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# Evaluation of the Cardiac Morphologic Alterations Secondary to Autoimmune Thyroid Disorder Using Cardiac Magnetic Resonance Imaging

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**Purpose:** Thyroid functional disease is associated with clinically significant cardiovascular changes. The aim of this study was to assess changes in the cardiac magnetic resonance imaging of patients with autoimmune thyroid disorders (AITs).

**Materials and Methods:** Forty patients with AIT (12 men, 28 women; age range, 20 to 82 y; mean age, 59 y) were identified and included in our study. In addition, 20 controls (12 men, 8 women; age range, 21 to 76 y; mean age, 50 y) without AIT or cardiac disorders were included.

**Results:** In patients with AIT, the mean value calculated for the end diastolic volume was 161.2 mL, the mean end systolic volume value was 95.3 mL, and the mean left ventricular ejection fraction value was 45.2%. In comparing AIT patients with the control group, we found a significant difference in the end systolic volume, ejection fraction, stroke index, cardiac output, cardiac index, and left ventricular diameter ($P < 0.05$).

**Conclusions:** We conclude that our data show that there is a correlation between thyroid function and cardiac function, as evaluated with cardiac magnetic resonance imaging. This can be useful in the diagnosis of cardiovascular changes associated with AIT.

**Key Words:** cardiac magnetic resonance imaging, autoimmune thyroid disorders, magnetic resonance imaging

(*J Thorac Imaging* 2018;33:254–259)

A utoimmune thyroid disorders (AITs) are characterized by the destruction of thyroid cells and cellular and

antibody-mediated autoimmune responses.[1] Thyroid gland dysfunction affects the structure and function of various organ systems. The most obvious clinical manifestations of thyroid disease have been recognized to be the direct effects of thyroid hormones on the heart and cardiovascular system. Clinically significant cardiovascular changes are associated with thyroid functional diseases. For example, hormonal imbalances produce alterations in myocardial oxygen absorption, heart rate (HR), cardiac muscle contractility, cardiac output (CO), systemic blood pressure (BP), and systemic vascular resistance.[2,3] Further cardiovascular changes associated with a hyperthyroid state include atrial tachyarrhythmia, mitral valve dysfunction, and congestive heart failure.[4]

In particular, hypothyroidism induces a decrease in myocardial contractility. Pericardial effusion may also occur, depending on the severity of the disease. A minimal reduction in the ejection fraction (EF) and cardiac reserve are often seen in hypothyroid patients.[5] A prolonged duration of contraction and relaxation may also be seen in patients with hypothyroidism.

Changes in several cardiac parameters have also been shown in subclinical forms of hypothyroidism in clinical studies.[6] For example, an increased HR is associated with endogenous subclinical hypothyroidism,[7,8] and hemodynamic alterations may be associated with impairments in ventricular function.[9] Subtle increases in HR and CO might imply long-term consequences and increased cardiovascular disease and mortality. Selmer et al[10] have stated that heart failure is the leading cause of the increased cardiovascular mortality in patients with overt or subclinical hyperthyroidism.

Magnetic resonance imaging (MRI) has the potential to detect cardiac involvement in various cardiac infiltrative disorders. It has high accuracy and is independent of the observer.[11–14] Echocardiography, in contrast, is dependent on the observer, and there is a high intraobserver and interobserver variation.

MRI has good spatial resolution and is noninvasive. The lack of radiation and the opportunity for 3-dimensional imaging with highly reproducible measurements make MRI an ideal modality for imaging and diagnosing myocardial and pericardial diseases. MRI is useful for the diagnosis and quantification of ventricular volume and stroke volume (SV) in hypertrophic and dilated cardiomyopathy (DCM). It also aids in the diagnosis and differentiation of cardiac infiltrative disorders, such as amyloidosis, hemochromatosis, and sarcoidosis.[15]

In this study, cardiac magnetic resonance imaging (CMRI) was utilized to identify the etiology of cardiac dysfunction in subjects in whom diagnoses from

conventional tools were unclear. The aim of this study was to assess changes in the CMRI of patients with AIT.

