ORIGINAL ARTICLE

Echocardiographic Assessment of Right Ventricular Function by Two-Dimensional Strain In Patients with Left-Sided Valvular Heart Disease: Comparison with Three-Dimensional Echocardiography

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Abstract

Background: Right ventricular (RV) dysfunction is a well-known predictor of mortality in patients with valvular heart disease (VHD). The assessment of RV function is often difficult due to complex geometry and hemodynamic factors.

Objective: We aim to analyze RV function in patients with severe mitral and/or aortic valve disease using two-dimensional strain (2DS) imaging and conventional echocardiographic parameters, comparing it with right ventricular ejection fraction (RVEF) measured by three-dimensional echocardiography (3DE).

Methods: Fifty-three patients with severe mitral and/or aortic VHD underwent complete transthoracic echocardiogram in the preoperative setting for cardiac surgery, including conventional echocardiographic parameters of RV function and speckle-tracking derived 2DS indices: RV global longitudinal strain (RVGS) and RV free wall longitudinal strain (RVFWS). Conventional echocardiographic and 2DS parameters were compared with real-time 3DE RVEF using Spearman correlation test. For comparison between two groups of patients based on the presence of RV dysfunction (normal RVEF ≥ 44% - A, abnormal RVEF < 44% - B), we used nonparametric Mann-Whitney U test. ROC (receiver operating characteristic) curve analysis was used to assess the clinical utility of all RV function variables in defining RV dysfunction. P values <0,05 were considered statistically significant.

Results: We found a significant correlation between all parameters and RVEF ($p<0.05$), with best results for RV fractional area change (FAC), RVGS, and RVFWS. Dividing the population into two-groups based on RVEF, we found 14 patients with RV dysfunction (27.4%), and significant differences between the groups for all RV function variables. For detection of RV dysfunction defined by 3DE, ROC curve analysis showed the best area under the curve (AUC) for RVGS (0.872), RVFWS (0.851) and FAC (0.932).

Conclusions: We observed significant correlation between RVGS, RVFWS and RVEF, with good accuracy in detecting RV dysfunction, comparable to FAC and better than other conventional parameters of RV function assessment. The evaluation of RV myocardial deformation with 2DS may have additional diagnostic and prognostic value in patients with severe left-sided VHD. (Int J Cardiovasc Sci. 2018;31(6)630-642)

Keywords: Ventricular Dysfunction, Right/diagnostic, imaging; Ventricular Dysfunction, Right/physiopathology; Echocardiography, Tridimensional/methods; Stroke Volume; Valvular Heart Diseases; Prognosis.

Introduction

The accurate assessment of right ventricular (RV) systolic function plays an important role for the evaluation, follow-up and treatment of a myriad of cardiac and non-cardiac diseases.[1-4] The assessment of RV function by conventional echocardiographic parameters has major challenges, and its accuracy is limited by the irregular geometry of the RV chamber, the distinct pattern of contractility (mostly based on longitudinal deformation), the trabeculated inner contour of the cavity with poor endocardial border definition, separate

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inflow and outflow chambers which may be adequately visualized only from separate views, load-dependency, and influence of ventricular interdependency.[5,6]

In some pathologic conditions where changes in preload (e.g. severe tricuspid regurgitation) and afterload (e.g. pulmonary hypertension) are seen, the evaluation of RV function is particularly difficult. In patients with severe VHD, RV function assessment is challenging, not only because of the hemodynamic alterations frequently seen in these patients, but also because its primary etiopathogenic process itself may impair RV function, as we often see in rheumatic heart disease.[7]

In the last few years, studies have shown the applicability and clinical value of three-dimensional echocardiography (3DE) and two-dimensional strain (2DS) techniques in the evaluation of RV systolic function, with good accuracy for detecting RV dysfunction, and additional prognostic value in various diseases.[8] Speckle-tracking echocardiography (STE) derived techniques, specially 2DS, allows myocardial deformation analysis, is less dependent on angle and loading conditions, with great potential for RV evaluation (considering the complex geometry of the RV and great exposure to load changes), and has been shown to be a very sensitive technique, allowing early detection of subclinical RV involvement in a great variety of diseases.[9-12] Real-time 3DE is a well-established echocardiographic technique that has the great advantage of displaying the entire right ventricle in a single dataset, despite its irregular shape. The technique, hence, overcomes inherent limitations of tomographic methods for assessment of ejection fraction (EF), with good accuracy when compared with cardiac magnetic resonance (CMR).[13-17]

Objectives

The aim of this study was to analyze RV systolic function in patients with severe left-sided VHD using conventional echocardiography and 2DS techniques, testing the correlation of these techniques with RV ejection fraction (RVEF) measured by 3DE, and to evaluate the accuracy of these three techniques for the detection of RV dysfunction (RVEF < 44%).

Methods

This prospective observational cross-sectional study was approved by the local ethics committee.

Study population

From May 2013 to May 2014, in a tertiary cardiology hospital, we recruited consecutive adult patients with diagnosis of severe mitral and/or aortic valve disease[18] referred for preoperative evaluation for cardiac surgery (valve replacement, repair or both). We only included patients with no previous history of cardiac surgery, to avoid the influence of pericardiotomy on the accuracy of echocardiographic parameters of RV systolic function, and patients with no history of coronary artery disease to avoid confounding factors in determining the cause and severity of pulmonary hypertension and RV disease. We excluded patients with poor echocardiographic window for analysis of RV systolic function (either conventional parameters or 2DS), patients with severe tricuspid regurgitation (TR) and those who refused to participate in the study.

Conventional echocardiography

Echocardiography was performed using standard views, with the patient in the left lateral decubitus position, using a commercially available ultrasound machine (Vivid E9, GE Healthcare, Horten, Norway). Conventional echocardiographic images and cine loops of all patients were obtained by a single experienced examiner using a M5S transducer. Left ventricular (LV) EF was calculated using the biplane method of discs, and all the Doppler parameters necessary to quantitate the severity of valvular lesions and pulmonary artery systolic pressure (PASP) were obtained and analyzed in accordance with the criteria defined on the EAE/ASE/EACVI guidelines.[19,20] RV diastolic and systolic areas were measured to calculate RV fractional area change (FAC). With the pulsed-wave Doppler sample volume positioned at the lateral tricuspid annulus in the RV focused apical 4-chamber view, the peak systolic velocity (PSV) by tissue Doppler was obtained. We also measured the tricuspid annular plane systolic excursion (TAPSE), placing the M-mode cursor through the base of the lateral tricuspid annulus, quantitating its longitudinal motion at peak systole.

