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ORIGINAL ARTICLE

Prospective Echocardiographic Evaluation of the Right Ventricle and Pulmonary Arterial Pressure in Hyperthyroid Patients

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Background Pulmonary arterial hypertension (PAH) occurs in 35% to 65% of hyperthyroid patients. Despite this high frequency, only a few authors have examined the effects of hyperthyroidism treatment on PAH and the right ventricle. We evaluated the effects of hyperthyroidism and its reversal on cardiovascular structure and function using Doppler echocardiography.

Methods We prospectively evaluated 32 patients (42.5 ± 11.9 years old) with thyrotoxicosis. Exclusion criteria included previous cardiovascular disease. An echocardiogram was performed at the time of hyperthyroidism diagnosis and after normalisation of free thyroxine (T4) levels. Patients were divided into two groups according to the presence or absence of PAH at the diagnosis, or at two moments, before and after T4 normalisation.

Results Graves' disease was the most frequent aetiology (75%) of hyperthyroidism. Pulmonary arterial hypertension was observed in 43.8% of patients. Free T4 concentration was higher in PAH than non-PAH patients. Free T4 normalised after 5 (2.0-10.5; median and percentiles) months of treatment. Cardiac chamber sizes and cardiac output were higher in PAH. Right ventricular (RV) systolic function was impaired in PAH. Cardiac output and free T4 ($r = 0.42$; $p < 0.05$) correlated with pulmonary artery systolic pressure (PASP). Cardiac chamber size, cardiac output, left ventricular ejection fraction, and PASP (34.0 ± 8.6 to 21.7 ± 4.5 mmHg) reduced after treatment. Right ventricular myocardial performance index and fractional area change improved after T4 normalisation.

Conclusions Pulmonary arterial hypertension is highly prevalent in hyperthyroid patients and is combined with increased cardiac chambers size and cardiac output, and impaired RV function. Cardiovascular changes are reversible after T4 normalisation in patients without cardiovascular disease.

Keywords Hyperthyroidism • Pulmonary hypertension • Right ventricle • Cardiac remodelling • Echocardiography • Graves

Introduction

Hyperthyroidism is associated with several cardiovascular disturbances. Graves [1] in his seminal work, described dyspnoea, palpitations, and heart sounds that could be heard three feet away from the patient. The most commonly reported clinical cardiovascular changes in thyrotoxicosis are sinus tachycardia, atrial arrhythmias, increased cardiac output, and widened pulse pressure [2,3]. Although uncommon, high output heart failure has also been described and

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associated with an increased mortality risk [4]. The main cardiovascular effects of thyroid hormones include reduced peripheral vascular resistance and afterload and increased heart rate, myocardial contractility, blood volume, and cardiac output [5]. Therefore, echocardiographic and haemodynamic evaluation of hyperthyroid patients usually show increased left ventricle (LV) systolic volume index and ejection fraction and reduced peripheral vascular resistance. These alterations may be reversed by thyroid hormone levels normalisation [6,7].

More recently, pulmonary arterial hypertension (PAH) has also been described in hyperthyroid patients, with a frequency ranging from 35% to 65% [2,8–11]. The presence of PAH has been linked to right ventricular dysfunction in thyrotoxicosis [12]. Despite the high frequency of PAH, only a few authors have examined the effects of hyperthyroidism treatment on PAH and right ventricular structure and function using Doppler echocardiography [2,8–10,12,13]. Therefore, this study aimed to evaluate the effects of hyperthyroidism and its reversal on cardiovascular structure and function by transthoracic Doppler echocardiography at diagnosis and after thyroid hormone normalisation. In order to better characterise hyperthyroidism-induced changes in pulmonary systolic arterial pressure and the right ventricle, we have only evaluated patients with no history of previous cardiovascular disease.

Materials and Methods

Study Population

In a longitudinal observational case series study, we prospectively evaluated 32 consecutive patients with thyrotoxicosis attending the Endocrinology Division of the Internal Medicine Department of Amazonas Federal University, AM, Brazil, between February 2010 and February 2014. The study was approved by the Ethics Committee of Amazonas Federal University and all participants provided informed consent.