## MATERIALS AND METHODS

### Patient Selection

We evaluated 60 subjects. We retrospectively searched CMRI examinations performed from January 2008 to 2016 for patients suffering from AIT. Forty patients with AIT (12 men, 28 women; age range, 20 to 82 y; mean age, 59 y) were identified and included in our study. The mean body mass index of the patients was 26, and the mean weight was 68 kg. At the time of the CMRI examinations, 5 chronic auto-immune thyroiditis (CAT) patients had been undergoing thyroxin substitution for no more than 2 months, and all other patients were unmedicated. In addition, we included a control group (CG) of 20 subjects (12 men, 8 women; age range, 21 to 76 y; mean age, 50 y) without AIT or cardiac disorders. The mean body mass index of the CGs was 25, and the mean weight was 64 kg. Patients with hereditary nonthyroidal cardiovascular diseases or clinically evident diabetes mellitus, renal diseases, pituitary/hypothalamic disorders, and/or pregnancy were excluded. In patients with DCM, the clinical history indicated no inherited causes. Subjects displayed no signs of drug, alcohol, or toxic substance addictions. Clinical examinations ruled out nutritional deficiencies. Negative human immunodeficiency virus and hepatitis C virus serologies eliminated potential viral causes. There was no history of fever, joint pain, chest pain and cough, loss of weight, or loss of appetite. In the CG, the subjects were healthy and without any identified cardiac disorders.

Patients were diagnosed with DCM on the basis of laboratory tests, electrocardiogram (ECG), chest radiograph, echocardiography, and CMRI examination. Atrial fibrillation was diagnosed on the basis of ECG. CMRI was performed because of inconclusive results from the echocardiography examination.

All patients had been diagnosed with CAT or Graves' disease (GD). The serum levels of thyroid antibodies were obtained from the medical records at the time of CMRI examination. The CAT diagnosis was based on the presence of high titers of antithyroid antibodies (anti-TPO and/or anti-Tg) and a diffuse hypoechogenicity or heterogeneity of the thyroid parenchyma in a thyroid ultrasound. The diagnosis of GD was based on the criteria of the American Thyroid Association; initial thyrotoxicosis is confirmed by the suppression of thyroid-stimulating hormone (TSH) and the presence of TSH receptor antibodies.[16]

### Echocardiography

An experienced physician performed the echocardiography with a Vivid 9 scanner in second harmonic mode (GE Vingmed, Horten, Norway) equipped with a 3.5-MHz transducer. An introductory standard echo test, including measurements of the dimensions, was performed first. Images were obtained in the standard chamber views. Volumes and left ventricular ejection fraction (LVEF) were calculated using the Simpson biplane method.

### CMRI

CMRI was performed on the 60 subjects with a 1.5 T scanner (Achieva, Philips Healthcare, Best, the Netherlands). A phased-array coil and ECG-triggered image acquisition with standard software were used for the study.

**TABLE 1.** The Clinical and Demographic Characteristics of the Patients With AIT

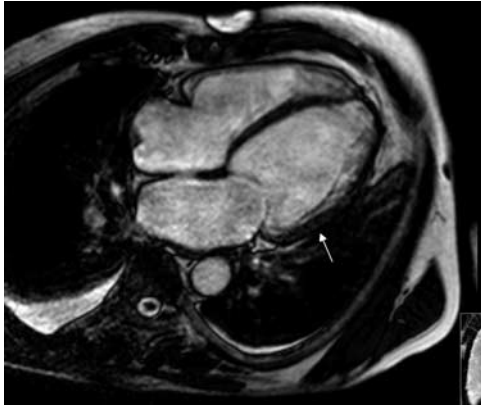| Group | Patients [n (%)] | Sex | Palpitation | TSH Mean (0.4-4.0 mIU/L) | fT3 Mean (230-619 pg/d) | Pericardial Effusion | Dilated CMP | Atrial Fibrillation | Myocarditis | ECG T-Wave Changes | Low-voltage ECG |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CAT | 35 (88) | 9 men and 26 women | 0 | 6 | 1 | 3 | 10 | — | 1 | — | 1 |
| GD | 5 (12) | 3 men and 2 women | 3 | 0.1 | 5 | 1 | — | 2 | 1 | 1 | — |

CMP indicates cardiomyopathy.