Speckle-tracking echocardiography

For STE analysis, digital loops of the right ventricle were obtained from apical 4-chamber and/or right ventricle-focused apical 4-chamber views. Three cardiac cycles were acquired from each view at a frame rate of

40-80 frames/sec in patients in sinus rhythm and five consecutive cycles in patients with atrial fibrillation (AF). The data were exported at the end of the test to a workstation (EchoPac BT12, GE Vingmed, Horten, Norway) for further offline analysis.

Preliminary analysis was performed online in the ultrasound machine was performed online in the ultrasound machine to check if the image quality of the loops was good enough to permit adequate tracking of the acoustic markers (speckles) of the myocardium during the entire cardiac cycle. STE analysis was performed semi-automatically by the system, after manual setting of 3 points on the endocardial border of the right ventricle by the operator (2 basal and one at the apex). When the region of interest (ROI) included the whole thickness of the right ventricle and excluded other structures such as trabeculae, moderator band and valvular tissue, the processing was started, and analysis proceeded on a frame-to-frame basis using an automatic tracking system (Figure 1). If the tracking was poor, the operator could repeat the the acquisition of loops, readjusting the endocardial tracing (editing) or change software parameters such as ROI width, frame rate or gain, until an adequate tracking of the entire myocardium was achieved.

The ROI generated by the software included basal, mid and apical segments of RV free wall and septum, dividing it into 6 segments (Figure 1). Longitudinal peak strain values were measured for each segment, and the RV free wall longitudinal strain (RVFWS) and the RV global longitudinal strain (RVGS), analyzed by 2DS, were calculated by averaging the values from the three segments of the RV free wall and all the six segments along the entire right ventricle, respectively. These initial results were blinded to the investigators until the offline analysis of the remaining parameters was performed.

Three-dimensional echocardiography

3DE was performed in all subjects immediately after the two-dimensional echocardiographic examination using the same ultrasound machine, equipped with a 4V probe. RV three-dimensional (3D) images were obtained in a full-volume dataset from the apical four-chamber view, optimized for analysis of RV function. Multi-beat (3-6 beats) data were obtained during apnea, on the multislice (short axis) visualization mode, to make sure that the right ventricle was entirely included in the dataset (Figure 2).

All the measurements of RV volumes and EF were made off-line, using a dedicated software (TomTec Imaging Systems GmbH, Munich, Germany). Semi-automatic analysis was performed, with manual tracing of the endocardial borders in end-systolic and end-diastolic frames in the sagittal, four-chamber and coronal views, obtained from the full-volume dataset. In addition, end-diastolic volume (EDV), end-systolic volume (ESV), stroke volume and EF were calculated using the software (Figure 2).

Assessment of reproducibility

Evaluation of inter- and intraobserver reproducibility were performed. Fourteen patients, chosen by simple random selection, were assessed by two observers for analysis of interobserver variability, and for intra-observer variability, the second analysis was performed with a minimum interval of two weeks from the first analysis. The readers were blinded to previous measurements. Interobserver and intraobserver variability were assessed using the intraclass correlation coefficient and Bland-Altman analysis.[21]

Statistical analysis

Demographic data are presented as mean ± standard deviation (SD) and categorical data are presented as frequencies. Normality of the distribution of numerical variables was tested by the Kolmogorov-Smirnov test; normally distributed variables were expressed as mean ± SD and variables with abnormal distribution as median with interquartile range. We compared all RV function parameters between subgroups of patients according to their predominant valvular lesion. To reduce the occurrence of alpha error, we used one-way ANOVA test with Bonferroni post-hoc correction. Conventional echocardiographic and 2DS parameters were compared with real-time 3DE RVEF using Spearman correlation test. For comparisons between groups of patients (A and B), based on the presence of RV dysfunction defined as RVEF (3DE) < 44%, we used nonparametric Mann-Whitney U test. ROC (receiver operating characteristic) curve analysis was used to assess the clinical utility of all RV function variables in defining RV dysfunction. P values < 0.05 were considered statistically significant. Statistical analyses were performed using SPSS version 13 (SPSS Inc, Chicago, IL).