Thyrotoxicosis was defined by a decreased thyrotropin (TSH) level – less than 0.5 mIU/L – with normal or elevated free thyroxine (T4) concentration (normal range: 10.30–21.88 pmol/L). Hyperthyroid patients with toxic diffuse goiter (Graves' disease), autonomous nodular goiter, or toxic multinodular goiter were included in the study. Diagnosis of Graves' disease was based on the presence of ophthalmopathy or a diffuse increase in iodine uptake on thyroid isotope scanning. Autonomous nodular goiter was characterised by nodular iodine uptake and iodine uptake suppression in the rest of the thyroid gland using thyroid isotope scanning. Diagnosis of toxic multinodular goiter was based on multiple nodular iodine uptake in thyroid isotope scanning.

Exclusion criteria were: the absence of tricuspid valve regurgitation flow; previous diagnosis of heart valve disease, coronary heart disease, uncontrolled systemic arterial hypertension and diabetes mellitus, Chagas disease, hypertrophic or dilated cardiomyopathy, and heart failure; concomitant diseases causing pulmonary hypertension, such as pulmonary thromboembolism, chronic lung disease, connective tissue diseases, and use of anorexigenic drugs; secondary hyperthyroidism; inadequate echocardiographic images or cardiac arrhythmias which can interfere with echocardiographic parameters (atrial fibrillation, atrial flutter, or frequent extrasystoles); use of antithyroid drugs for longer than one week; and previous participation in research studies over the last 3 months. Patients who were pregnant, current smokers or using drugs that can modulate thyroid function such as beta blockers, amiodarone, lithium, high doses of corticosteroids, or immunosuppressors were also excluded.

All patients were evaluated through clinical history and physical examination. Transthoracic echocardiogram was performed at the time of hyperthyroidism diagnosis and after normalisation of free T4 levels. Patients were divided into two groups according to the presence or absence of PAH at the time of diagnosis and at two evaluation moments, before and after T4 normalisation. Eighteen (18) (56.3%) patients were treated with methimazole with doses ranging from 10 to 40 mg/day. The remaining patients were treated with radioactive iodine. Most patients were prescribed beta blockers after echocardiographic evaluation, which were discontinued as soon as patients became asymptomatic and/or after reaching normal free T4 levels. Five (5) patients were lost to follow-up. Accordingly, the final evaluation comprised 27 patients; one patient did not achieve free T4 levels normalisation using methimazole and radioactive iodine and was excluded from the temporal analyses.

Echocardiographic Evaluation

Echocardiographic evaluation was performed at The Francisca Mendes Heart Foundation, Manaus, Brazil, using a Vivid 3 ultrasound machine (GE Medical System, Milwaukee, WI, USA) with a 2.5–3.0 MHz transducer, as previously described [14–17] and following both American Society of Echocardiography and European Association of Cardiovascular Imaging recommendations [18]. All studies were performed and analysed by a single experienced cardiologist (MLG). All patients had sinus rhythm before and after treatment. Short parasternal axis and apical two, four, and five chambers views were used for analyses. The average of three measurements was calculated for each variable.

Left ventricular (LV) systolic (LVSD) and diastolic (LVDD) diameters were measured using two-dimensional guided M-mode images. Left ventricular systolic function was evaluated by ejection fraction calculated according to the Teicholz formula [18] and tissue Doppler imaging (TDI) of mitral annulus systolic velocity (S', arithmetic average of lateral and septal walls). In apical four-chamber view, we measured early transmitral peak (E) and late atrial diastolic (A) velocities with the sample volume placed at the tips of the mitral leaflets, and TDI early diastolic mitral annular velocity (E') with the sample volume placed at the lateral mitral annulus. Cardiac output (CO) was obtained in apical five-chamber view from pulsed wave Doppler measurements of the LV outflow tract (LVOT) velocity by the following equation:

CO = LVOT area x LVOT velocity time integral x heart rate. Pulmonary capillary wedge pressure (PCWP) was calculated as follows: PCWP = 1.9 + (1.24xE/E').

