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ORIGINAL INVESTIGATION

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Right ventricle assessment in patients with severe aortic stenosis undergoing transcatheter aortic valve implantation

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Abstract

Introduction: Limited data are available regarding the evaluation of right ventricular (RV) performance in patients with aortic stenosis (AS) undergoing transcatheter aortic valve implantation (TAVI).

Objective: To evaluate the prevalence of RV dysfunction in patients with severe AS undergoing TAVI and long-term changes.

Methods: Consecutive patients with severe AS undergoing TAVI from January 2016 to July 2017 were included. RV anatomical and functional parameters were analyzed: RV diameters, fractional area change, tricuspid annular plane systolic excursion (TAPSE), S-wave tissue Doppler of the tricuspid annulus (RV-S'TDI), global longitudinal strain (RV-GLS), and free wall strain (RV-FWS). Preprocedure and 1-year echo were analyzed.

Results: Final population included 114 patients, mean age 83.63 ± 6.31 years, and 38.2% women. The prevalence of abnormal RV function was high, variable depending on the parameter that we analyzed, and it showed a significant reduction 1 year after TAVI implantation: 13.9% vs 6.8% (TAPSE < 17mm), $P = .04$; 26.3% vs 20% (fractional area change < 35%), $P = .048$; 41.2% vs 29.2% (RV-S'TDI < 9.5cm/s), $P = .04$; 48.7% vs 39.5% (RV-GLS > [20]), $P = .049$; and 48.7% vs 28.9% (RV-FWS > [20]), $P = .03$. Significant differences were noted between patients with low-flow (LF) vs normal-flow (NF) AS in RV dysfunction prevalence as well as in RV function recovery which is less evident in LF compared with NF patients.

Conclusions: RV dysfunction is high among symptomatic AS patients undergoing TAVI, with variable prevalence depending on the echocardiographic parameter used.

KEYWORDS
pulmonary hypertension, right ventricle, right ventricle strain, severe aortic stenosis, TAVI

1 | INTRODUCTION

Aortic stenosis (AS) is the most common primary valve disease leading to surgery or catheter intervention in the Western world. The frequency of aortic valve sclerosis is approximately 25% at 65 years of age, rising to 48% after 75 years, while the frequency of AS is 4%-5% in those aged over 65.[1] Echocardiography is the key diagnostic tool for assessing the severity of AS. Intervention is indicated in patients with symptomatic severe AS, and aortic valve replacement has been traditionally offered in order to improve survival.[2] TAVI has emerged as an alternative for these patients. However, it is important to characterize these patients, in order to avoid futility and select those that would benefit the most from this strategy.

In the last years, different clinical, imaging, and analytic parameters have been used to stratify AS patients undergoing TAVI. This way, tricuspid regurgitation and pulmonary hypertension are associated with worse prognosis.[3,4] RV function is a well-known prognosis parameter in many cardiac conditions. In patients undergoing TAVI, RV dysfunction seems to have prognostic implications; however, data on true prevalence and changes of RV function after the procedure are lacking.[5] This may be due, at least in part, to the different methodology used to assess RV function and the inherent limitation of its echocardiographic evaluation. This way, in most papers, a comprehensive evaluation of RV as recommended by Scientific Societies[6] is not performed and new parameters as RV strain (more sensitive and less dependent on loading conditions) are rarely used. However, there are some groups that have investigated the left and RV function after TAVI, and in patients with severe AS.[7-13]

The aim of the study was to evaluate the prevalence and long-term changes of RV dysfunction, according to the different echocardiographic available parameters, in patients with severe AS undergoing TAVI.

2 | METHODS

2.1 | Study population

Consecutive patients with severe AS undergoing TAVI from January 2016 to July 2017 in our institution were included. Patients without pre- and/or post-procedure echo (18 patients) or with poor acoustic window (20 patients) were excluded. Clinical and demographic characteristics were collected from medical electronic history.

