Echocardiographic Assessment of Right Chambers by Gender and Body Surface Area

Análise Ecocardiográfica das Câmaras Direitas segundo Sexo e Superfície Corporal

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Abstract

Introduction: Assessment of right chambers dimensions and function according to gender, age, body surface area and body mass index is not uniformly performed.

Objective: To evaluate, by transthoracic echocardiography dimensions and function of right chambers, according to gender, body surface area and body mass index in an outpatient population.

Method: Cross-sectional study. Eighty-one patients were selected, 60.4 ± 13.5 years (57 women, 70%). Parameters assessed were the following: proximal, basal, medium and longitudinal, right ventricle diameter; right atrium area and right atrium volume; right ventricle wall thickness; tricuspid annular plane systolic excursion; and tricuspid annulus tissue Doppler and S' wave.

Results: Female sex presented lower diameters (Student's t-test) of proximal right ventricle diameter (20.6 mm ± 2.4 vs. 22.7 mm ± 2.2; p = 0.001), basal right ventricle diameter (34,4 mm ± 3,5 vs. 38,2 mm ± 4,8; p <0.001), medium right ventricle diameter (27 mm ± 3.3 vs. 32.4 mm ± 4.9; p <0.001), right atrium area (13.7 cm^2 ± 2.7 vs. 16.6 cm^2 ± 3.9; p = 0.002) and right atrium volume (37 mL ± 10.6 vs. 50.7 mL ± 15.6 ; p = 0.002). Body mass index and body surface area correlated with proximal right ventricle diameter (correlation coefficient - CC 0.24; p = 0.03), basal right ventricle diameter (CC 0.22; p = 0.04), medium right ventricle diameter (CC 0.23; p = 0.04), longitudinal right ventricle diameter (CC 0.28; p = 0.01), right atrium area (CC 0.40; p = 0.001), and right atrium volume (CC 0.24; p = 0.0006).

Conclusion: Right ventricular diameters, right atrial area and volume were lower in females. A correlation was found with body mass index and body surface area. Tricuspid annular plane systolic excursion and S' were not influenced by sex, body mass index and body surface area.

Keywords: Heart Ventricles; Organ Size; Echocardiography.

Resumo

Introdução: *A avaliação sistemática das dimensões e da função das câmaras direitas, de acordo com sexo, idade, superfície corporal e índice de massa corporal, não é uniformemente realizada.*

Objetivo: *Avaliar, ao ecocardiograma transtorácico, as dimensões e a função das câmaras direitas de acordo com o sexo, superfície corporal e índice de massa corporal em uma população ambulatorial.*

Métodos: *Estudo observacional, transversal. Foram selecionados 81 pacientes, 60,4 ± 13,5 anos, de ambos os sexos (57 mulheres, 70%). Foram avaliados: diâmetro proximal do ventrículo direito, basal do ventrículo direito, médio e longitudinal; área do átrio direito e volume do átrio direito; espessura da parede livre do ventrículo direito; excursão sistólica do anel valvar tricúspide; e Doppler tecidual do anel tricúspide, onda S'.*

Resultados: *O sexo feminino apresentou menores diâmetros em relação ao sexo masculino (teste t de Student) de diâmetro proximal do ventrículo direito (20,6 mm ± 2,4 vs. 22,7 mm ± 2,2; p = 0,001), basal do ventrículo direito (34,4 mm ± 3,5 vs. 38,2 mm ± 4,8; p < 0,001), diâmetro médio do ventrículo direito (27 mm ± 3,3 vs. 32,4 mm ± 4,9; p < 0,001), área do átrio direito (13,7 cm^2 ± 2,7 vs. 16,6 cm^2 ± 3,9; p = 0,002) e volume do átrio direito (37 mL ± 10,6 vs. 50,7 mL ± 15,6 ; p = 0,002). O índice de massa corporal e a superfície corporal se correlacionaram positivamente com o diâmetro proximal do ventrículo direito (coeficiente de correlação - CC 0,24; p = 0,03), diâmetro basal*

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do ventrículo direito (CC 0,22; p = 0,04), diâmetro médio do ventrículo direito (CC 0,23; p = 0,04), diâmetro longitudinal do ventrículo direito (CC 0,28; p = 0,01), área do átrio direito (CC 0,40; p = 0,001) e volume do átrio direito (CC 0,24; p = 0,0006).