**FIGURE 1.** CMRI of a patient with AIT and DCM. Four-chamber view SSFP sequence demonstrating left ventricular dilatation (arrow).

The steady-state free precession (SSFP) sequences and T2-weighted breath-hold sequences were used in this study. Short-axis, vertical long-axis, 4-chamber, and 5-chamber views were acquired. SSFP sequences were performed to assess regional wall motion alterations. The following acquisition parameters were used for SSFP cine imaging: repetition time/echo time, 3.2/1.6 ms; flip angle, 530; temporal resolution, 35 to 39 ms; and in-plane resolution, 1.4 to 1.74 mm$^2$ contingent on the patient's dimensions. For all patients, a late gadolinium-enhanced MRI was conducted 10 minutes after the intravenous administration of 0.1 mmol/kg gadolinium-DTPA (gadopentetate meglumine, 0.1 mmol/kg; Schering, Berlin, Germany) using an inversion-recovery–prepared, T1-weighted, gradient-echo sequence. After the inversion pulse, 16 to 24 gradient echoes (repetition time/echo time/flip angle: 6.5 ms/2.0 ms/14 degrees) were collected per heartbeat during diastole, with an inversion delay that was iteratively adjusted to optimally null the signal from normal myocardium. The total acquisition time was 16 heartbeats per image slice. Selected 8 mm thick, long-axis slices were acquired, along with a series of contiguous short-axis slices. The images were acquired in the same orientations as the cine SSFP sequences.

## Data Analysis

The data were transferred to a commercially available postprocessing workstation (ViewForum; Philips Medical Systems, Best, the Netherlands). Image analyses were retrospectively performed by 2 experienced imaging radiologists. The physicians were unaware of the patients' clinical history and any results. The interobserver agreement was assessed with κ statistics, and the mean κ index (k) for CMRI measurements (0.77) was good.

The radiologists drew the endocardial and epicardial contours of the left ventricle at the end diastole and end systole. The pixels circumscribed by these contours were summed and multiplied by the slice thickness (through the voxel-summation method) to obtain global parameters, such as end diastolic volume (EDV), end systolic volume (ESV), and left ventricular mass. From the EDV and ESV, secondary parameters, such as the SV (EDV−ESV) and LVEF (LVEF = SV/EDV), were calculated for each patient.

On the basis of each CMRI, the following individual cardiac parameters were calculated: left ventricular diameter (LVD), ventricular septal thickness (VST), and left ventricular myocardial thickness. Normal LVEF was defined as a percentage value according to the studies conducted by Plana et al[17] and Kawel-Boehm et al.[18]

HR and BP were measured during the MRI procedure. Calculation of CO was performed on the basis of the measures of EDV, ESV, and HR.

## Ethics Statement

The local ethics committee granted ethical approval for this study. Informed consent was obtained from all participants. This study conformed to the Declaration of Helsinki.

## Statistical Analysis

All data were recorded in a Microsoft Excel file, and statistical analysis was conducted using SPSS software (version 23; IBM). For quantitative analyses, we performed analysis of variance tests to assess the differences between the groups. The limits of agreement between imaging methods were estimated as the mean difference (bias) +2 SD of the differences, as described by Bland and Altman.