2.2 | Echocardiography

All patients (except for the excluded ones) underwent a transthoracic echocardiographic study (TTE) previous to TAVI (the day before) and 1 year after the implantation. All echocardiograms were performed in the same system (EPIQ, X5 transducer; Philips Healthcare, Andover, MA). RV evaluation was performed according to ESC guidelines on RV function evaluation.[6]

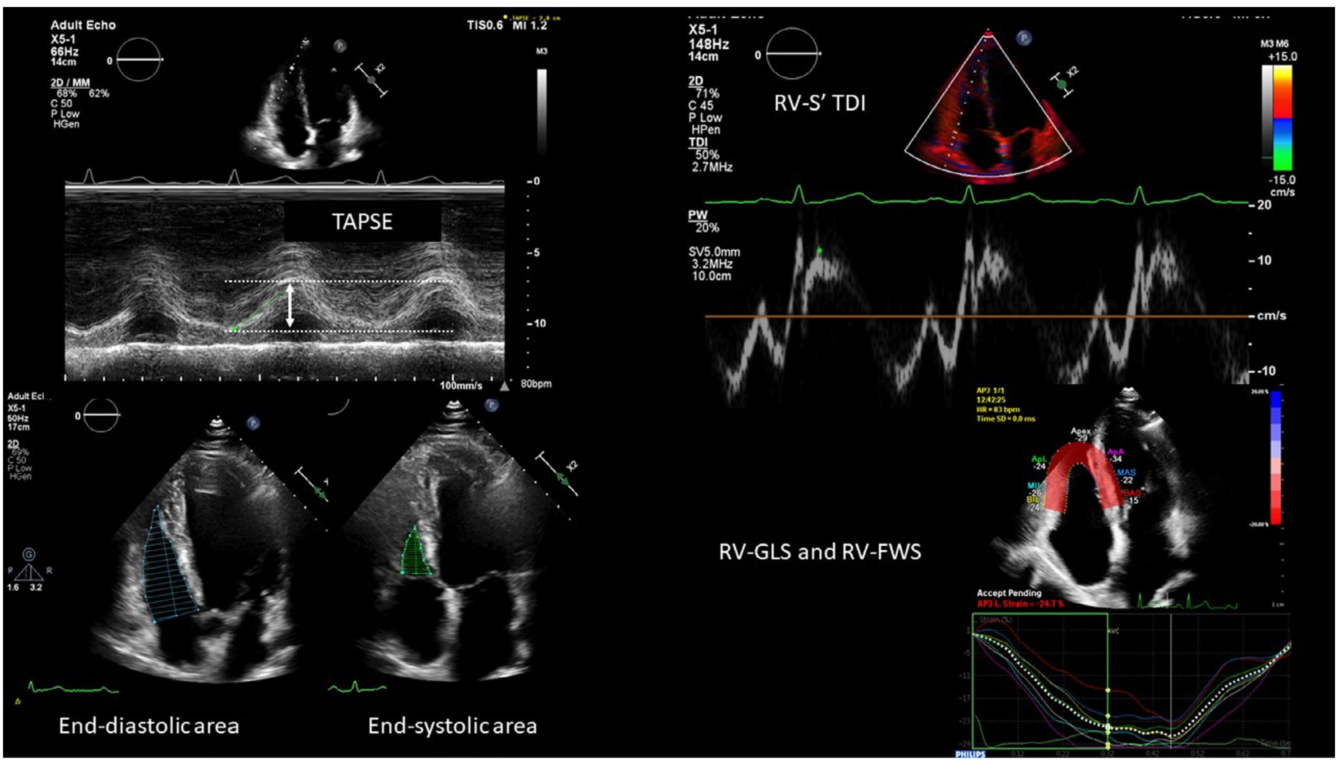

FIGURE 1 RV evaluation. RV- S'TDI lateral tricuspid annulus (cm/s); RV-FWS, right ventricular free wall strain; RV-GLS, right ventricular global longitudinal strain; TAPSE, tricuspid annular plane systolic excursion

A full TTE was performed including all recommended parameters to assess and classify AS. According to indexed stroke volume, the patients were classified as low-flow AS (indexed stroke volume < 35 mL/m^2) or normal-flow AS (index stroke volume > 35 mL/m^2).[7] RV dysfunction was assessed using fractional area change (abnormal < 35%), tricuspid annular plane systolic excursion (TAPSE) (abnormal < 17 mm), systolic wave tissue Doppler of the tricuspid annulus (RV-S'TDI) (abnormal < 9.5 cm/s), global longitudinal (RV-GLS) (abnormal < [20]), and free wall strain (RV-FWS) (abnormal < [20]).[14] (Figure 1).

2.3 | Statistical analysis

Baseline, echocardiographic data are presented as number (percentage, with *P* values from Fisher's exact test for 2-by-2 comparisons or chi-square test) or mean ± standard deviation (with *P* values from Student's *t* test for 2-group comparison, of F-test for comparisons of more than 2 groups), as appropriate. Analysis was conducted using SPSS software V. 22. 0, with a two-tailed significance value of 0.05.