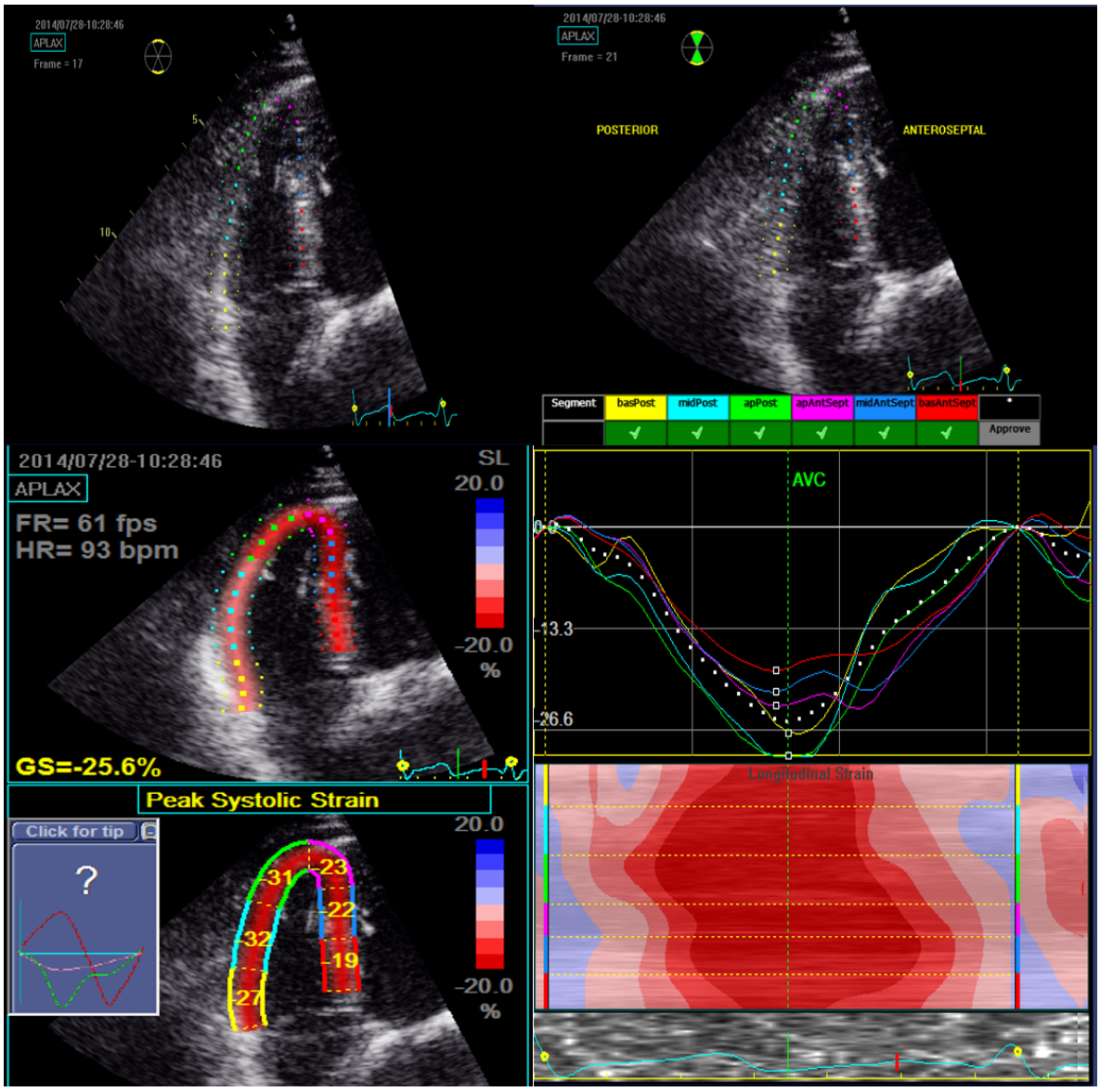

Figure 1 - Speckle-tracking analysis of right ventricular (RV) systolic function using the automated function imaging technique. (Top) Semi-automated delineation of endocardial borders and definition of the region of interest (ROI). Mid and lower images illustrate two-dimensional strain analysis: (middle-left) shows global longitudinal RV strain (-25.6%), (middle-right) two-dimensional strain (2DS)-time curves, (bottom-left) peak 2DS values per segment, and (bottom-right) 2DS-time parametric analysis.

Results

Patients' characteristics

A total of 57 consecutive patients with severe VHD were enrolled in this study. Of these, two had severe TR and other two refused to participate, thus the final study group was comprised of 53 patients (31 women; mean age, 52,4 ± 15,9 years). Most patients were symptomatic, with 50.9% classified as New York Heart Association (NYHA) functional class II and 43.4% as NYHA III (Table 1). The predominant etiology of valve diseases was rheumatic valve disease (53.6%), myxomatous valve disease (18.9%), degenerative valve disease (13.2%) and congenital valve disease (11.3%). All patients were submitted to conventional echocardiography, RV 2DS and 3DE. Most patients were in sinus rhythm; 14 patients (26.4%) with permanent AF were not excluded because we were able to analyze all echocardiographic parameters despite the presence of arrhythmia.

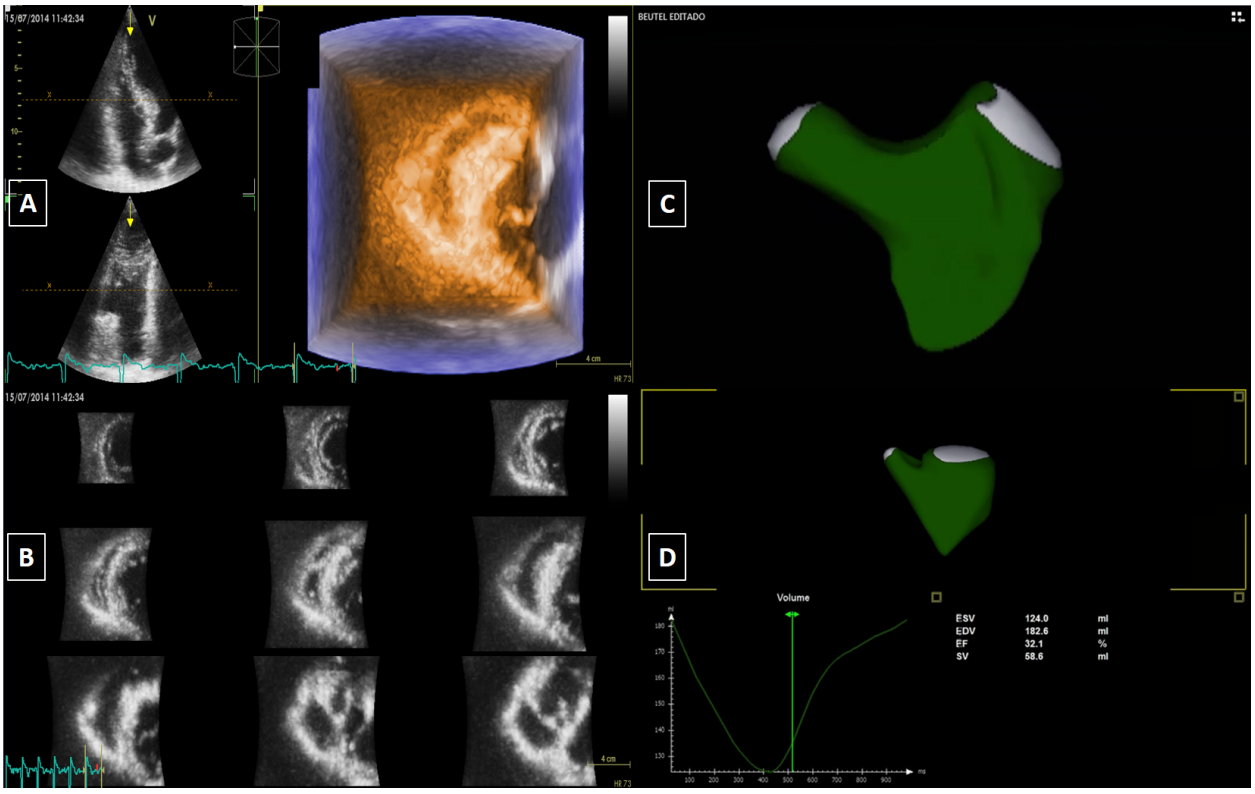

Figure 2 - (a,b) Right ventricular (RV) multi-beat, full-volume acquisition by three-dimensional echocardiography. (c,d) RV volumes and ejection fraction analysis using TomTec software. Rendering of RV chamber on the top (c), and volume-time curve and quantitative measurements on the bottom (d)