The difference between MRI and standard echo measurements of LVEF, LVD, and VST was tested for significance using the 2-tailed test. *P*-values of <0.05 were considered significant.
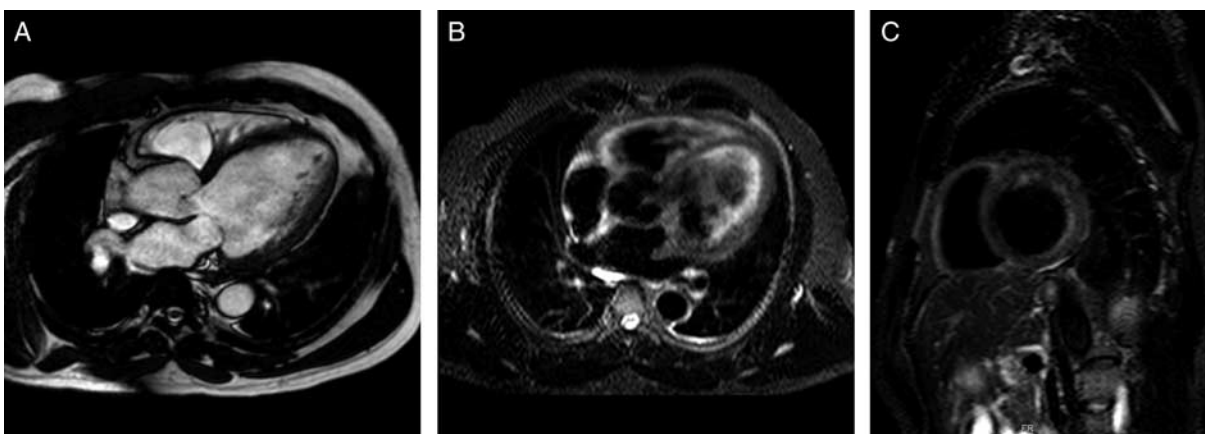


**FIGURE 2.** A, CMRI 5-chamber view, SSFP sequence in a patient with DCM. No signs of edema on the T2-weighted axial 5-chamber (B) and short-axis views (C).
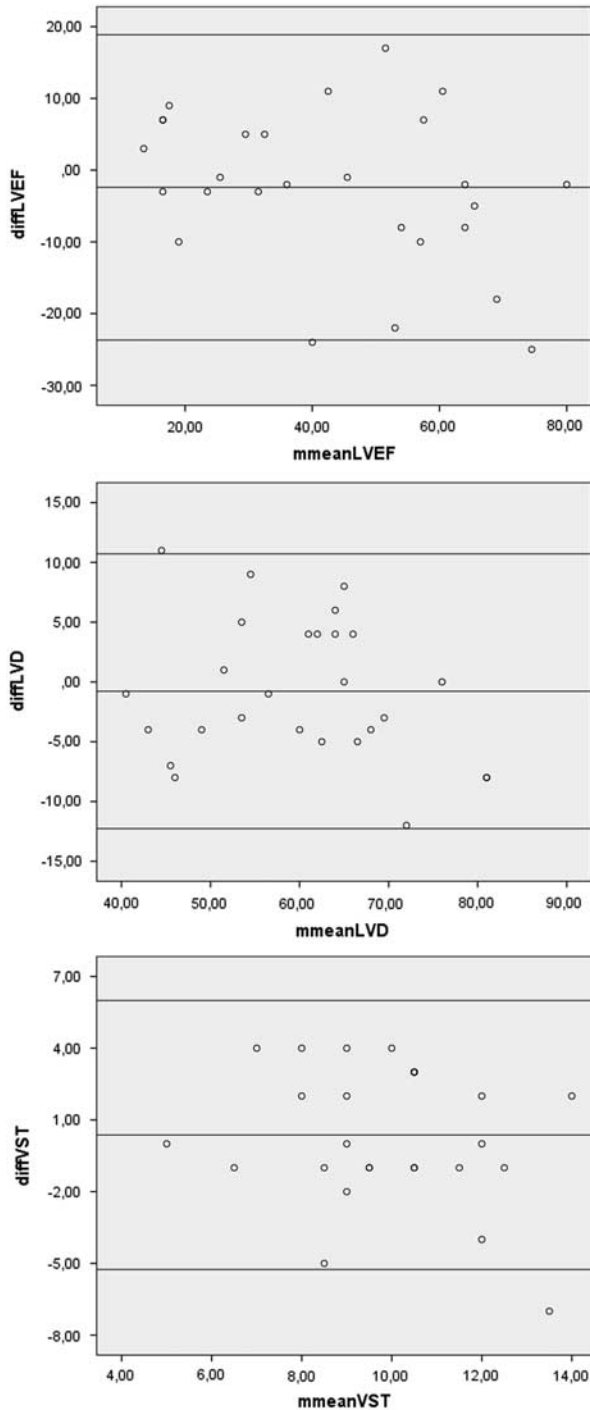
**FIGURE 3.** Bland-Altman plots were prepared to assess the agreement between echocardiography and CMRI measures of LVEF, VST, and LVD. Bland-Altman diagrams of EDV, ESV, and EF, demonstrating mean differences and limits of agreement between baseline echocardiography and MRI findings.