3 | RESULTS

Final study population included 114 patients. Clinical and echocardiographic data characteristics of the overall population are shown in Tables 1 and 2.

The prevalence of significant tricuspid regurgitation (moderate to severe) in the echo before TAVI was 14.5% (n = 16). There were echocardiographic signs of significant pulmonary hypertension (sPAP > 50 mm Hg) in 20% of the sample (n = 23).

Significant differences were found on RV function according to flow state with patients with LF AS showing significant lower values of both TAPSE and S`lateral tricuspid annular velocities (Table 3).

In the overall population, prevalence of RV dysfunction according to the different parameters was as follows: 13.9% TAPSE < 17 mm, 26.3% RV fractional area change of <35% RV, and 41.2% RV-S`TDI < 9.5 cm/s. RV dysfunction was observed in 48.7% for both RV-GLS and RV-FWS < [20] (Figure 2). At 1 year, in the overall population, significant improvements were observed in the RV fractional area change (*P* = .048) and RV-FWS (*P* = .014), without any differences in the rest of the parameters. The prevalence of patients with RV dysfunction was 13.9% with TAPSE < 17 mm before TAVI vs 6.8% after TAVI (*P* = .04), 26.3% RV fractional area change of < 35% before TAVI vs 20% after TAVI (*P* = .048), 41.2% RV-S`TDI < 9.5 cm/s before TAVI vs 29.2% after TAVI (*P* = .04), 48.7% for RV-GLS < [20] before TAVI vs 39.5% after TAVI (*P* = .049), and 48.7% for RV-FWS < [20] before TAVI vs 28.9% after TAVI (*P* = .03).

In the subgroups analysis by normal-flow/ low-flow populations, at 1 year, a significant change in RV-FWS only in the normal-flow population was noted (−20.2 ± 5.3 vs −23 ± 5.5, *P* < .05) without any significant changes in the rest of the parameters (Table 4). Prevalence of RV dysfunction according to the different parameters for both basal and 1 year after TAVI is shown in Figure 2.

4 | DISCUSSION

Our study shows a high prevalence of RV dysfunction among symptomatic AS patients undergoing TAVI and the different prevalence according to different echocardiographic parameters. This

TABLE 1 Clinical characteristics of the sample

Demographic, clinical, and echocardiographic characteristics	
Clinical data	
Age, years	83.73 ± 6.31
Female, n (%)	43 (38.2)
NYHA > II n (%)	76 (67,1)
Euroscore 2	3.67 ± 2.96
Hypertension n (%)	91 (80.3)
Diabetes n (%)	37 (32.9)
Dyslipidemia n (%)	67 (59.2)
Smokers n (%)	4 (3.9)
Pulmonary disease n (%)	25 (22.4)
Chronic kidney disease n (%)	21 (18.4)
Coronary artery disease n (%)	18 (15.8)
Atrial fibrillation n (%)	40 (35.5)
ACE inhibitors n (%)	72(63.2)
Beta blockers n (%)	46 (40.8)
Diuretics n (%)	61 (53.9)

Abbrevaitions: ACE, angiotensin-converting enzyme; NYHA, New York Heart Association functional class.

TABLE 2 Echocardiographic characteristics of the sample

Echocardiographic data (n = 114)	
LVEF (Simpson) %	59 ± 15
Low flow n (%)	25 (22.5)
Peak aortic gradient (mm Hg)	74 ± 25
Mean aortic gradient (mm Hg)	41 ± 15
Aortic valve area (cm^2)	0.66 ± 0.15
RV function	
Basal Diam RV (mm)	37 ± 10
TAPSE (mm)	21 ± 5
Fractional area change (%)	44 ± 12
S' lateral tricuspid annulus (cm/s)	10.5 ± 3
RV-GLS	−19.6 ± 5.6
RV-FWS	−20 ± 5.7
sPAP (mm Hg)	43 ± 14.8

Abbreviations: RV-FWS, right ventricular free wall strain; RV-GLS, right ventricular global longitudinal strain; sPAP, systolic pulmonary artery pressure; TAPSE, tricuspid annular plane systolic excursion.