Conclusão: *As médias dos diâmetros ventriculares, área e volume atriais direitos foram menores no sexo feminino. Foi encontrada correlação positiva destes parâmetros com o índice de massa corporal e a superfície corporal. Os valores da excursão sistólica do anel valvar tricúspide e S' não foram influenciados por sexo, índice de massa corporal e superfície corporal.*

Palavras-chave: Ventrículos do Coração; Tamanho do Órgão; Ecocardiografia.

Introduction

The right ventricle (RV) plays an important role in the morbidity and mortality of patients with cardiopulmonary diseases.[1–3] However, its systematic evaluation is not uniformly performed. This is partly due to the enormous attention given to left heart evaluation, the scarcity of studies providing normal reference values for right ventricular size and function, and because right ventricular echocardiographic examination has many limitations.[1] Much of the chamber is located behind the sternum, has an irregular shape, trabeculated walls and a variable location within the chest, depending on the patient's position. Besides, RV is known to be functionally different from LV, as its contraction is mainly determined by longitudinal shortening due to the structural organization of its myocardial fibers.[2] Despite these problems, echocardiography may provide useful information about RV, including the determination of its dimensions and function.[4]

Current RV reference values are based on large populations or grouped values from various studies; most are not indexed for body surface area (BSA) and only cite lower reference values for women. As a result, patients with near-normal values may be erroneously classified as being outside the reference average. The available data are insufficient to classify mild, moderate and severe abnormalities. When interpreting an examination, common sense should be used to determine the extent of abnormality for any given parameter.[5]

In light of the above, the purpose of this study was to evaluate, by transthoracic echocardiography, the dimensions and function of the right chambers according to gender, age, BSA and body mass index (BMI) in a varied outpatient population.

METHODS

Population studied

Cross-sectional observational study. The study included 81 patients, aged 60.4±13.5 (24 to 88 years old, with a median of 61 years), of both genders (57 women, 70%), older than 18, from the cardiology outpatient clinic of Hospital da Cruz Vermelha de Curitiba, of any ethnicity, referred by the attending physician for transthoracic echocardiography for any clinical indication. The choice of patients was not established by any statistical criteria, but by convenience, according to the individual's availability to participate in the study. For each patient, a protocol form including clinical and echocardiographic parameters was filled out. The following clinical data were collected: age, gender, weight, height, body surface (BSA), body mass index (BMI), presence of systemic arterial hypertension (SAH), diabetes mellitus (DM), coronary artery disease (CAD), smoking (current or past) and dyslipidemia. The diagnoses of SAH, DM, dyslipidemia and smoking were found in the patients' medical records and/or were reported by them (self-reported information). The presence of CAD was confirmed by medical and patient records, including: nonfatal myocardial infarction and surgical or percutaneous coronary artery bypass grafting. The medications regularly used by the patient were also noted.

Exclusion criteria were: a) patients with significant valve diseases (moderate and severe); b) patients with valve prostheses; c) patient with LV contraction segmental abnormalities due to ischemic heart disease or other cardiomyopathies; and d) patients with pulmonary emphysema or self-reported chronic obstructive pulmonary disease; e) patients with moderate to severe pulmonary arterial hypertension (pulmonary artery systolic pressure, PSAP >50 mmHg); f) patients with left ventricular contractile dysfunction (ejection fraction <52% for men and <54% for women); g) patients with infiltrative diseases and periocardiopathies; h) patients with congenital heart disease with pulmonary hyperflow with or without surgical correction; and i) patients with pacemaker.

The patients underwent a complete two-dimensional transthoracic echocardiography scan by one of either Phillips IE 33, Envisor or Vivid E General Electric echocardiography equipment. All acoustic windows with all standard echocardiographic measurements and analyzes were performed on each patient. Ultrasound scans were performed by two experienced echocardiographers with echocardiography qualification from the Department of Cardiovascular Imaging of the Brazilian Society of Cardiology (DIC-SBC).

All patients signed two copies of an informed consent form, one copy of which was retained by the study participant. The study was approved by the local Research Ethics Committee.

Main echocardiographic parameters analyzed in this study

Diameters: proximal RV diameter from the longitudinal parasternal window ((RVP; normal up to 28 mm), basal RV diameter from the 4-chamber apical window (RVB; normal up to 41 mm), médium RV diameter from the 4-chamber apical window (RVM; normal up to 35 mm) and longitudinal diameter (RVL; normal up to 83 mm) from the 4-chamber apical window. All linear RV measurements were performed at the final diastole (Figure 1).

