correlation coefficient was slightly lower: 0.93, 0.94, and 0.76, respectively. Inter-reader reproducibility for the identification of LV fibrosis and RV fibrosis was k=0.95 and k=0.75, respectively. Overall, interreader reproducibility was higher than inter-reader assessment (Table 3).

Myocardial Fibrosis

Late gadolinium enhancement technique for myocardial fibrosis assessment was performed in all individuals, but it was unsuitable for analysis in 5 subjects, because of poor-quality images. Fibrosis was identified in LV and RV in 113 (74%) and 11 (7%) individuals, respectively. Among those with RV fibrosis identified by CMR, RV systolic dysfunction was found in 5 patients, whereas 6 individuals had preserved RV systolic function. All participants with RV fibrosis also showed LV fibrosis. Of note, RV systolic dysfunction was found in 12 individuals with no fibrosis in either the LV or the RV.

Clinical Correlates of RV Systolic Dysfunction

New York Heart Association functional class II, angiotensin-converting enzyme inhibitor/angiotensin receptor blockers, β-blockers, furosemide, atrial fibrillation, and LV systolic dysfunction were associated with the RV systolic dysfunction in the univariate analysis. In the multivariable analysis (Table 4), including all those correlates in the same model, only atrial fibrillation and LV systolic dysfunction were independently associated with the presence of RV systolic dysfunction, with odds ratio of 10.00 (95% confidence interval, 1.94–51.48) and 3.76 (95% confidence interval, 1.36–10.43), respectively.

Figure 1. Right ventricular evaluation by cardiac resonance imaging using steady-state–free precession (SSFP) pulse sequences. Long-axis tomographic slices were used to define right ventricular basal and apical limits (A and B). Right ventricular endocardial borders were delineated in short-axis tomographic slices (yellow contours), from basal (1) to apical (9) regions at end diastole and end systole for ejection fraction calculation. Red and green contours represent left ventricular endocardial and epicardial delineation, respectively (C).
Table 1. Baseline Characteristics According to the Presence or Absence of RV Systolic Dysfunction