Table 1 - Clinical profile and comorbidities of the enrolled subjects

Clinical variable	Number of patients (% total)
Female	31 (58.5%)
NYHA I	3 (5.7%)
NYHA II	27 (50.9%)
NYHA III-IV	23 (43.4%)
Systemic arterial hypertension	23 (43.4%)
Atrial fibrilation	14 (26.4%)
Tabagism	14 (26.4%)
DM	5 (9.4%)
Obesity (BMI > 30 kg/m²)	6 (11.3%)

NYHA: New York Heart Association functional class; DM: diabetes mellitus.

Echocardiographic parameters

Technically adequate measurements of TAPSE, PSV, FAC and 2DS parameters were obtained in all patients.

Real-time 3DE images of the RV were successfully analyzed in 51 of the 53 patients evaluated (96.2%). Image quality was considered inadequate for analysis in two patients, due to unsatisfactory echocardiographic window (missing the anterior wall of the RV).

Considering the entire study population, mean values of LV chamber dimensions were increased, despite normal LV systolic function. Overall, RV dimensions and function were normal, as summarized in Table 2.

We compared conventional parameters of RV function and 2DS with RVEF measured by 3DE and found a significant correlation between RVFWS ($r = -0.578$; $p < 0.001$) and RVGS ($r = -0.596$; $p < 0.001$), very similar to FAC performance ($r = 0.635$; $p < 0.001$), and far better than TAPSE and PSV (Figure 3).

Table 2 - Two-dimensional, Doppler, 2D strain and three-dimensional parameters of the enrolled subjects

Parameters	Values (mean ± SD)
LA (mm)	48.81 ± 9.96*
RV (mm)	17 (16 - 20) **
LV EDD (mm)	57.34 ± 10.24*
LV ESD (m)	36.21 ± 8.65*
LVEF Teichholz (%)	67.0% (61.5 - 73.0%)**
LVEF Simpson (%)	66 (61 - 72%)**
RV basal (mm)	37 (31 - 41)**
RV mid-cavity (mm)	27 (22 - 34)**
RV apical-TV distance (mm)	60 (55 - 69)**
Tricuspid Annulus (mm)	30.19 ± 4.32*
PASP (mmHg)	40 (30 - 54)**
RVFWS (%)	-23.81 ± 6.77*
RVGS (%)	-21.42 ± 4.96*
PSV (cm/sec)	11.91 ± 3.73*
TAPSE (mm)	20.21 ± 5.92*
FAC (%)	44.46 ± 13.3*
RVEDF 3DE (ml)	80.4 (64.4 - 114.7)**
RVESV 3DE (ml)	34.1 ml (25.6 - 54.1)**
RVEF 3DE (%)	60 (42.5 - 63.4)**

**Data are mean ± SD. **Data are median with interquartile range. FAC: fractional area change; LA: left atrium; LV EDD: left ventricular end diastolic dimension; LVEF: left ventricular ejection fraction; PASP: pulmonary artery systolic pressure; LV ESV: left ventricular end systolic dimension; PSV: peak systolic velocity of tricuspid annulus; RV: right ventricle; RVFWS: RV free wall longitudinal 2D strain; RVGS: RV global longitudinal 2D strain; TAPSE: tricuspid annular plane systolic excursion; TDI: tissue Doppler imaging; TV: tricuspid valve.*

The patients were classified into subgroups according to their predominant valve lesion as follows: (1) mitral stenosis (n = 11; 20.8%), (2) mitral regurgitation (n = 21; 39.6%), (3) aortic stenosis (n = 8; 15.1%), (4) aortic regurgitation (n = 9; 17%), and (5) combined lesions (n = 4; 7.5%). We defined combined lesions as the presence of two or more severe mitral and/or aortic valve lesions in the same patient. Of the four patients with combined lesions, two had severe mitral stenosis and regurgitation, one had severe aortic stenosis and regurgitation and the other one had severe mitral regurgitation and aortic regurgitation.

The echocardiographic variables were compared between these subgroups (ANOVA for multiple comparisons), and we found a significant difference between the groups in all the parameters, except for PSV (Figure 4). Patients with stenotic valve lesions had lower values of PSV compared with patients with regurgitant lesions. Patients with combined lesions had lower values of all conventional RV function parameters compared with the other groups. We observed lower absolute values of RVFWS, RVGS (less deformation) and higher PASP, and lower FAC and RVEF 3D in patients with mitral stenosis and patients with combined lesions.

Dividing the patients into two categories according to their RVEF by 3DE, considering patients with RVEF ≥ 44% as preserved function (A), and patients with RVEF < 44% as RV systolic dysfunction (B), we found a total of 14 patients with RV dysfunction (27.4%), with significant difference between the groups for all variables: PSV ($p = 0.005$), TAPSE ($p < 0.001$), FAC ($p < 0.001$), PASP ($p < 0.001$), RVFWS ($p < 0.001$), RFGS ($p < 0.001$) (Figure 5).

ROC curve analyses tested the clinical utility of all parameters for the diagnosis of RV dysfunction (determined by RVEF < 44% by 3DE), and established sensitivity (Se), specificity (Sp) and best cut-off values. The parameters with the largest areas under the curve (AUC) were: RVFWS (0.851), RVGS (0.872) and FAC (0.932), with best cut-off values of: -18.6% (Se: 86.5%, Sp: 79.6%), -20.1% (Se: 83.8%, Sp: 85.7%) and 41% (Se: 86,5%, Sp: 92,9%), respectively (Table 3).

