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

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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 300 000 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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Chronic Chagas cardiomyopathy is the most common and serious presentation form.[6] Heart failure symptoms usually appear at late stages, usually with predominant systemic congestion and less pronounced signs of pulmonary congestion.[7,8] This right-sided heart failure predominance was first recognized in early clinical reports and seminal studies using radionuclide angiography, showing an early and prominent right ventricular (RV) function impairment in patients with Chagas disease.[9–11] In addition, RV dysfunction may be an independent predictor of survival in chronic Chagas cardiomyopathy.[12]

However, other studies using echocardiography failed to detect isolated RV dysfunction in the absence of significant involvement of the left ventricle (LV) and pulmonary hypertension, suggesting that RV systolic dysfunction is more dependent on increased afterload than a consequence of a primary impairment of the RV in Chagas disease.[13–15]

Cardiac magnetic resonance (CMR) is considered a reference method for anatomic and functional evaluation because it offers high spatial resolution and does not depend on geometric assumptions to determine LV and RV volumes and ejection

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fraction.[16] 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.[17–21]

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 the RV function. CMR, standard 12-lead ECG, and chest x-ray were performed in all participants. The participants were divided into 2 groups: (1) indeterminate/isolated digestive form group, including patients with the indeterminate form (asymptomatic individuals with normal ECG and normal radiological examination of the chest, esophagus, and colon) or patients with the isolated digestive form, defined by the presence of megaesophagus or megacolon, but with no cardiac symptoms, and normal ECG and normal chest x-ray and (2) cardiomyopathy group, including patients with cardiac symptoms, abnormal ECG patterns usually found in this entity or chest x-ray with evidence of cardiomegaly or pulmonary congestion. The study protocol was approved by the institutional research ethics committee (process number 4913/2010) and was conducted in accordance with the Helsinki Declaration. Written informed consent was obtained from all participants.

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.[22] 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[23] (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, χ^2 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 κ 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

Clinical and demographic characteristics of all 158 participants are described in Table 1. 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.

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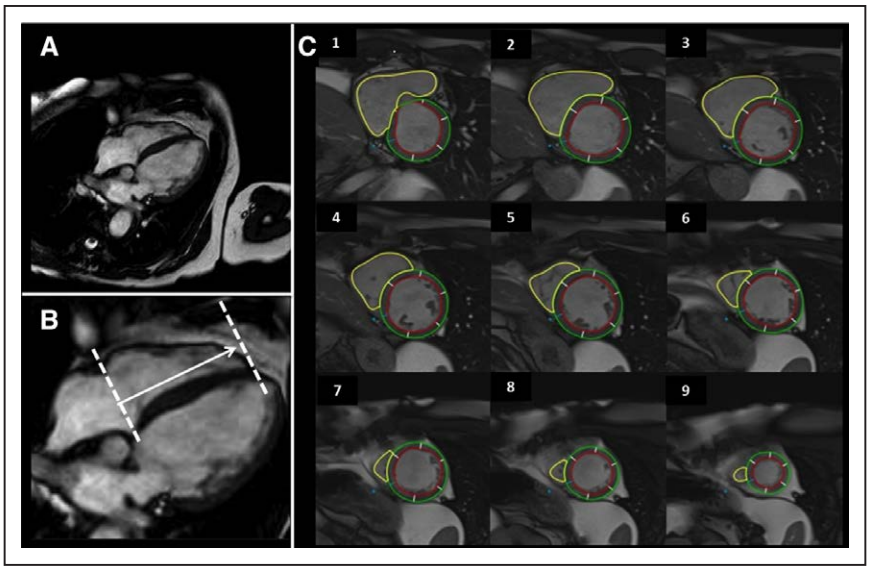

Figure 1. Right ventricular evaluation by cardiac resonance imaging using steady-state–free precession (SSFP) pulse sequences. Long-axis tomographic slices were used to define right ventricular basal and apical limits (**A** and **B**). Right ventricular endocardial borders were delineated in short-axis 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**).

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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 κ=0.95 and κ=0.75, respectively. Overall, intrareader 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.

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.[10,11,24] 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.[25,26] 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.[27,28] Also, in the indeterminate form of Chagas disease, invasive hemodynamic evaluation showed increased RV end-diastolic pressure in comparison with healthy subjects.[29]

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.[13,14] These apparently discordant results might be explained, at least in part, on account of inherent differences in the population samples and techniques used.[30] 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.[13] In another study using the novel speckle-tracking echocardiography, no

Table 1. Baseline Characteristics According to the Presence or Absence of RV Systolic Dysfunction

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

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.

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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	
Age, y	48 [42–62]	57 [44–67]	0.202
Males (%)	7 (50%)	74 (51%)	0.921
Body mass index, kg/m^2	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
Comorbidities			
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.