Right ventricle (RV) size was assessed in apical four-chamber view using basal diameter and in parasternal longitudinal view. Right ventricle end-systolic and end-diastolic area were measured by planimetry in four-chamber view. Right atrium (RA) volume was evaluated by the modified Simpson method, and RA end-systolic area by planimmetry [19]. Right ventricular systolic function was analysed by fractional area change (FAC), myocardial performance index, tricuspid annular plane systolic excursion (TAPSE), and peak systolic velocity (S'). TAPSE was defined as the difference in displacement of the RV base between diastole and systole and measured in M-mode with the cursor oriented to the junction of the tricuspid valve plane with the RV free wall using apical four-chamber view images. S' was assessed by TDI and measured in the free wall side of the tricuspid annulus. Tricuspid flow velocities were obtained in apical four-chamber view with the sample volume positioned adjacent to the tip of tricuspid leaflets in diastole. Right ventricular diastolic function was evaluated by early filling (E) and atrial filling (A) peak velocities, E/A ratio and tricuspid E', measured by TDI at the free wall side of tricuspid annulus in apical four-chamber view.

Pulmonary vascular resistance (PVR) was estimated by Doppler echocardiography according to the formula: PVR = (tricuspid regurgitation peak velocity/right ventricular outflow tract VTI) X 10 + 0.16. Pulmonary artery systolic pressure (PASP) was estimated by Doppler echocardiography using a modified Bernoulli equation: PASP = 4 X (tricuspid regurgitation peak velocity)^2 + right atrial pressure. Right atrial pressure was estimated from inferior vena cava diameter [20]. Pulmonary hypertension was defined as a PASP of at least 36 mmHg [20].

Statistical Analysis

Data are expressed as mean ± standard deviation or median and 25 and 75 percentiles. Normality was evaluated by the Shapiro–Wilk test. Comparisons between groups with and without PAH were performed with unpaired Student's t test or Mann-Whitney test. Comparisons of data before and after treatment were performed with the paired Student's t test or Wilcoxon test. Association between variables was assessed with Pearson's correlation coefficient. Categorical variables were analysed by the Fisher exact test. The level of significance was 5%. Analyses were performed using IBM SPSS Statistics software Version 22 (Armonk, NY, USA).

Results

All subjects had symptoms or signs of thyrotoxicosis. All but one patient had elevated free T4 levels. Clinical and laboratorial data are shown in Table 1. Most patients had Graves' disease. Free T4 levels were higher in Graves' than non-Graves' patients (free T4: Graves' patients 58.9 ± 31.5; non-Graves' patients 32.6 ± 20.0 pmol/L; $p < 0.05$). One patient had diabetes mellitus controlled with metformin and two had systemic arterial hypertension controlled with low doses of angiotensin-converting-enzyme inhibitors.

Pulmonary arterial hypertension was observed in 43.8% of our sample. Patients with PAH had higher free T4 levels than those without PAH. Heart failure functional class, according to New York Heart Association classification, did not differ between groups. No individual had class III or IV functional heart failure. Pulmonary arterial hypertension was observed in 3 (37.5%) non-Graves' patients and in 11 (45.8%) Graves' patients ($p = 0.68$, Fisher exact test). Free T4 (before treatment 45.8 [24.3–69.5]; after T4 normalisation 13.9 [11.5–18.5] pmol/L; $p < 0.001$) and TSH (before treatment 0.02 [0.01–0.07]; after

Table 1 Clinical and laboratory data according to the presence or absence of pulmonary arterial hypertension (PAH) at the time of diagnosis.

	No PAH (n = 18)	PAH (n = 14)	P-value
Age (years)	41.2 ± 12.0	44.1 ± 12.0	NS
Gender (M/F)	1/17	2/12	NS
Body weight (Kg)	55.5 (51.8–59.8)	57.5 (50.0–63.0)	NS
BMI (Kg/m^2)	21.9 (20.9–23.2)	22.2 (20.3–24.5)	NS
Heart rate (bpm)	87 (77–101)	96 (80–113)	NS
Free T4 (pmol/L)	31.4 (22.4–65.0)	64.9 (42.7–84.6)	<0.05
TSH (mIU/L)	0.015 (0.010–0.103)	0.020 (0.009–0.054)	NS
Graves' disease etiology	13 (72%)	11 (79%)	NS
HF FC I	11 (61.1%)	4 (28.6%)	NS
HF FC II	7 (38.9%)	10 (71.4%)	NS

Data are expressed as mean ± SD or median and percentiles.