## RESULTS

Sixty subjects were identified: 40 subjects with AIT and 20 control subjects. Thirty-five of the 40 patients, 26 women and 9 men, were diagnosed with CAT. A small thyroid gland was present in > 50% of the patients with CAT.

Normal TSH values range from 0.4 to 4.0 mIU/L. The mean serum TSH of the CAT patients was 6 mIU/L (range, 1 to 17 mIU/L) at the time of CMRI examation. Eleven (28%) patients with AIT revealed nonuniform or relatively low thyroid activity in the background activity of the thyroid scans.

The 5 remaining patients, 2 women and 3 men, were diagnosed with GD. The mean serum TSH of the GD patients was 0.1 mIU/L (range, 0.01 to 0.3 mIU/L) at the time of CMRI examination. Cardiac palpitation was seen in 8% of the patients with AIT and 60% of the patients with GD.

Ten patients (25%) had a DCM (Table 1 and Figs. 1, 2). The mean serum TSH of the DCM patients was 7.4 mIU/L (range, 0.3 to 16.71 mIU/L) at the time of CMRI examination. There were no signs of drug, alcohol, or toxic substance addictions. Clinical examinations ruled out nutritional deficiencies. Negative human immunodeficiency virus and hepatitis C virus serologies eliminated potential viral causes. There was no history of fever, joint pain, chest pain and cough, loss of weight, or loss of appetite in the study's participants. A reduced EF was observed in the CMRI of the 10 DCM patients.

The mean value for the LVEF of patients with DCM was 40.1%. Three months after CMRI examinations, cardiac ultrasound showed significant improvement of the systolic LVEF, with a mean value of 47% in the DCM patients. The evaluation was conducted using echocardiography in both cases.

A significant negative correlation was found between fT3 and ESV ($R = 0.64$, $P < 0.002$) and EDV ($R = 0.63$, $P < 0.001$), and a significant positive correlation was found between fT3 and LVEF ($R = 0.59$, $P < 0.001$) in AIT patients with DCM.

The Pearson correlation analysis showed a significant positive correlation between TSH and ESV ($R = 0.58$, $P < 0.01$) and EDV ($R = 0.70$, $P < 0.01$) in AIT patients with DCM.

Cardiac tissue characterization was performed through CMRI to rule out other diseases. Late gadolinium-enhanced and T2-weighted sequences were normal in all patients.

Bland-Altman plots were prepared to assess the agreement between echocardiographic and CMRI measurements of LVEF, VST, and LVD (Fig. 3).