Right atrial area (RAA; normal up to 8.5 cm^2) and right atrial volume index (RAV; normal up to 27 ml/m^2 in women and up to 32 ml/m^2 in men) measured from the 4-chamber apical window (Figure 1).

RV free wall thickness measured in diastole at the subcostal

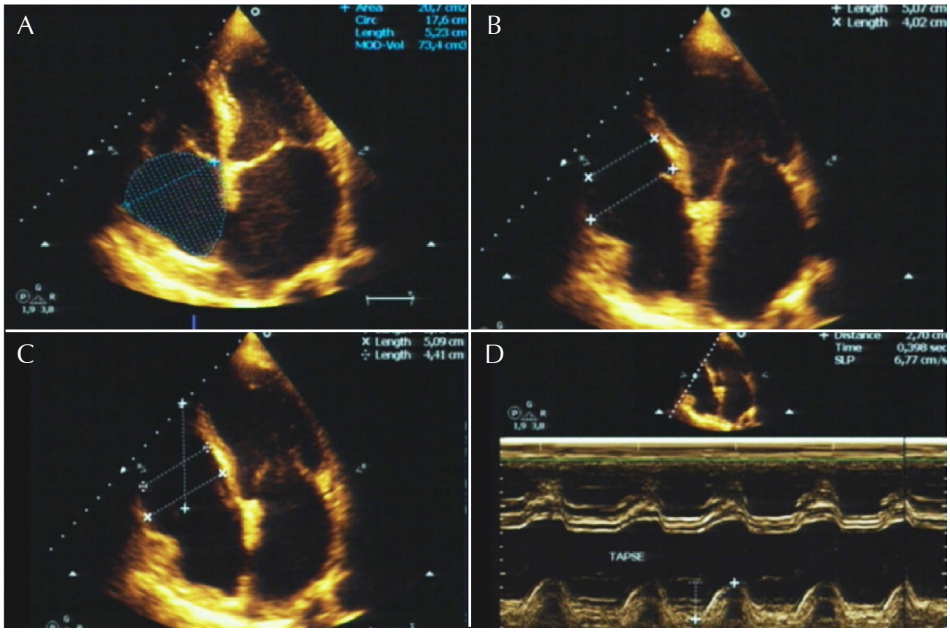

Figure 1 – *Echocardiogram showing on (A) Left top panel Four-chamber view of right atrial volume. (B) Right top panel: Two-dimensional measurements of basal and middle right ventricular diameters at end diastole. (C) Left bottom panel: Four-chamber view of two-dimensional measurements of basal, middle and longitudinal right ventricular diameters at end diastole. (D) Right bottom panel: Four-chamber apical view of unidimensional measure of tricuspid annular plane systolic excursion.*

section by M-mode or two-dimensional echo. Thickness >5 mm indicates RV hypertrophy (RVH).

Tricuspid annular plane systolic excursion (TAPSE) measured from the 4-chamber apical window (normal ≥17 mm). Evaluates RV systolic longitudinal function (Figure 1).

Tissue Doppler of the tricuspid annulus, S' wave measured from the 4-chamber apical section at the tricuspid annulus level (normal >9.5 cm/s) and on the RV free wall. Evaluates RV systolic longitudinal function.

All quantifications and values considered in this study were based on the guidelines of the American Society of Echocardiography and the European Association of Cardiovascular Imaging. [1,4–7]

Statistical analysis

The results obtained in the study were described by means, medians, minimum values, maximum values and standard deviations (quantitative variables) or by frequencies and percentages (categorical variables). To evaluate the association between two quantitative variables, Pearson's or Spearman's correlation coefficient was estimated. A comparison of two groups regarding quantitative variables was performed using Student's t-test for independent samples or Mann-Whitney's non-parametric test. More than two groups were compared considering the one-way analysis of variance (ANOVA) and the least significant difference (LSD) test for multiple comparisons or Kruskal-Wallis' non-parametric test. The normality condition of the variables was evaluated using the Kolmogorov–Smirnov test. In this study, p values <0.05 were considered statistically significant.

Data were analyzed using the IBM SPSS Statistics v.20.0 computer program. Armonk, NY: IBM Corp.