Abbreviations: M, male; F, female; BMI, body mass index; bpm, beats per minute; T4, thyroxine; TSH, thyrotropin; HF FC, heart failure functional class according to the New York Heart Association. Student's t test or Mann-Whitney test; NS, not statistically significant.

T4 normalisation 1.32 [0.33–3.13] mIU/L; $p < 0.001$) normalised after 5 (2.0–10.5) months of treatment. Heart rate decreased after T4 normalisation (before treatment 90 ± 15; after T4 normalisation 72 ± 9 beats/minute; $p < 0.001$).

Echocardiographic baseline data are shown in Table 2. Left ventricular diastolic diameter, LA diameter, cardiac output, and cardiac index were higher in the PAH than no PAH group. No differences were observed in LV systolic function between groups. Pulmonary arterial hypertension patients had larger right chambers. Global RV function, assessed by myocardial performance index, and systolic function were impaired in PAH patients. A total of 12 patients (37.5%) had impaired RV myocardial performance index, presenting values higher than 0.55. Right ventricular fractional area change and pulmonary vascular resistance did not differ between groups. Before treatment, cardiac output ($r = 0.538$; $p < 0.01$) and free T4 concentration (Figure 1A) positively correlated with PASP levels. Free T4 concentration did not correlate with cardiac output ($r = 0.151$; $p = 0.218$).

Results comparing the periods before treatment and after T4 normalisation are shown in Table 3. Left ventricular diastolic diameter, LA diameter, cardiac output, cardiac index, LV ejection fraction, right atrium area and volume, RV diastolic and systolic areas, and RV diameter were lower after treatment. Right ventricular myocardial performance index and fractional area change improved after free T4 normalisation. Pulmonary arterial systolic pressure normalised in all patients after treatment. Figure 1B shows the reduction in PASP after T4 normalisation (mean PASP decreased from 34.0 ± 8.6 to 21.7 ± 4.5 mmHg; $p < 0.001$).

Discussion

In this study, we prospectively evaluated echocardiographic parameters in a series of hyperthyroid patients at two times, hyperthyroidism diagnosis, and after T4 normalisation.

Table 2 Echocardiographic data according to the presence or absence of pulmonary arterial hypertension (PAH) before treatment.

	No PAH (n = 18)	PAH (n = 14)	P-value
LVDD (mm)	46.0 (43.8–50.0)	52.5 (49.3–53.3)	<0.05
LVSD (mm)	28.0 ± 3.7	30.3 ± 2.9	NS
LA (mm)	34.2 ± 2.7	37.2 ± 3.7	<0.05
LV EF (%)	70 (68–73)	70 (66–74)	NS
CO (L/min)	5.75 ± 1.51	7.40 ± 2.62	<0.05
CI (L/min/m^2)	3.62 ± 0.90	4.67 ± 1.59	<0.05
Mitral S′ (cm/s)	13.5 ± 3.7	12.1 ± 3.1	NS
Mitral E/A ratio	1.23 ± 0.33	1.36 ± 0.38	NS
Mitral E′ (cm/s)	14.0 ± 5.0	14.0 ± 5.0	NS
Mitral E/E′ ratio	6.88 ± 2.40	8.01 ± 2.71	NS
PCWP (mmHg)	10.4 ± 3.0	11.8 ± 3.4	NS
RV parasternal view (mm)	22.2 ± 3.5	26.9 ± 3.6	<0.05
RV basal four-chamber view (mm)	27.2 ± 3.3	34.8 ± 6.5	<0.05
RV end-diastolic area (cm^2)	12.2 (9.8–14.3)	16.9 (14.8–25.3)	<0.01
RV end-systolic area (cm^2)	5.14 ± 1.06	9.31 ± 3.57	<0.05
RA area (cm^2)	12.5 (10.4–15.3)	16.3 (13.1–18.0)	<0.05
RA volume (mL)	26.2 ± 6.6	37.6 ± 10.6	<0.05
RV FAC (%)	57.3 ± 7.0	51.5 ± 10.2	NS
TAPSE (mm)	22.7 ± 2.6	25.6 ± 2.7	<0.05
Tricuspid S′ (cm/s)	15.0 ± 2.5	18.7 ± 3.4	<0.05
RV MPI	0.49 ± 0.13	0.60 ± 0.16	<0.05
Tricuspid E/A ratio	1.26 (1.03–1.51)	1.29 (1.20–1.65)	NS
Tricuspid E/E′ ratio	5.26 ± 1.77	5.11 ± 1.77	NS
PASP (mmHg)	25.9 ± 6.5	40.3 ± 3.9	<0.001
PVR (Wood)	1.47 ± 0.37	1.60 ± 0.31	NS