TABLE 3 RV parameters

	NF (n = 88)	LF (n = 26)	*P*
Basal Diam RV (mm)	36 ± 9	40 ± 13	.15
TAPSE (mm)	22 ± 4.3	19 ± 4	.01
Fractional area change (%)	45 ± 12	39 ± 11	.04
S' lateral tricuspid annulus (cm/s)	11.5 ± 3	8 ± 2.2	.03
RV-GLS	−19.6 ± 5	−18 ± 5.2	.25
RV-FWS	−20 ± 5.3	−18 ± 5.3	.15
sPAP (mm Hg)	42 ± 15	43 ± 16	.90

Abbreviations: LF, low-flow aortic stenosis; LVEF, left ventricular ejection fraction; RV-FWS, right ventricular free wall strain; RV-GLS, right ventricular global longitudinal strain; sPAP, systolic pulmonary artery pressure; TAPSE, tricuspid annular plane systolic excursion.

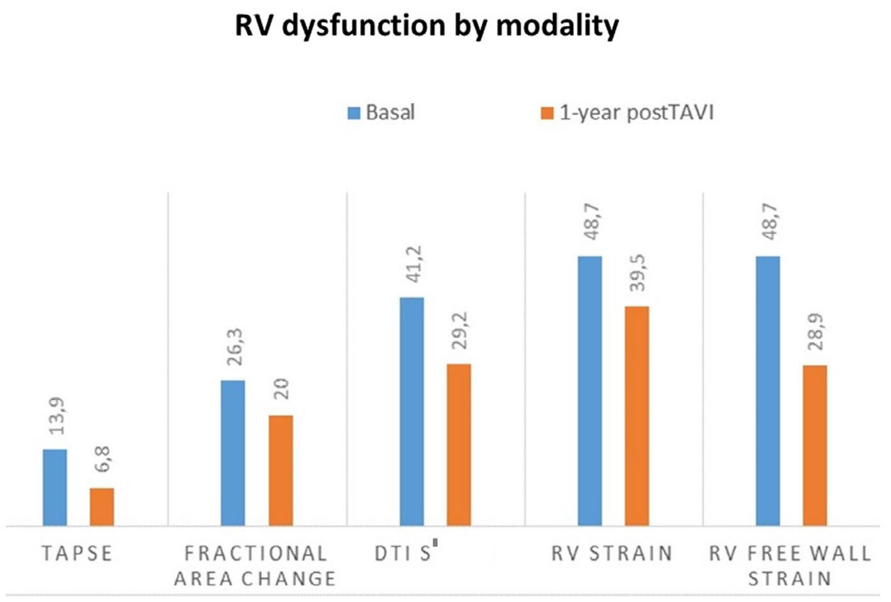

FIGURE 2 RV dysfunction by modality: at baseline and 1 y after TAVI. DTI S', S' lateral tricuspid annulus (cm/s); RV-FWS, right ventricular free wall strain; RV-GLS, right ventricular global longitudinal strain; TAPSE, tricuspid annular plane systolic excursion

TABLE 4 RV parameters in NF and LF groups

	NF (n = 88)			LF (n = 26)		
	basal	1 y	*P*	basal	1 y	*P*
TAPSE (mm)	22.1 ± 4.3	25.2 ± 10	.11	19.1 ± 4.3	21.4 ± 4.6	.08
Fractional area change (%)	45 ± 11.5	46 ± 16.1	.47	39 ± 11.5	43 ± 13.4	.39
S' lateral tricuspid annulus (cm/s)	11.5 ± 3.0	11.9 ± 3.7	.68	8 ± 2.2	8 ± 0.8	.82
RV-GLS	−19.6 ± 5.1	−22 ± 5.8	.18	−18 ± 5.2	−18.4 ± 6	.33
RV-FWS	−20.2 ± 5.3	−23 ± 5.5	.05	−18 ± 5.3	−19.4 ± 5.1	.15
sPAP (mm Hg)	42 ± 14.6	41 ± 13	.96	43 ± 16	47 ± 16	.31

Abbreviations: LF, low-flow aortic stenosis; LVEF, left ventricular ejection fraction; RV-FWS, right ventricular free wall strain; RV-GLS, right ventricular global longitudinal strain; sPAP, systolic pulmonary artery pressure; TAPSE, tricuspid annular plane systolic excursion.

prevalence is even higher in LF AS, probably reflecting a more advanced disease. After TAVI, prevalence of RV dysfunction decreases, reflecting a reversible condition that may influence prognosis and help in risk stratification.

For years, LV function has been the focus of interest in AS patients and limited data are available regarding the evaluation of RV performance. Galli et al[5] reported a prevalence of RV dysfunction of 24% that was associated with worst prognosis. The authors suggest that this finding may be explained by the RV–LV interdependence and not just by the LV dysfunction in late stages of the disease.