<table>
<thead>
<tr>
<th></th>
<th>All</th>
<th>No RV Systolic Dysfunction</th>
<th>With RV Systolic Dysfunction</th>
<th>P Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>n=158</td>
<td>n=100</td>
<td>n=58</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td>56 [44–66]</td>
<td>54 [43–64]</td>
<td>60 [46–68]</td>
<td>0.190</td>
</tr>
<tr>
<td>Males (%)</td>
<td>81 (51%)</td>
<td>47 (47%)</td>
<td>34 (59%)</td>
<td>0.159</td>
</tr>
<tr>
<td>Body mass index, kg/m²</td>
<td>22.3 [21.2–23.6]</td>
<td>22.5 [21.2–23.7]</td>
<td>22.3 [21.2–23.3]</td>
<td>0.795</td>
</tr>
<tr>
<td>NYHA functional class (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>120 (76%)</td>
<td>82 (82%)</td>
<td>38 (66%)</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>26 (16%)</td>
<td>12 (12%)</td>
<td>14 (24%)</td>
<td>0.064</td>
</tr>
<tr>
<td>III</td>
<td>12 (8%)</td>
<td>6 (6%)</td>
<td>6 (10%)</td>
<td></td>
</tr>
<tr>
<td>Comorbidities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension (%)</td>
<td>65 (41%)</td>
<td>39 (39%)</td>
<td>26 (45%)</td>
<td>0.473</td>
</tr>
<tr>
<td>Dyslipidemia (%)</td>
<td>51 (32%)</td>
<td>30 (30%)</td>
<td>21 (36%)</td>
<td>0.421</td>
</tr>
<tr>
<td>Diabetes mellitus (%)</td>
<td>11 (7%)</td>
<td>4 (4%)</td>
<td>7 (12%)</td>
<td>0.058</td>
</tr>
<tr>
<td>Ischemic stroke (%)</td>
<td>8 (5%)</td>
<td>3 (3%)</td>
<td>9 (5%)</td>
<td>0.121</td>
</tr>
<tr>
<td>Smoking (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td>10 (6%)</td>
<td>7 (7%)</td>
<td>3 (5%)</td>
<td></td>
</tr>
<tr>
<td>Former</td>
<td>39 (25%)</td>
<td>25 (25%)</td>
<td>14 (24%)</td>
<td>0.961</td>
</tr>
<tr>
<td>Never</td>
<td>109 (69%)</td>
<td>68 (68%)</td>
<td>41 (71%)</td>
<td></td>
</tr>
<tr>
<td>Medications (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACEI or ARB</td>
<td>98 (62%)</td>
<td>53 (53%)</td>
<td>45 (78%)</td>
<td>0.002</td>
</tr>
<tr>
<td>Spironolactone</td>
<td>23 (14%)</td>
<td>13 (13%)</td>
<td>10 (17%)</td>
<td>0.466</td>
</tr>
<tr>
<td>β-blocker</td>
<td>68 (43%)</td>
<td>33 (33%)</td>
<td>35 (60%)</td>
<td>0.001</td>
</tr>
<tr>
<td>Calcium channel blocker</td>
<td>5 (3%)</td>
<td>3 (3%)</td>
<td>3 (2%)</td>
<td>0.607</td>
</tr>
<tr>
<td>Furosemide</td>
<td>41 (26%)</td>
<td>17 (17%)</td>
<td>24 (41%)</td>
<td>0.001</td>
</tr>
<tr>
<td>Thiazide diuretic</td>
<td>25 (16%)</td>
<td>18 (18%)</td>
<td>7 (12%)</td>
<td>0.325</td>
</tr>
<tr>
<td>Amiodarone</td>
<td>30 (19%)</td>
<td>17 (17%)</td>
<td>22 (33%)</td>
<td>0.403</td>
</tr>
<tr>
<td>Digoxin</td>
<td>14 (9%)</td>
<td>7 (7%)</td>
<td>7 (12%)</td>
<td>0.280</td>
</tr>
<tr>
<td>Electrocardiography</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart rhythm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sinus rhythm</td>
<td>138 (88%)</td>
<td>96 (96%)</td>
<td>42 (72%)</td>
<td></td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>15 (9%)</td>
<td>2 (2%)</td>
<td>13 (22%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Right atrial rhythm</td>
<td>5 (3%)</td>
<td>2 (2%)</td>
<td>3 (5%)</td>
<td></td>
</tr>
<tr>
<td>Ventricular premature beats</td>
<td>26 (16%)</td>
<td>17 (17%)</td>
<td>9 (15%)</td>
<td>0.594</td>
</tr>
<tr>
<td>First-degree atrial ventricular block</td>
<td>30 (19%)</td>
<td>15 (15%)</td>
<td>15 (26%)</td>
<td>0.063</td>
</tr>
<tr>
<td>Right bundle branch block</td>
<td>63 (40%)</td>
<td>35 (35%)</td>
<td>28 (48%)</td>
<td>0.100</td>
</tr>
<tr>
<td>Incomplete right bundle branch block</td>
<td>15 (9%)</td>
<td>7 (7%)</td>
<td>8 (14%)</td>
<td>0.160</td>
</tr>
<tr>
<td>Left bundle branch block</td>
<td>6 (4%)</td>
<td>4 (4%)</td>
<td>2 (3%)</td>
<td>0.613</td>
</tr>
<tr>
<td>Left anterior fascicular block</td>
<td>68 (43%)</td>
<td>39 (39%)</td>
<td>29 (50%)</td>
<td>0.141</td>
</tr>
<tr>
<td>Low QRS voltage</td>
<td>22 (14%)</td>
<td>11 (11%)</td>
<td>11 (19%)</td>
<td>0.276</td>
</tr>
<tr>
<td>Primary ST-T wave changes</td>
<td>56 (35%)</td>
<td>37 (37%)</td>
<td>19 (33%)</td>
<td>0.591</td>
</tr>
<tr>
<td>Chest x-ray</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiomegaly</td>
<td>33 (39%)</td>
<td>33 (33%)</td>
<td>28 (48%)</td>
<td>0.057</td>
</tr>
</tbody>
</table>

Continuous variables are reported as median [interquartile range]. Categorical variables are expressed as n (%). ACEI indicates angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker; NYHA, New York Heart Association; and RV, right ventricular.