Intra- and interobserver variability analysis

Reproducibility analysis showed excellent accordance between repeated measurements for the RV 2DS parameters by Bland-Altman analysis (Figure 6). Both RVFWS and RVGS showed high intraclass correlation coefficient (range, 0.97 - 0.98) with narrow confidence intervals (Table 4).

Discussion

There are few studies in literature focusing on RV function in left-sided VHD, most of which had limited number of patients and analyzed only conventional RV function parameters, without using 2DS parameters or 3DE. The great challenge in VHD is to detect early alterations in RV function, when subclinical disease may point to a worse clinical prognosis and contribute

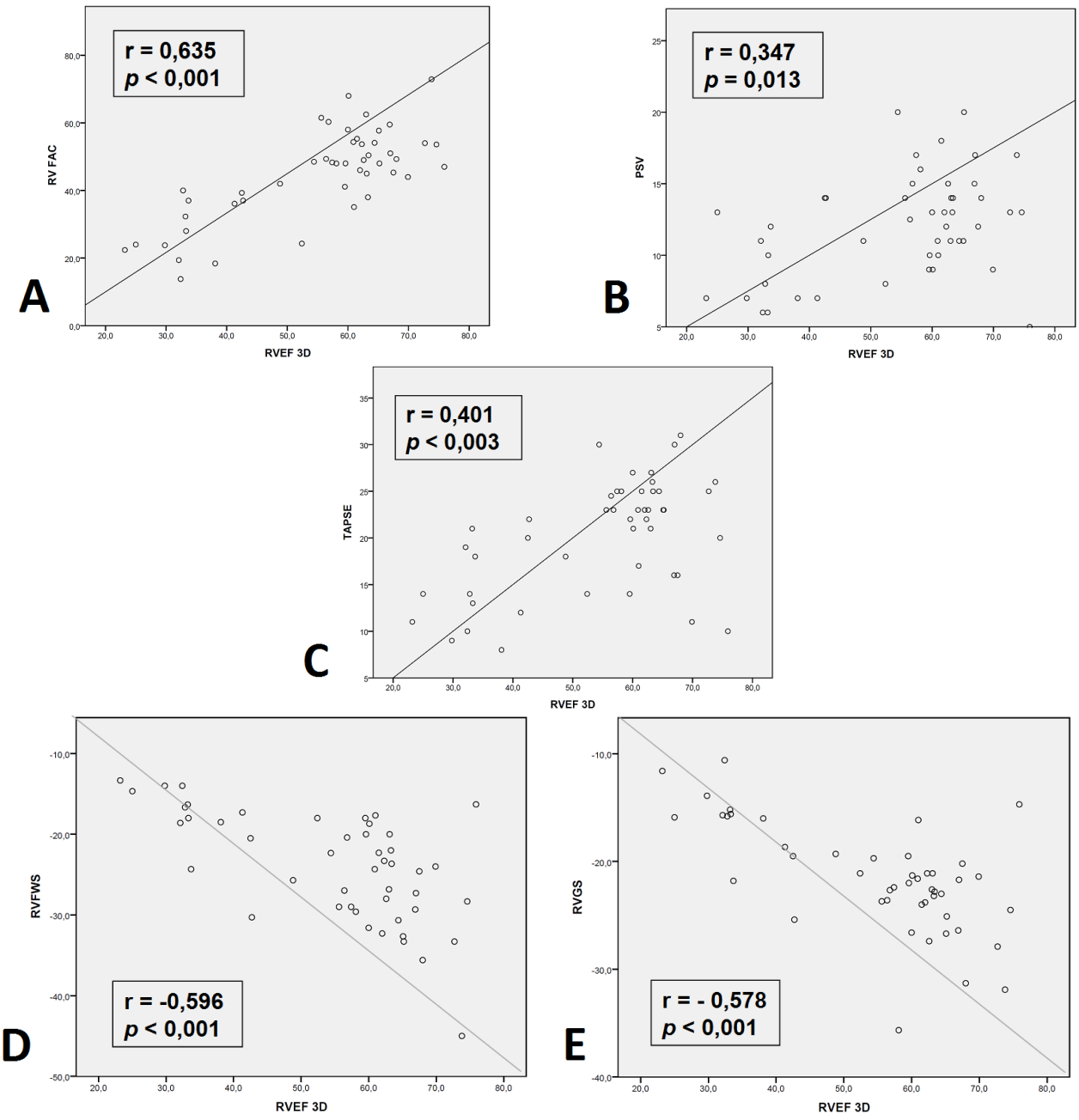

Figure 3 - Correlation between fractional area change (FAC) (a), peak systolic velocity (PSV) of tricuspid annulus by tissue Doppler (b), tricuspid annular plane systolic excursion (TAPSE) (c), right ventricular (RV) free wall longitudinal strain (RVFWS) (d), RV global longitudinal strain (RVGS) (e), and RV ejection fraction (RVEF), measured by three-dimensional echocardiography.

to surgery indication in appropriate timing. In this regard, STE based techniques as 2DS have shown good applicability and reproducibility for the evaluation of RV function, with great accuracy in detecting RV dysfunction when compared to gold standard methods.

A population of severe mitral and/or aortic valve disease patients was enrolled in this study, predominantly rheumatic in etiology, unlike other studies from Europe and North America that also evaluated RV function in VHD patients, in which the predominant etiology was degenerative valvular disease.[22,23] In Brazil, rheumatic fever is still a prevalent cause of VHD, and almost 60% of the patients that undergo cardiac surgery for valvular repair or replacement have rheumatic etiology.[24] These