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.[31] 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

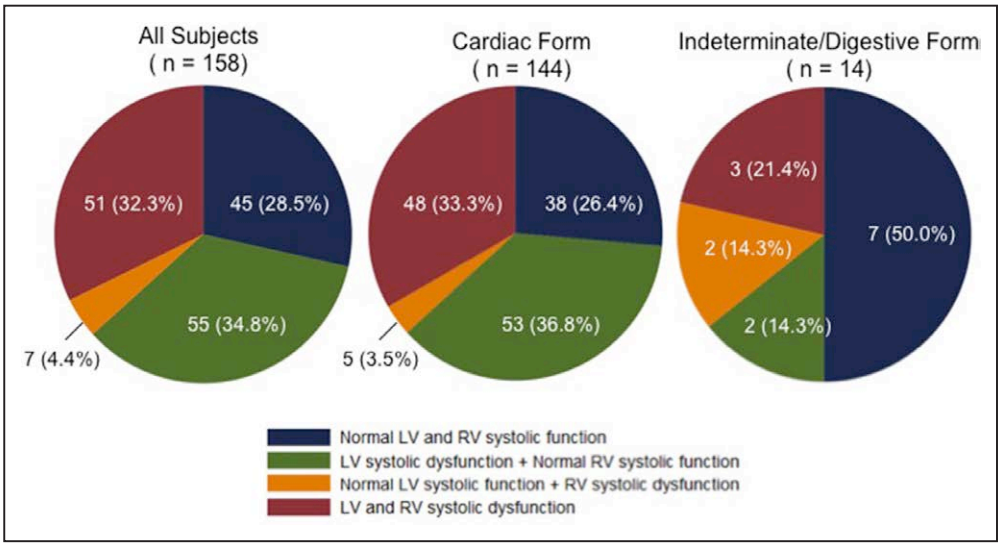

Figure 2. Left ventricular (LV) and right ventricular (RV) dysfunction combinations in Chagas disease assessed by cardiac magnetic resonance imaging.

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Table 3. Reproducibility of Volumetric Analysis and Fibrosis Identification

	Inter-Reader	Intrareader
Left ventricle		
End-diastolic volume*	0.98	0.99
End-systolic volume*	0.97	0.98
Ejection fraction*	0.86	0.97
Fibrosis†	0.95	1.00
Right ventricle		
End-diastolic volume*	0.93	0.94
End-systolic volume*	0.94	0.96
Ejection fraction*	0.76	0.82
Fibrosis†	0.75	0.80

*Intraclass correlation coefficient.
†Cohen κ coefficient.

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.[38] 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.[38]

Limitations

In our sample, few patients presented the noncardiac forms of Chagas disease. Those individuals are usually asymptomatic and rarely referred to our tertiary outpatient center. Although we have found RV systolic dysfunction in individuals with noncardiac forms, a comprehensive description of RV impairment in those conditions may need further investigation. This study also included subjects with hypertension, dyslipidemia, diabetes mellitus, and smoking. Those risk factors are commonly encountered in general population samples. However, no association between those cardiovascular risk factors and RV systolic function was found in our sample. Individuals with cardiac devices, not able to undergo CMR, were excluded. Thus, our results cannot be extrapolated to that clinical setting. RV outflow tract was not included in the RV volumetric analysis, to reproduce the methods used for the reference ranges, which acquired short-axis cines from the atrioventricular ring to the apex.[23] Because the most basal slice does not necessarily show the outflow tract in all exams, we decided not to include this RV region in our measurements.

Table 4. Multivariable Logistic Regression to Assess the Association of RV Systolic Dysfunction With Clinical Parameters

	Univariate Analysis	Multivariable Analysis*
	Odds Ratio (95% CI)	Odds Ratio (95% CI)
Age	1.02 (0.99–1.04)	1.00 (0.97–1.02)
Sex (Male as reference)	1.60 (0.83–3.07)	1.23 (0.57–2.67)
NYHA functional class		
I	(reference)	(reference)
II	2.51 (1.06–5.95)	1.32 (0.47–3.68)
III	2.15 (0.65–7.12)	1.06 (0.28–3.99)
Medications		
ACEI or ARB	3.06 (1.47–6.37)	1.24 (0.49–3.12)
β-blocker	3.08 (1.57–6.04)	1.26 (0.52–3.05)
Furosemide	3.44 (1.64–7.21)	1.74 (0.69–4.42)
Atrial fibrillation	14.15 (3.06–65.37)	10.00 (1.94–51.48)
LV systolic dysfunction	5.96 (2.46–14.46)	3.76 (1.36–10.43)

ACEI indicates angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker; CI, confidence interval; LV, left ventricular; and RV, right ventricular.
*Multivariable analysis included all the variables listed in the table in a full model.

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.

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CLINICAL PERSPECTIVE

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 in individuals with clinical manifestations of Chagas cardiomyopathy. Using a reference method to evaluate the RV, this study demonstrates that RV systolic dysfunction is a common finding in patients with Chagas disease and can rarely be found in absence of apparent left ventricular impairment assessed by magnetic resonance imaging. Furthermore, RV systolic dysfunction is present even in early stages of Chagas disease. These findings corroborate previous studies using other techniques to assess RV function, such as radionuclide angiography, and contribute to better understanding of why systemic congestion is usually predominant over pulmonary congestion in patients with heart failure due to Chagas cardiomyopathy, as previously depicted in seminal reports from experienced clinicians decades ago. RV impairment may bring difficulties in managing congestive heart failure and may be related to poor prognosis of this disease, as revealed by other investigations. Thus, in the clinical scenario of Chagas disease, particular attention should be devoted to the RV exploration. Moreover, in face of isolated RV systolic dysfunction, Chagas disease should be considered in the clinical differential diagnosis in an individual from an endemic region.

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SUPPLEMENTAL MATERIAL

Supplemental table 1. Cardiac magnetic resonance pulse sequence parameters

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

† 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

Age (years)	20-29	30-39	40-49	50-59	60-69	70-79
RVEF (%) 95% CI						
Males	(48-74)	(50-76)	(52-77)	(53-79)	(55-81)	(57-83)
Females	(49-73)	(51-75)	(53-77)	(55-79)	(57-81)	(59-83)

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