*P value for comparisons between the individuals with or without RV systolic dysfunction.
difference of RV longitudinal strain was shown in patients with the indeterminate form of Chagas disease in comparison with a healthy control group.14 Also, other investigators found RV systolic dysfunction only in late stages of Chagas disease, using different nonvolumetric echocardiographic techniques.15 In contrast, also using echocardiography for the evaluation of RV function, another study reported a RV systolic dysfunction prevalence of 26% in individuals with the indeterminate form of Chagas disease.16 These early impairment of RV function was also found in another study that showed delayed RV isovolumic contraction time and abnormalities in parameters of RV filling in early stages of Chagas disease in comparison with a healthy control group.32

In our view, evaluation of RV systolic function by echocardiography can be challenging, because of peculiar characteristics of this cardiac chamber, such as a complex geometric shape, thin walls, prominent apical trabeculae, and the presence of the moderator band.33 Accuracy of echocardiographic parameters to detect RV systolic dysfunction in patients with Chagas disease is therefore unknown. RV involvement in Chagas disease usually affects the midcavity and especially the apical region, preserving the basal segments.34 Therefore, echocardiographic accuracy for the detection of RV systolic dysfunction in Chagas disease should not be derived from other clinical conditions.

Assessment of RV fibrosis using delayed enhancement magnetic resonance imaging was previously shown in other clinical settings, such as arrhythmogenic RV cardiomyopathy and repaired tetralogy of Fallot.35,36 In our study, RV fibrosis was identified in only 7% of the participants, with no relationship with RV dysfunction. Although feasible, standard CMR techniques still remain insensitive to detect a small amount of RV fibrosis, especially because of reduced spatial resolution and through-plane motion, both limitations related to thinner RV walls,37 what might explain this small proportion of RV fibrosis revealed in our study.

Clinical Correlates of RV Systolic Dysfunction in Chagas Disease

RV systolic dysfunction was associated with the presence of chronic atrial fibrillation, independently of LV systolic dysfunction, but with a large 95% confidence interval for the odds ratio (1.94–51.48), which could be due a few cases (only 13) with atrial fibrillation in our sample. A higher prevalence of atrial fibrillation might be necessary to certify the association of this arrhythmia with RV dysfunction in Chagas disease. Functional class and use of angiotensin-converting enzyme inhibitor/angiotensin receptor blockers, β-blockers, and furosemide were associated with RV dysfunction in the univariate analysis, but not in the multivariable analysis, including LV systolic dysfunction and atrial fibrillation. Despite the early RV involvement in

| Table 2: Clinical and Demographic Characteristics of Groups I and II |
|-----------------|-----------------|-----------------|-----------|
|                 | Group I (Indeterminate or Isolated Digestive Forms) | Group II (Cardiac Form) | P Value |
| n=14            | n=144           |                   |
| Males (%)       | 7 (50%)         | 74 (51%)         | 0.921    |
| Body mass index, kg/m² | 22.7 [21.2–23.7] | 22.4 [21.3–23.7] | 0.852    |
| NYHA functional class (%) |                   |                   |
| I               | 13 (93%)        | 107 (74%)        |          |
| II              | 1 (7%)          | 25 (18%)         | 0.468    |
| III             | 0 (0%)          | 12 (8%)          |          |
| Digestive findings (%) | 3 (12%)        | 23 (16%)         | 0.414    |
| Hypertension (%) | 4 (29%)         | 61 (42%)         | 0.240    |
| Dyslipidemia (%) | 2 (14%)         | 49 (34%)         | 0.110    |
| Diabetes mellitus (%) | 1 (7%)         | 10 (7%)          | 0.652    |
| Smoking (%)     |                 |                   |
| Never           | 12 (9%)         | 97 (7%)          |          |
| Former          | 2 (14%)         | 37 (26%)         | 0.485    |
| Current         | 0 (0%)          | 10 (7%)          |          |

Continuous variables are reported as median [interquartile range]. Categorical variables are expressed as n (%). NYHA indicates New York Heart Association.
Chagas disease, clinical manifestations of right-sided heart failure usually appear only in advanced stages of Chagas cardiomyopathy. A hypothesis is that although the RV is pumping into a low pulmonary vascular resistance, the remaining driving force supplied by the LV to the blood flow in the systemic venous territory (vis-a-tergo) would be enough to prevent clinical consequences. However, in a setting of significant LV dysfunction, with subsequent increased pulmonary arterial pressure, RV failure would be clinically expressed, therefore, explaining the prominent systemic congestion in this scenario.