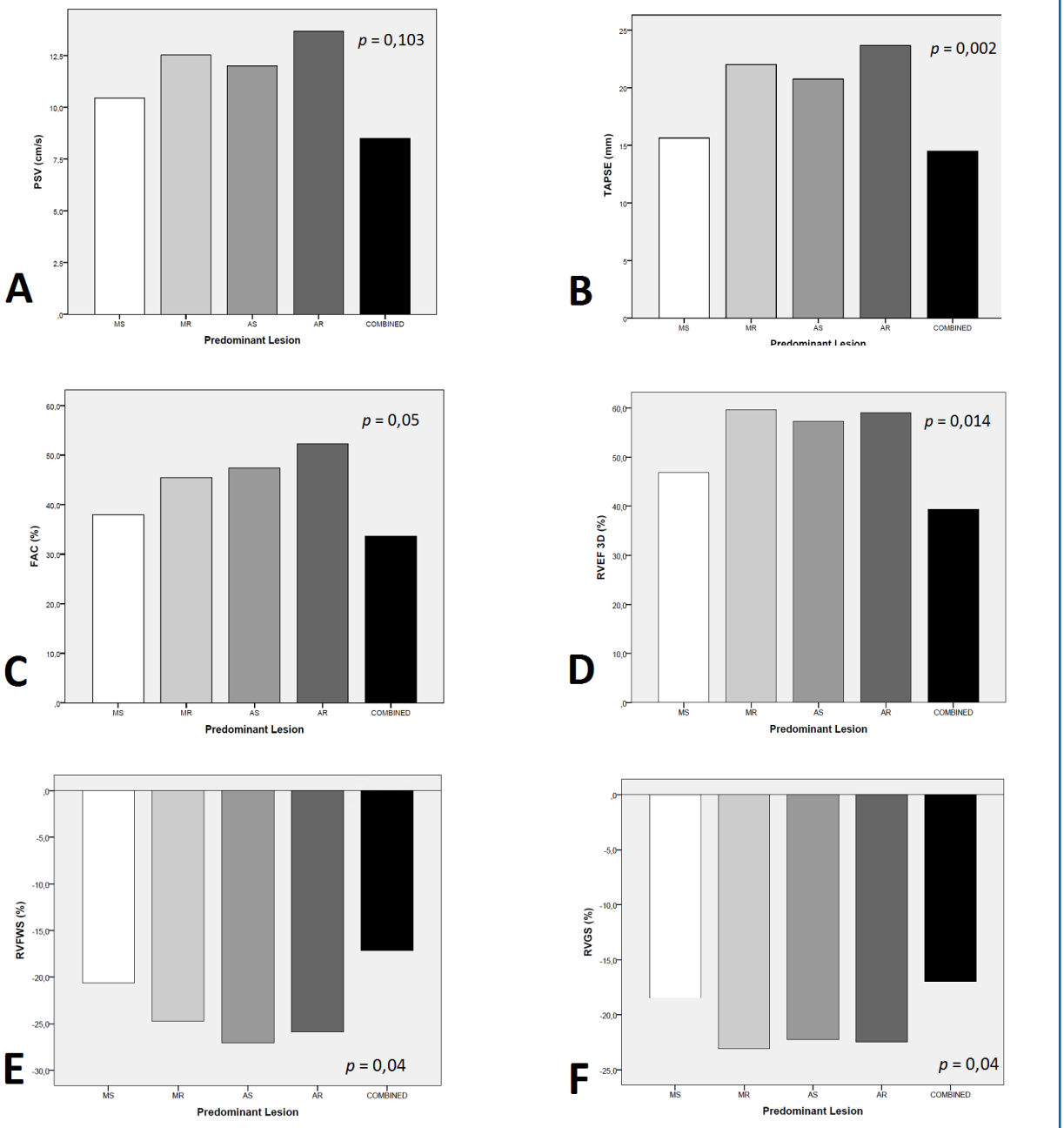

Figure 4 - Mean values of echocardiographic parameters by predominant valve lesion. P value refers to difference between all groups by multiple comparisons (ANOVA). MS: mitral stenosis, MR: mitral regurgitation, AS: aortic stenosis, AR: aortic regurgitation, PSV: peak systolic velocity of tricuspid annulus(a); TAPSE: tricuspid annular plane systolic excursion (b); FAC: fractional area change (c); RVEF 3D: right ventricular (RV) ejection fraction three-dimensional echocardiography (d); RVFWS: RV free wall longitudinal two-dimensional strain (e); RVGS: RV global longitudinal (two-dimensional) strain (f).

patients frequently present with disease in more than one valve, and therefore, we decided to include in the present study patients with combined mitral and/or aortic lesions, to better represent the entire clinical spectrum of the disease.

Considering RVEF measured by 3DE as an established reference standard for evaluation of RV function, most patients in our study had normal RV function (RVEF 3D ≥ 44%), although the number of patients with RV dysfunction was significant (n = 14; 27.4%). The mean

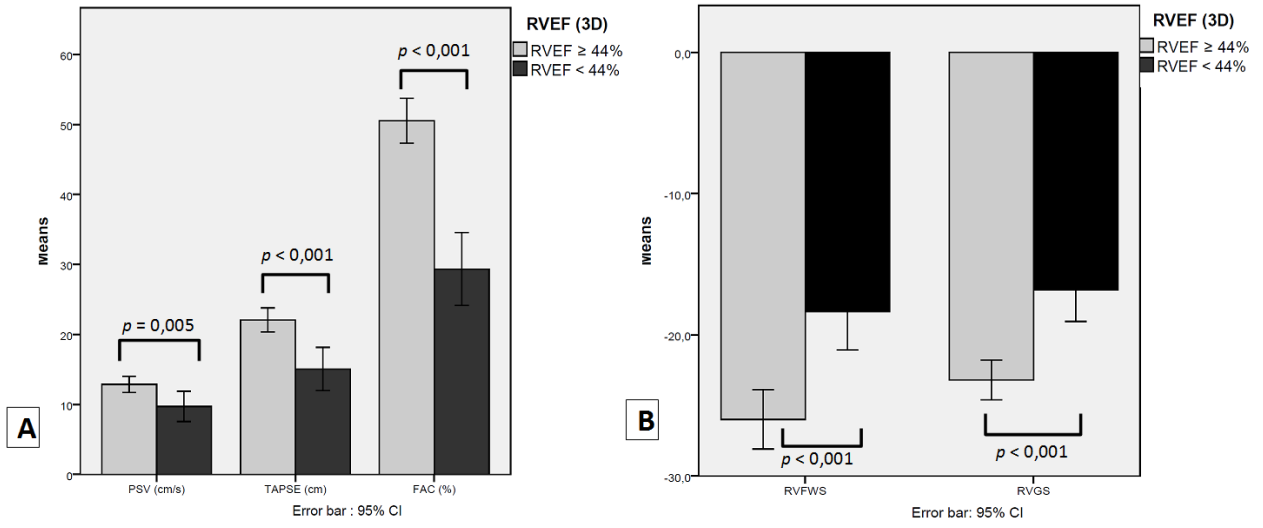

Figure 5 - Comparison of mean values of echocardiographic parameters between the groups: right ventricular (RV) preserved systolic function (RVEF = 44%; n = 37) and RV systolic dysfunction (RVEF < 44%; n = 14). (a) PSV: peak systolic velocity of tricuspid annulus; TAPSE: tricuspid annular plane systolic excursion; FAC: fractional area change; (b) RVFWS: RV free wall longitudinal (two-dimensional) strain; RVGS: RV global longitudinal (two-dimensional) strain.