In patients with AIT, the mean value calculated for EDV was 161.2, the mean value of ESV was 95.3 mL, and the mean EF value was 45.2% (Table 2). In the CG, the mean value calculated for EDV was 111.2 mL, the mean value of ESV was 37.7 mL, and the mean value of EF was 68.5%.

In patients with GD, the mean value calculated for EDV was 200 mL, the mean value of ESV was 146.8 mL, and the mean EF value was 39.2% (Table 2). In the CAT group, the mean value calculated for EDV was 160.1 mL, the mean value of ESV was 94.7 mL, and the mean value of LVEF was 45.1% (Table 2).

When comparing CAT patients with the CG, we found a significant decrease in LVEF and cardiac index (CI) and an increase in EDV, ESV, and LVD ($P < 0.05$). The stroke index (SI), CO, and SV values did not differ significantly between the CAT and CG patients. No significant differences in the thicknesses of the interventricular septum or the left ventricular cardiac wall were observed between the groups. A significant difference was observed for ESV, SI, CI, and LVD ($P < 0.05$) between the GD patients and the CG.

**TABLE 2.** The Mean CMRI Results of the AIT Patients and the CG are Presented in the Table

| | Patient [n (%)] | Mean TSH (0.4-4.0) (mIU/L) | EDV ± SD (mL) | ESV ± SD (mL) | SV ± SD (mL) | CO ± SD (L/min) | CI ± SD (L/min/m²) | LVE ± SD (%) | LVD ± SD (cm) | VST ± SD (mm) | LVMT ± SD (mm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AIT | 40 (67) | 4.08 | 161.2 ± 88 | 95.3 ± 83 | 62.1 ± 20 | 4.1 ± 1 | 2.1 ± 1 | 45.2 ± 22 | 5.9 ± 1 | 11 ± 0.8 | 6.7 ± 2 | |
| CAT | 35 (88) | 6 | 160.1 ± 87 (95% CI, P = 0.02) | 94.0 ± 76 (95% CI, P = 0.004) | 63.1 ± 21.2 (95% CI, P = 0.04) | 4.2 ± 2 | 2.2 ± 1 (95% CI, P = 0.001) | 45.1 ± 22 (95% CI, P = 0.001) | 6 ± 1 (95% CI, P = 0.001) | 11 ± 0.9 | 6.6 ± 2 | CAT vs. CG |
| GD | 5 (12) | 0.1 | 200 ± 121 | 146.8 ± 132 (95% CI, P = 0.02) | 53.6 ± 15.2 | 3.7 ± 1 | 1.7 ± 1 (95% CI, P = 0.03) | 39.2 ± 28 | 6 ± 2 (95% CI, P = 0.001) | 10 ± 0.2 | 6.8 ± 2 | GD vs. CG |
| CG | 20 (33) | 2.4 | 111.2 ± 36 | 37.7 ± 21 | 73.8 ± 22 | 5.1 ± 2 | 2.7 ± 1 | 68.5 ± 12 | 4.8 ± 1 | 9.7 ± 0.2 | 6.6 ± 2 | |

CI indicates confidence interval; LVMT, left ventricular myocardial thickness.

A significant positive correlation was found between TSH and ESV ($R = 0.80$, $P < 0.001$) and EDV ($R = 0.61$, $P < 0.001$), and a negative correlation was found between TSH and LVEF ($R = 0.70$, $P < 0.001$) in CAT patients. A significant negative correlation was found between fT3 and ESV ($R = 0.60$, $P < 0.001$) and EDV ($R = 0.51$, $P < 0.001$), and a positive correlation was observed between fT3 and LVEF ($R = 0.60$, $P < 0.001$) in CAT patients.