**Limitations**

In our sample, few patients presented the noncardiac forms of Chagas disease. Those individuals are usually asymptomatic in early stages of the disease and even in patients without Chagas cardiomyopathy as defined by the usual clinical criteria.

**Table 3. Reproducibility of Volumetric Analysis and Fibrosis Identification**

<table>
<thead>
<tr>
<th></th>
<th>Inter-Reader</th>
<th>Intrareader</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Left ventricle</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>End-diastolic volume*</td>
<td>0.98</td>
<td>0.99</td>
</tr>
<tr>
<td>End-systolic volume*</td>
<td>0.97</td>
<td>0.98</td>
</tr>
<tr>
<td>Ejection fraction*</td>
<td>0.86</td>
<td>0.97</td>
</tr>
<tr>
<td>Fibrosis†</td>
<td>0.95</td>
<td>1.00</td>
</tr>
<tr>
<td><strong>Right ventricle</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>End-diastolic volume*</td>
<td>0.93</td>
<td>0.94</td>
</tr>
<tr>
<td>End-systolic volume*</td>
<td>0.94</td>
<td>0.96</td>
</tr>
<tr>
<td>Ejection fraction*</td>
<td>0.76</td>
<td>0.82</td>
</tr>
<tr>
<td>Fibrosis†</td>
<td>0.75</td>
<td>0.80</td>
</tr>
</tbody>
</table>

*Intraclass correlation coefficient. †Cohen κ coefficient.

**Conclusions**

RV systolic dysfunction, defined as reduced RVEF by CMR, is common in Chagas disease. It is usually associated with LV systolic dysfunction but can be present with normal LVEF and in early stages of the disease and even in patients without Chagas cardiomyopathy as defined by the usual clinical criteria.

**Disclosures**

None.

**References**

Chagas cardiomyopathy has peculiar features differing it from other dilated cardiomyopathies because of its unique pathogenesis. Right ventricular (RV) dysfunction plays a pivotal role in Chagas disease, leading to a prominent right-sided heart failure state free precession cardiovascular magnetic resonance. *Heart J.* 2006;27:823–830. doi: 10.1093/eurheartj/ehh336.


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Circ Cardiovasc Imaging. 2017;10:
doi: 10.1161/CIRCIMAGING.116.005571

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### Supplemental table 1. Cardiac magnetic resonance pulse sequence parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SSFP†</th>
<th>IR-FGRE‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repetition time (ms)</td>
<td>3.8</td>
<td>5.4</td>
</tr>
<tr>
<td>Echo time (ms)</td>
<td>1.6</td>
<td>1.3</td>
</tr>
<tr>
<td>Flip angle (degrees)</td>
<td>45</td>
<td>20</td>
</tr>
<tr>
<td>Number of acquisition phases</td>
<td>30</td>
<td>1</td>
</tr>
<tr>
<td>Matrix</td>
<td>256 x 160</td>
<td>256 x 192</td>
</tr>
<tr>
<td>Field of view (mm)</td>
<td>360-400</td>
<td>360 x 400</td>
</tr>
<tr>
<td>Slice thickness (mm)</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Gap between slices (mm)</td>
<td>2</td>
<td>no gap</td>
</tr>
<tr>
<td>Inversion time (ms)</td>
<td>-</td>
<td>150-280</td>
</tr>
</tbody>
</table>

† SSFP = steady-state free precession
‡ IR-FGRE = inversion recovery fast gradient echo

### Supplemental table 2. Reference values for RV ejection fraction assessed by CMR extracted from reference 23

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>20-29</th>
<th>30-39</th>
<th>40-49</th>
<th>50-59</th>
<th>60-69</th>
<th>70-79</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Males</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RVEF (%)</td>
<td>(48-74)</td>
<td>(50-76)</td>
<td>(52-77)</td>
<td>(53-79)</td>
<td>(55-81)</td>
<td>(57-83)</td>
</tr>
<tr>
<td><strong>Females</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RVEF (%)</td>
<td>(49-73)</td>
<td>(51-75)</td>
<td>(53-77)</td>
<td>(55-79)</td>
<td>(57-81)</td>
<td>(59-83)</td>
</tr>
</tbody>
</table>

95% CI = 95% confidence interval; RV = right ventricular; RVEF = right ventricular ejection fraction; CMR = cardiac magnetic resonance