Results

Table 1 shows the clinical characteristics of the study population. There was a predominance of females (70%), 60% hypertensive, 35% diabetics, 29% dyslipidemics, 3% smokers, most of them overweight and obesity. Table 2 shows the baseline echocardiographic parameters of the study population. A positive correlation was found between age and proximal RV diameter (correlation coefficient [CC] 0.25; p = 0.02) and a negative correlation between RAA (CC -0.25; p=0.04) and RAV (CC -0.26; p = 0.03). The other variables did not correlate with age (Table 3). Females had smaller RVP diameters than males (20.6±2.4 mm versus 22.7±2.2 mm; p=0.001), RVB (34.4±3.5 mm versus 38.2±4.8 mm; p<0.001), RVM (27±3.3 mm versus 32.4±4.9 mm; p<0.001), RVA (13.7±2.7 cm^2 versus 16.6±3.9 cm^2; p=0.002) and RVV (37±10.6 ml versus 50.7±15.6 ml; p=0.002) (Table 4). BMI and BSA correlated positively and significantly with the RVP diameters (p=0.03), RVB (p=0.04), RVM (p=0.04), RVL (p=0.01), RAA (p=0.001) and RAV (p=0.0006), (Table 5). The parameters of right ventricular function (TAPSE and S') did not vary significantly with age and between genders (Tables 3 and 4). The presence of SAH, DM, dyslipidemia and smoking did not influence the variables analyzed (data not shown).

Discussion

In this study, the absolute values of the echocardiographic parameters of the right chambers presented mean within normality limits[4] for both genders, with smaller diameters, area and volume in females, and this difference decreased

Table 1 - Baseline characteristics of the study population.

Variable		n (%)
Age (years)	60.4 ± 13.5	81
Gender		
Male		24 (30)
Female		57 (70)
Systemic Arterial hypertension		
No		30 (37)
Yes		51 (63)
Diabetes mellitus		
No		53 (65)
Yes		28 (35)
Dyslipidemia		
No		57 (70)
Yes		24 (30)
Smoking		
No		77 (96)
Yes		4 (4)
Body mass index (kg/m²)	28.2 ± 5.5	81
Body surface area (m²)	1.84 ± 0.24	81

Table 2 - Basal echocadiographic parameters in the study population.

Variable	n	Mean ± standard deviation
TAPSE (mm)	79	24.4 ± 3.2
RVB (mm)	80	35.5 ± 4.3
RVM (mm)	80	28.6 ± 4.5
RVL (mm)	78	59.2 ± 6.7
RVP (mm)	79	21.2 ± 2.5
RAA (cm²)	66	14.6 ± 3.3
RAV (ml)	66	40.9 ± 13.6
S'B. cm/s	75	13 ± 0.03
S'L. cm/s	76	11 ± 0.03
RV thickness. cm	75	0.38 ± 0.07
AAD/SC. cm²/m²	66	8.0 ± 1.4
VAD/SC. mL/m²	66	22.3 ± 6.1

TAPSE = tricuspid annular plane systolic excursion; RVD = right ventricular (RV) proximal diameter; RVB = basal LV diameter; RVM = mean RV diameter; RVL = RV longitudinal diameter; RAA = right atrial area; RAV = right atrial volume; S'B = lateral tricuspid annular tissue Doppler; S'L = RV free wall tissue Doppler; BSA = body surface area.

Table 3 - Correlation between echocardiographic parameters and age (years).

Variables	n	Correlation coefficient	p
Age x TAPSE (mm)	78	-0.06	0.584
Age x RVB (mm)	79	-0.08	0.465
Age x RVM (mm)	79	-0.10	0.375
Age x RVL (mm)	77	0.02	0.872
Age x RVP (mm)	78	0.25	0.028
Age x RAA (cm²)	66	-0.25	0.043
Age x RAV (ml)	66	-0.26	0.038
Age x S'B (cm/s)	75	0.13	0.250
Age x S'L (cm/s)	76	-0.07	0.538
Age x RV Thickness (cm)	74	0.17	0.151
Age x RAA/BSA (cm²/m²)	66	-0.13	0.299
Age x RAV/BSA (ml/m²)	66	-0.22	0.077