Data are expressed as mean ± SD or median and percentiles.

Abbreviations: LVDD and LVSD, left ventricle (LV) end-diastolic diameter and end-systolic diameter, respectively; LA, left atrial diameter; LV EF, LV ejection fraction; CO, cardiac output; CI, cardiac index; mitral S′, tissue Doppler imaging (TDI) of mitral annulus systolic velocity; mitral E/A, ratio between early (E)-to-late (A) diastolic mitral inflow; mitral E′, TDI of early mitral annulus diastolic velocity; PCWP, pulmonary capillary wedge pressure; RV, right ventricle; RA, right atrium; FAC (%), fractional area change; TAPSE, tricuspid annular plane systolic excursion; Tricuspid S′, peak systolic velocity; RV MPI, right ventricle myocardial performance index; PASP, pulmonary arterial systolic pressure; PVR, pulmonary vascular resistance; NS: not statistically significant.

Student's t test or Mann–Whitney test.

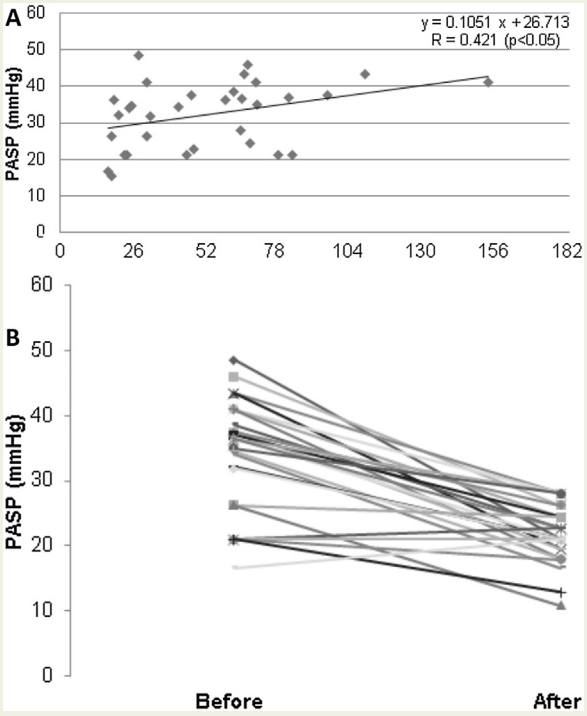

Figure 1 (A) Correlation between pre-treatment free thyroxine (T4) concentration and pulmonary artery systolic pressure (PASP). (B) Pulmonary artery systolic pressure (PASP) before and after free T4 normalisation in hyperthyroidism patients; n = 26; $p < 0.001$

Graves' disease was the most frequent aetiology of hyperthyroidism. Slight PAH was observed in 43.8% of individuals. In the literature, mild PAH has been found in a frequency ranging from zero in a small series [13] to 58.5% in larger series [2,8,10–12,21,22] of hyperthyroid patients.