## DISCUSSION

Hyperthyroidism and hypothyroidism may lead to severe cardiac dysfunction if either condition persists for a prolonged period or is not detected in the early stages. Previous studies have shown that AIT, even in subclinical form, can lead to cardiac dysfunction.[19]

Zoncu et al[20] reported deterioration in the systolic and diastolic cardiac function of patients with AIT, even those patients found in an euthyroid state. Boccalandro et al[21] found that cardiomyopathy in hyperthyroidism might be common in middle-aged patients and could occur even in the absence of underlying heart disease. Both hyperthyroidism and hypothyroidism produce changes in cardiac contractility, myocardial oxygen consumption, CO, BP, and systemic vascular resistance.[22]

A review of multiple cross-sectional studies indicates that 30% of patients with congestive heart failure have low T3 levels.[23] The decrease in serum T3 is proportional to the severity of the heart disease, as assessed by the New York Heart Association functional classification.[4]

In contrast to the study by Bengel et al,[24] in which only CI and CO obtained by CMRI were significantly altered in hyperthyroidism, our study showed no significant changes in CO but a significant change in CI. However, in our study, ESV, SI, and LVD differed significantly in GD patients in comparison with the CG. In CAT patients, we found a significant increase in EDV, ESV, and LVD and a decrease in LVEF and CI ($P < 0.05$), in contrast to the CG. In this context, the study by Bengel et al[25] showed a significant increase in ESV and a decrease in EDV, SV, LVEF, and CO.

The cardiac dysfunction induced by long-standing hypothyroidism or hyperthyroidism may be partly reversible after the achievement of euthyroidism. Any diminution observed in cardiac dysfunction can be regarded as favorable and clinically important. The regression of left ventricular hypertrophy and its association with a lower risk of cardiovascular events has been reported in previous studies.

DCM is usually a progressive, idiopathic, and irreversible disease with a poor prognosis. However, in some cases, DCM can be secondary to various conditions, such as hypothyroidism.[26,27]

In general, CMRI is considered the most valid method to obtain functional and structural cardiac information in vivo because of its high reproducibility and accuracy.[28] In comparison with echocardiography, CMRI has major advantages. CMRI is independent of the observer during the acquisition of cardiac images. By contrast, echocardiography images depend on the experience of the practitioner. In comparison with studies based on echocardiography, studies that utilize CMRI benefit from a higher statistical power and require smaller sample sizes to detect significant differences.[11,29,30]

We investigated cardiac function in patients with untreated and treated thyroid functional disorders. Our

results showed statistically significant differences in systolic and diastolic function in patients with thyroid dysfunction in comparison with the CG.

In some studies, differences have not been found in patients in comparison with previous echocardiographic results. In these cases, this could be explained by the short duration of the dysfunctional state; it is possible that the thyroid functional disorder did not persist long enough in those patients for the development of notable cardiac functional changes.

When we analyzed systolic function, we also found significantly lower mean LVEF values in the AIT patient group in comparison with the CG. The information gained from CMRI in our study confirms the importance of early diagnosis in the prevention of the cardiac impairment that is associated with thyroid functional disorders.

To our knowledge, there are few studies using CMRI to investigate the effects of thyroid functional disorders on the heart. In our study, CMRI was performed in addition to clinical, laboratory, and echocardiographic examinations in order to make the right diagnosis and rule out diseases that affect the cardiac tissue. The patients in our study did not suffer from any other chronic diseases. The extrapolation of our results to younger patients or patients with comorbidity should be carried out with caution. The diastolic as well as systolic function after adequate long-term therapy and the beneficial effect of substitutional medication on cardiac function were also not addressed in this study.

Nonetheless, CMRI represents a noninvasive modality that could play an important role in detecting cardiac dysfunction. In addition, our results confirm the importance of early diagnosis to prevent the cardiac impairment associated with thyroid functional disorders.

In conclusion, CMRI allows clinicians to obtain a complete morphofunctional cartography of patients with AIT. It is a noninvasive tool for imaging and diagnosing myocardial and pericardial diseases. We conclude that our data show that there is a correlation between thyroid function and cardiac function, as evaluated with CMRI. This can be useful in the diagnosis of the cardiovascular changes associated with AIT.

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