Pearson's correlation coefficients (TAPSE, RVB, RVM, RVL, RV, RAV, RAA/BSA and RAV/BSA) and Spearman's correlation coefficient (RAA, S'B, S'L and TV Thickness). TAPSE = tricuspid annular plane systolic excursion; RVD = right ventricular (RV) proximal diameter; RVB = basal LV diameter; RVM = mean RV diameter; RVL = RV longitudinal diameter; RAA = right atrial area; RAV = right atrial volume; S'B = lateral tricuspid annular tissue Doppler; S'L = RV free wall tissue Doppler; BSA = body surface area.

when indexed by body surface. The current recommendations for quantifying the cardiac chambers define higher values for men and lower values for women.[4] These differences become smaller after indexation by body surface, a finding observed in this study for right atrial volume and area. However, most values cited in the literature regarding RV diameters are not indexed for gender and BSA.[8] This also occurs regarding LV measurements. Considering that there was a significant predominance of females (70%) in the population studied here, these data become relevant and should be taken into consideration in the evaluation of the right chambers, including for the right atrium as, for the left atrium, the reference values are the same for men and women.[4]

There was also a positive and significant correlation between BMI and BSA with the dimensions of the right chambers. This finding is corroborated by Lang R et al.[4] and Grunig et al.,[7] who determine a standard deviation of normality between the genders in all parameters of diameter, area and volume.

Regarding the assessment of right ventricular function, no significant differences were found between the genders or variation with age. These data are consistent with the study by Lindqvist P et al.[9] In this study, involving 255 healthy individuals, a RV diastolic function disorder was found, but not a systolic function disorder with increasing age. A plausible explanation for this finding is the fact that the population studied was relatively healthy, with no significant pulmonary arterial hypertension and no other cardiac pathologies that could alter the results. There is much discussion in the literature about the accurate assessment of RV function, since due to the anatomical particularities of this chamber, there is no single criterion, but several methods for its evaluation. Although RV function is noninvasively assessed by magnetic resonance imaging (considered the gold standard for RV volume), angiography or computed tomography, TTE is the most widely used technique due to its availability, safety, versatility, reproducibility and ability to capture real-time imaging with temporal and spatial resolution.[10–13] Echocardiographic indices of right ventricular function include:

Table 4 - Comparison of echocardiographic parameters between males and females.

Variable	n	Mean ± Standard deviation	p*
TAPSE, mm			
Female	56	24.7 ± 3.1	
Male	23	23.8 ± 3.6	0.268
RVB (mm)			
Female	57	34.4 ± 3.5	
Male	23	38.2 ± 4.8	< 0.001
RVM (mm)			
Female	57	27.0 ± 3.3	
Male	23	32.4 ± 4.9	< 0.001
RVL (mm)			
Female	55	58.9 ± 6.3	
Male	23	60.0 ± 7.6	0.514
RV (mm)			
Female	56	20.6 ± 2.4	
Male	23	22.7 ± 2.2	0.001
RAA (cm²)			
Female	47	13.7 ± 2.7	
Male	19	16.6 ± 3.9	0.002
RAV (ml)			
Female	47	37.0 ± 10.6	
Male	19	50.7 ± 15.6	0.002
S'B, cm/s			
Female	55	0.13 ± 0.03	
Male	20	0.12 ± 0.04	0.332
S'L, cm/s			
Female	56	0.11 ± 0.04	
Male	20	0.11 ± 0.03	0.739
RV thickness (cm)			
Female	55	0.38 ± 0.08	
Male	20	0.39 ± 0.06	0.250
RAA/BSA (cm²/m²)			
Female	47	7.87 ± 1.34	
Male	19	8.36 ± 1.49	0.199
RAV/BSA (ml/m²)			
Female	47	21.1 ± 5.2	
Male	19	25.4 ± 7.0	0.008

**Student's t test for independent samples or Mann-Whitney's non-parametric test, p<0.05. TAPSE = tricuspid annular plane systolic excursion; RVD = right ventricular (RV) proximal diameter; RVB = basal LV diameter; RVM = mean RV diameter; RVL = RV longitudinal diameter; RAA = right atrial area; RAV = right atrial volume; S'B = lateral tricuspid annulus tissue Doppler; S'L = RV free wall tissue Doppler; BSA = body surface area.*

Table 5 - Correlation between echocardiographic parameters and body mass index (BMI) and body surface area (BSA).