To evaluate PAH characteristics, we assigned patients at the time of diagnosis into two groups according to the presence or absence of PAH. Our University is located in Brazilian Amazonas, a poor area of Brazil. It is therefore probable that our patients presented to the Endocrinology Division with longstanding disease, which may explain the high frequency of dyspnoea found in this study. Dyspnoea frequency did not differ between PAH and non-PAH groups.

Increased pulmonary arterial systolic pressure was combined with increased cardiac chambers size and cardiac output. Left ventricular functional indexes did not differ between groups. However, RV systolic functional indexes TAPSE and tricuspid S' were improved and myocardial performance index was impaired in PAH compared to the non-PAH group. The higher TAPSE and tricuspid S' in PAH patients could have been caused by a higher RV pre-load, which activates myocardial contractility through the Frank-Starling mechanism [23]. On the other hand, the impaired RV myocardial performance index in PAH patients suggests impaired global ventricular function. Impaired RV function has been previously observed in both hyperthyroid patients [12] and patients with subclinical hyperthyroidism [24].

The increased cardiac output and cardiac index in PAH patients indicate a hyperdynamic state suggesting that hyperflux may be involved in PAH pathogenesis. In fact, cardiac output and free T4 concentration positively correlated with SPAP. Correlation between T4 levels and SPAP has been previously reported [8].

The factors responsible for PAH in hyperthyroid patients are not completely understood [25,26]. Possible mechanisms include immune-mediated endothelial damage and dysfunction, increased cardiac output, and abnormal metabolism of substances that modulate pulmonary vasodilatation [3]. Although it has been suggested that pathogenic auto-antibodies targeting endothelial cells might injure the pulmonary endothelium and cause vascular dysfunction [22,27], the relationship between autoimmune thyroid disease and PAH remains controversial [11,12,26].

Increased cardiac output can elevate pulmonary artery systolic pressure. In hyperthyroid patients, cardiac output may be increased by increased heart rate and blood volume, improved myocardial contractility, and reduced systemic vascular resistance. Sympathetic nervous system activation and improved net tubular sodium reabsorption are involved in increased cardiac output [3]. Decreased systemic vascular resistance is mostly caused by excessive nitric oxide production [28]. Opposite to what occurs in systemic vascular resistance, pulmonary vascular resistance is not decreased in hyperthyroidism. Several authors have suggested local and systemic factors that may contribute to preserving or even increasing pulmonary vascular resistance in hyperthyroidism [29–31]. Finally, increased cardiac output may injure the pulmonary endothelium and increase pulmonary vascular resistance [3,22].

In this study, the fact that pulmonary vascular resistance did not differ between PAH and non-PAH groups suggests a lack of vasodilatory reserve caused by insufficient pulmonary circulation to adapt to the increased cardiac output, thus showing that the preserved resistance may actually play a role in PAH pathogenesis.

Due to the prospective design of this study, we were able to evaluate patients during hyperthyroidism and after T4 normalisation. After thyrotoxicosis treatment, patients had reductions in cardiac chambers size, cardiac output, LV ejection fraction, systolic pulmonary artery pressure, and pulmonary vascular resistance. Right ventricular function improved after treatment, as fractional area change and myocardial performance index were improved. Only a few studies have prospectively evaluated the effects of hyperthyroidism treatment on cardiac function and pulmonary arterial hypertension [2,8–10,12,13]. Our results are in agreement with literature, which shows a reduction in systolic pulmonary arterial pressure and RV hyperdynamic status after treatment. Therefore, when PAH is discovered in the setting of hyperthyroidism, further investigation may not be needed as it resolves on treating the underlying condition.