Prevalence and prognosis significance of RV dysfunction in patients undergoing TAVI have been a matter of debate in the last years. Regarding prognosis, two recent meta-analysis addressing this issue show similar results and it is well accepted now that the presence of RV dysfunction carries a higher mortality risk after TAVI.[15,16] Moreover, a recent study of more than 1000 patients, not included in the mentioned meta-analysis, confirms that RV dysfunction at baseline was associated with a more than twofold increased risk of cardiovascular death at 1 year after TAVI, with a gradient of risk according to RV recovery, being strongest independent predictor of 1-year cardiovascular mortality.

However, true prevalence of RV dysfunction and changes over time have not been fully studied. This is probably due to the fact that the different papers use diverse echocardiographic parameters to assess RV function and define RV dysfunction. Most of them rely on TAPSE or FAC with just two papers using a comprehensive echocardiographic evaluation or more advanced techniques. Asami et al[17] assessed RV function using TAPSE, FAC, and RV-S`TDI and define RV dysfunction if >50% of the available RV function parameters were below the lower cutoff value, reporting a prevalence of RV dysfunction of 29.1%. Furthermore, in this study they found that patients with RV dysfunction had a lower left ventricular ejection fraction at baseline (45.1 ± 16.5% vs 56.6 ± 12.5%; $P < .001$) and a lower mean transvalvular gradient (39.8 ± 17.7 vs 45.5 ± 17.3 mm Hg; $P < .001$). RV function tended to normalize in 57% in patients with impaired RV function at baseline after TAVI.

In the same line, Medvedofsky et al[18] evaluated changes in right cardiac chambers after TAVI using speckle tracking strain. Baseline mean RV strain values are reported for the first time in this type of patients which remain stable 1 year after TAVI.

To the best of our knowledge, this is the first time RV assessment is performed combining conventional and advanced echocardiographic parameters for the analysis of RV function in patients undergoing TAVI. As expected, different prevalence of RV dysfunction may be stablished according to the analyzed items and no single parameters is probably enough to establish RV dysfunction. In the study of Keyl et al,[9] the longitudinal component has been found to be reduced after cardiac surgery, although RV ejection fraction has not show significant changes. Our results are in line with previous publications that support the fact that deformation imaging is a more sensitive parameter to detect myocardial dysfunction compared with traditional echocardiographic assessment. In fact, recent studies suggested that RV-GLS assessed by speckle tracking better correlates with RV ejection fraction measured by cardiac magnetic resonance as compared with other echocardiographic parameters of RV function such as TAPSE, RV-S'TDI, or myocardial performance index.[10,11] RV ejection fraction and RV volumes assessed by 3D echocardiography have been regarded as standard evaluation of RV function, but we do not have this parameter and it constitutes a major limitation of the study.

Taking into account the proven prognosis significance of RV dysfunction in TAVI patients, our results rise the question of which parameter or combination of parameters best define RV dysfunction and helps in patients' risk stratification. Probably, as suggested by other authors,[8] RV function should be evaluated as a continuous variable with different levels of risk as the RV function decreases. Prognosis data on the different parameters and the combination of them should help in the clinical management of this patient to better define risk and decide optimal TAVI moment.

Regarding changes on RV function over time after TAVI, our results support a favorable effect of the procedure on RV function. Even though RV-FWS in the only parameter showing significant improvement after 1 year in the normal-flow group, there seems to be a trend toward improvement in all of them and prevalence of RV dysfunction decrease at 1 year as shown in Figure 1. It is interesting to analyze the RV in low-flow patients, since they seem to have baseline worst RV function compared with normal-flow patients without significant changes in the follow-up. However, the number of patients is small and further studies are needed to address changes in RV function in these patients and its role in risk stratification. Anyhow, taking into account the well-known influence of overt cardiac surgery on RV function, our data may suggest that TAVI could be a better option than surgery for patients that have RV dysfunction at baseline.

In conclusion, the presence of RV dysfunction in patients with symptomatic severe AS undergoing TAVI is high and decreases 1 year after TAVI. Prevalence of RV dysfunction assessed with echocardiography is highly variable depending on the parameter used. Strain imaging of the RV seems to be the more sensitive tool to detect RV dysfunction but its prognostic role need to be further studied.

CONFLICT OF INTEREST

The authors have no conflict of interest.

ETHICAL APPROVAL

This article does not contain any studies with human participants performed by any of the authors.

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