Table 3 - Echocardiographic parameters. Performance for the detection of RV dysfunction (RVEF 3DE < 44%)

Parameter	Se	Sp	PPV	NPV	Cut-off	AUC	CI
RVFWS	86.5%	79.6%	72%	90%	-18.65%	0.851	0.726 - 0.956
RFGS	83.8%	85.7%	92%	89%	-20.1%	0.872	0.750 - 0.994
PSV	78.4%	64.3%	57%	83%	10.5 cm/s	0.756	0.593 - 0.919
TAPSE	84.2%	64.3%	60%	91%	15 mm	0.828	0.697 - 0.960
FAC	86.5%	92.9%	87%	90%	41%	0.932	0.867 - 0.998

RVFWS: right ventricular (RV) free wall longitudinal 2D strain; RVGS: RV global longitudinal 2D strain; PSV: peak systolic velocity of tricuspid annulus; TAPSE: tricuspid annular plane systolic excursion; FAC: RV fractional area change.

values of conventional RV function parameters (TAPSE, PSV, FAC) and 2DS parameters (RVFWS, RVGS) were normal considering the overall study population, despite an elevation of the median values of PASP (40 mmHg (30-54)), secondary to the advanced stage of the disease in these patients. We excluded patients with severe TR, a condition that may affect the accuracy of RV functional assessment by alterations in RV preload.[25]

We obtained acceptable 3DE images for RVEF analysis in 51 patients (96,2%), showing good feasibility of the technique, as previously shown by other authors (Kong et al.,[26] - 97%, Niemann et al.,[27] - 100%). The mean values of EDV, ESF and EF were normal in the overall population.

Analyzing the patients according to their predominant valve lesions using multivariate analysis, we observed significant differences between the groups for RVGS, RVFWS, TAPSE, FAC, and RVEF 3D, showing a tendency towards lower absolute values of RVGS, RVFWS (less deformation) and lower levels of FAC and RVEF 3D in patients with mitral stenosis and combined lesions. These findings are probably related to higher levels of pulmonary capillary pressure and RV pressure overload in mitral stenosis and combined lesions than in regurgitant lesions and isolated aortic stenosis. Furthermore, all patients with combined lesions were rheumatic, pointing to the possibility of a concurrent

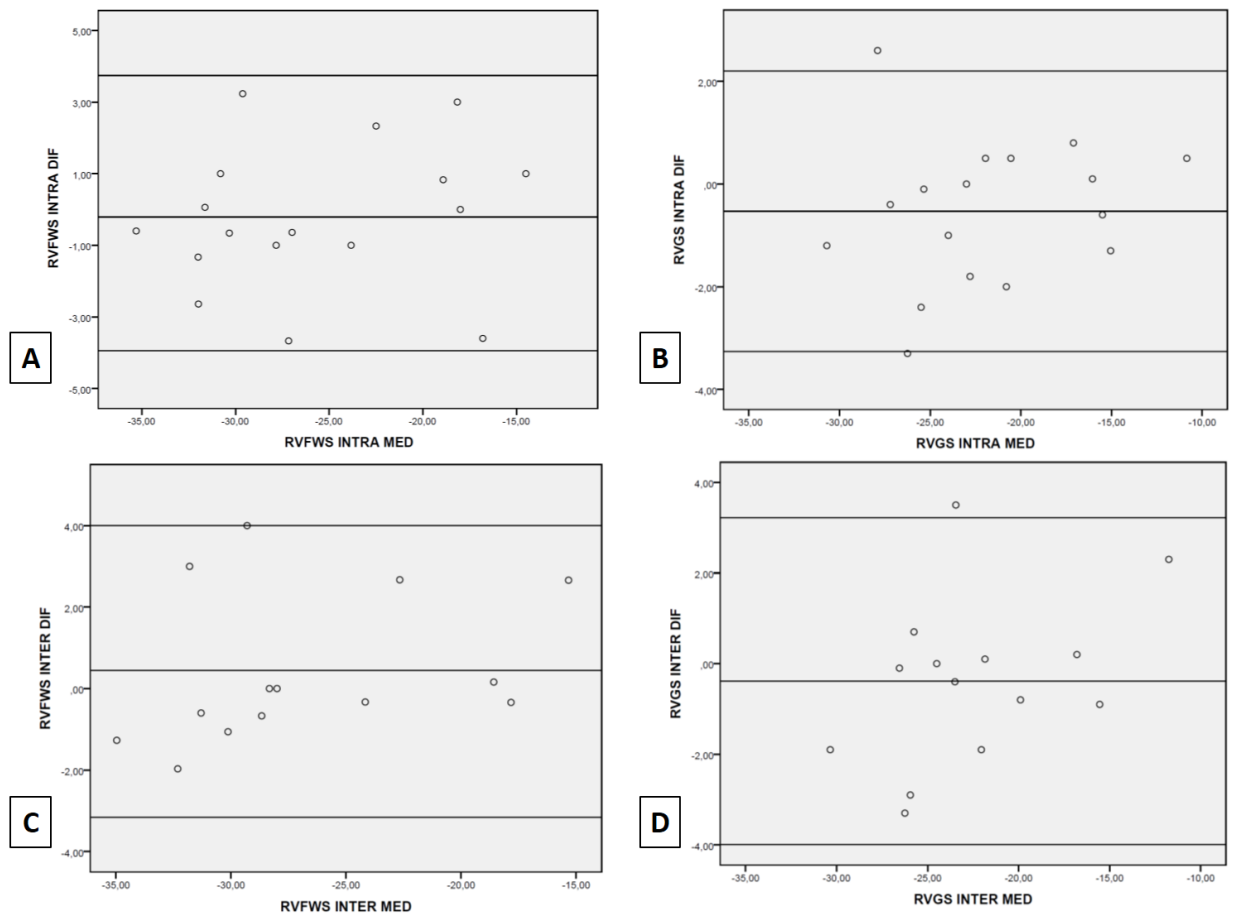

Figure 6 - Reproducibility analysis for repeated measurements of RV free wall longitudinal (two-dimensional) strain and RVGS: RV global longitudinal (two-dimensional) strain (Bland-Altman). (a) RVFWS intraobserver variability; (b) RVGS intraobserver variability; (c) RVFWS interobserver variability; (d) RVGS interobserver variability.