Variables	n	Correlation coefficient	p
BMI x TAPSE (mm)	78	0.16	0.173
BMI x RVB (mm)	79	0.22	0.046
BMI x RVM (mm)	79	0.23	0.043
BMI x RVL (mm)	77	0.28	0.015
BMI x RVP (mm)	78	0.24	0.032
BMI x RAA (cm²)	66	0.40	0.001
BMI x RAV (ml)	66	0.34	0.006
BMI x S'B (cm/s)	73	0.02	0.871
BMI x S'L (cm/s)	74	0.13	0.263
BMI x RV Thickness (cm)	74	0.04	0.759
BMI x RAA/BSA (cm²/m²)	66	0.03	0.806
BMI x RAV/BSA (ml/m²)	66	0.12	0.351
BMI x TAPSE (mm)	78	0.10	0.400
BSA x RVB (mm)	79	0.43	<0.001
BSA x RVM (mm)	79	0.47	<0.001
BSA x RVL (mm)	77	0.32	0.005
BSA x RV (mm)	78	0.40	<0.001
BSA x RAA (cm²)	66	0.60	<0.001
BSA x RAV (ml)	66	0.61	<0.001
BSA x S'B (cm/s)	73	-0.04	0.736
BSA x S'L (cm/s)	74	0.29	0.011
BSA x RV thickness (cm)	74	0.08	0.521
BSA x RAA/BSA (cm²/m²)	66	0.08	0.518
BSA x RAV/BSA (ml/m²)	66	0.27	0.031

TAPSE = tricuspid annular plane systolic excursion; RVP = right ventricular (RV) proximal diameter; RVB = RV basal diameter; RVM = mean RV diameter; RVL = RV longitudinal diameter; RAA = right atrial area; RAV = right atrial volume; S'B = lateral tricuspid annulus tissue Doppler; S'L = RV free wall tissue Doppler.

fractional area change (FAC), TAPSE, tricuspid annular tissue systolic velocity (tissue S'), tricuspid annulus isovolumetric acceleration and RV performance index. This study includes only TAPSE and tricuspid annular tissue Doppler because they are more widely used and have less inter and intraobserver variability, as the FAC analysis is limited due to the difficulty of defining endomyocardial border, with great variability in the literature.[12] Although TAPSE expresses a measure of longitudinal function only, it has shown good correlation with RV global systolic function estimation techniques, such as radionuclide-derived RV ejection fraction (EF) and two-dimensional variation of RV fractional area (FAC).[1] Previous studies have shown a decrease in TAPSE and tissue S' values with increasing age, although with values still considered within the normal range,[10–13] which was not reproduced in the data presented here. This fact can be explained by the

higher proportion of female patients, as D'Oronzio U et al.[14] and Henein et al.[15] suggested higher absolute values of TAPSE and FAC in women.

Regarding RA volume and area, there are few studies published in the literature and most of them include magnetic resonance imaging (MRI), considered the gold standard for atrial evaluation. The same studies cite a large inter and intraobserver variability and variability according to the ethnicity of the study population.[16,17] The data found here suggest an inverse variation in RA volume and area with age and a positive variation with gender, BMI and BSA. This finding regarding age is inconsistent with previous MRI studies that found no correlation with age and shows the great difficulty in correctly evaluating this chamber.[18,19] However, this study and those cited above were based on an older population that mostly included people older than 50. Studies involving younger healthy individuals found lower atrial reference values compared to older individuals.[20–22]

Similarly, the evaluation of RV hypertrophy lacks more consistent studies involving a larger number of individuals.[23–29] Cuspidi C. et al., [23] in a meta-analysis including 13 studies, with a limited number of participants, showed a mean difference of up to 1.3 mm in RV thickness in hypertensives compared to non-hypertensives with $P<0.001$. In this study, 51 participants were hypertensive (63%) and no significant differences in RV thickness were found regarding the non-hypertensive group.

Given the above, it is necessary to list the main limitations found here: small number of participants; failure to calculate intra and interobserver variability mainly regarding atrial measurement; analysis of RV TAPSE and S' only, without including the FAC calculation to evaluate RV systolic function; the non-inclusion of a larger number of individuals younger than 50 years of age and the inclusion of a larger and significant number of women compared to the number of men.

Conclusions

In this study, echocardiographic parameters of the right chambers presented mean ventricular diameters and lower atrial area and volume in females compared to males. A positive correlation of these parameters with BMI and BSA was also found. However, right ventricular function, TAPSE and S' values were not influenced by gender, BMI and BSA.

Conflict of interest

The authors declare that there is no conflict of interest regarding this manuscript.

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