One strength of this study is its broad exclusion criteria, preventing inclusion of patients with cardiovascular diseases such as systemic arterial hypertension and diabetes mellitus, which are highly prevalent in the general population and may jeopardise LV function and change systolic pulmonary

Table 3 **Echocardiographic data of hyperthyroid patients before and after free T4 normalisation.**

	Before treatment (n = 26)	After free T4 normalisation (n = 26)	P-value
LVDD (mm)	49.3 ± 4.2	48.5 ± 3.6	<0.05
LVSD (mm)	30.0 (27.8–32.0)	30.0 (29.0–32.3)	NS
LA (mm)	35.7 ± 3.6	34.5 ± 2.9	<0.05
LV EF (%)	70.0 (66.0–73.3)	66.0 (63.5–71.0)	<0.05
CO (L/min)	6.48 ± 2.26	4.09 ± 0.85	<0.001
CI (L/min/m^2)	4.09 ± 1.40	2.54 ± 0.56	<0.001
Mitral S′ (cm/s)	12.4 ± 3.30	11.9 ± 3.00	NS
Mitral E/A ratio	1.29 ± 0.35	1.25 ± 0.33	NS
Mitral E′ (cm/s)	13.0 (11.0–17.0)	13.0 (9.00–17.0)	NS
Mitral E/E′ ratio	7.20 (5.61–9.71)	6.82 (5.08–9.91)	NS
PCWP (mmHg)	10.8 (8.90–13.9)	10.4 (7.30–14.2)	NS
RV parasternal view (mm)	24.5 ± 4.40	23.0 ± 4.00	<0.05
RV basal four-chamber view (mm)	31.0 (27.8–35.0)	29.0 (24.8–33.3)	<0.001
RV end-diastolic area (cm^2)	15.0 (11.7–17.6)	13.4 (10.4–17.0)	<0.05
RV end-systolic area (cm^2)	6.20 (5.10–10.1)	4.70 (3.50–7.00)	<0.01
RA area (cm^2)	13.5 (11.2–17.0)	12.0 (10.0–14.0)	<0.01
RA volume (mL)	32.7 ± 10.5	29.1 ± 8.10	<0.01
RV FAC (%)	53.8 ± 9.60	62.4 ± 8.70	<0.001
TAPSE (mm)	24.4 ± 2.90	22.3 ± 2.40	<0.01
Tricuspid S′ (cm/s)	15.0 (13.0–20.0)	14.0 (13.0–15.3)	<0.05
RV MPI	0.52 (0.45–0.65)	0.43 (0.40–0.50)	<0.01
Tricuspid E/A ratio	1.26 (1.11–1.46)	1.51 (1.07–1.71)	NS
Tricuspid E/E′ ratio	5.14 (3.77–6.20)	4.65 (3.73–5.83)	NS
PASP (mmHg)	34.0 ± 8.60	21.7 ± 4.50	<0.001
PVR (Wood)	1.58 ± 0.33	1.42 ± 0.33	<0.05

Data are expressed as mean ± SD or median and percentiles.
Abbreviations: LVDD and LVSD left ventricle (LV) end-diastolic diameter and end-systolic diameter, respectively; LA, left atrial diameter; LV EF, LV ejection fraction; CO, cardiac output; CI, cardiac index; mitral S′, tissue Doppler imaging (TDI) of mitral annulus systolic velocity; mitral E/A, ratio between early (E)-to-late (A) diastolic mitral inflow; mitral E′, TDI of early mitral annulus diastolic velocity; PCWP, pulmonary capillary wedge pressure; RV, right ventricle; RA, right atrium; FAC (%), fractional area change; TAPSE, tricuspid annular plane systolic excursion; Tricuspid S′, peak systolic velocity; RV MPI, right ventricle myocardial performance index; PASP, pulmonary arterial systolic pressure; PVR, pulmonary vascular resistance; NS: not statistically significant.
Paired Student's t test or Wilcoxon test.

artery pressure. Another strength is the fact that all echocardiograms were performed by the same examiner, thus reducing interobserver variability.

Study Limitations

One limitation of this study is the fact that we have not evaluated thyroid antibodies, which could have helped to elucidate the relationship between auto-immunity and PAH in hyperthyroidism. Another limitation is the fact that the echocardiographer was not blind to patient thyroid status.

Conclusion

In conclusion, pulmonary arterial hypertension is highly prevalent in hyperthyroid patients and is combined with increased cardiac chamber size and cardiac output, and impaired right ventricular function. Cardiovascular changes are reversible after thyroid hormone normalisation in patients without previous cardiovascular disease.

Conflict of Interests

All authors state that there is no conflict of interest.

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