Table 4 - Reproducibility analysis for retest measurements of RVFWS and RVGS

Reproducibility analysis	ICC	CI(95%)
RVFWS intra-observer	0.975	0.932 - 0.991
RVFWS inter-observer	0.977	0.927 - 0.992
RVGS intra-observer	0.983	0.952 - 0.994
RVGS inter-observer	0.966	0.894 - 0.989

RVFWS: right ventricular (RV) free wall longitudinal 2Dstrain; RVGS: RV global longitudinal 2Dstrain; ICC: intra-class correlation coefficient; CI: confidence interval.

primary involvement of the myocardium, due to the inflammatory and fibrotic processes inherent to this disease. Using 2DS, Pirat et al.,[28] and Ikeda et al.,[29] demonstrated the occurrence of alterations in RV systolic function in patients with pulmonary artery hypertension, proportional to the severity of the disease, which could help explain some of our findings.

We compared the parameters of RV systolic function with RVEF 3D, and found a moderate, negative correlation between RVEF 3D and RVGS, RVEF 3D and RVFWS, and a moderate positive correlation between RFVE 3D and FAC, with weaker correlations for TAPSE and PSV. These findings are in accordance with previous studies, showing good correlation between RV 2DS parameters and RVEF measured by CMR[30] and FAC with RVEF measured by CMR.[31]

When the population was divided into two categories, according to the absence of RV dysfunction (group A, RVEF ≥ 44% by 3DE) and the presence of RV dysfunction (group B, RVEF < 44% by 3DE) we found a significant

difference in all parameters of RV function between the groups. ROC curve analysis was performed to test the diagnostic performance of these variables to detect RV dysfunction. The best AUC was obtained for FAC (0.932) followed by RVGS (0.872) and RVFWS (0.851), showing the clinical utility of these parameters in detecting RV dysfunction. Among all, FAC had the best performance, and this may be explained by the fact that this is the only parameter directly related to RV ejective function, while all others are closely related to longitudinal systolic function.

We performed intraobserver and interobserver analysis for RVGS and RVFWS and found good reproducibility for both parameters, making these measurements more robust and reliable, confirming previous data.[4,32,33]

Mittal et al.,[34] did not find any correlation between RV systolic parameters and PASP in 22 mitral stenosis patients, attributing RV myocardial dysfunction to inflammatory damage caused by the rheumatic disease. Ozdemir et al.,[35] demonstrated that patients with mild-to-moderate mitral stenosis had altered values of longitudinal RV 2DS compared to controls, probably unrelated to pulmonary hypertension, since they found only a mild elevation of PASP in these patients (39 ± 14 mmHg). Tanboga et al.,[32] studied patients with mild-to-moderate mitral stenosis and also found altered values of longitudinal RV 2DS compared to controls, but did not find any correlation of these values with PASP. Castro et al.,[36] studied 46 patients with isolated severe mitral stenosis, showing reduced longitudinal RV 2DS compared to controls, and a weak correlation between 2DS and PASP. Galli et al.,[37] studying 200 patients with degenerative aortic valve stenosis, demonstrated RV dysfunction in 24% of these patients, and established concomitant LV and RV dysfunction as the major predictor of mortality in 16 months. Le Tourneau et al.,[38] evaluating RV systolic function in 208 patients with severe organic mitral regurgitation found severe RV dysfunction (RVEF ≤ 35% measured by radionuclide angiography) in 63 patients (30%). The authors showed a weak correlation between PASP and RVEF and suggested a direct relation of RV dysfunction with septal function alteration and of LV enlargement with remodeling (ventricular interdependence). Mitral valve disease typically causes greater overload in the right chambers than aortic valve diseases,[39] probably due to an exceptional elevation of capillary pulmonary pressure, either by volume overload in mitral regurgitation or pressure overload in mitral stenosis.

Our findings suggest that RVGS and RVFWS may be reliable markers of RV dysfunction in VHD patients, with good accuracy and the potential advantage of early detection of alterations in myocardial function that precede alterations in the RV ejective function.

Limitations

Our findings must be validated in other studies involving a larger number of subjects. Our small sample size does not allow us to extrapolate these results to other populations. This was a clinical, uncontrolled study, which included consecutive patients with left-sided VHD from different etiologies and mechanisms of valvular dysfunction, reflecting the population of patients currently treated in our clinical practice.

Conclusion

In left-sided VHD patients, RVGS and RVFWS showed good correlation when compared with RVEF 3DE and good accuracy in detecting RV dysfunction. 2DS might be a useful tool for the early detection of changes in RV function in VHD patients.

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Author contributions

Conception and design of the research: Felix AS, Lorenzo AR, Azevedo Filho CF. Acquisition of data: Felix AS. Analysis and interpretation of the data: Felix AS, Siciliano APRV, Xavier SS. Statistical analysis: Felix AS, Xavier SS, Azevedo Filho CF. Obtaining financing: Felix AS. Writing of the manuscript: Felix AS, Lorenzo AR. Critical revision of the manuscript for intellectual content: Felix AS, Siciliano APRV, Belém LHJ, Azevedo FS, Xavier SS, Lorenzo AR, Azevedo Filho CF. Supervision / as the major investigador: Felix AS. Referral of Patients: Azevedo FS.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Ethics approval and consent to participate

This study was approved by the Ethics Committee of the INC under the protocol number 20217813.1.0000.5272. All the procedures in this study were in accordance with the 1975 Helsinki Declaration, updated in 2013. Informed consent was obtained from all participants included in the study.

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