Usefulness of Longitudinal Strain to Assess Remodeling of Right and Left Cardiac Chambers Following Transcatheter Aortic Valve Implantation

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Remodeling after transcatheter aortic valve implantation (TAVI) has been well characterized for the left ventricle (LV) but not for the other cardiac chambers. We aimed to describe conventional indices of cardiac remodeling and novel longitudinal strain (LS) in all 4 cardiac chambers post-TAVI and to explore gender remodeling disparities. Consecutive patients with significant aortic stenosis who underwent TAVI were included if echocardiograms in sinus rhythm before and 1-year postprocedure were available. Speckle tracking analysis was performed retrospectively to evaluate size and function of the 4 cardiac chambers. Baseline and 1-year data were compared. From a total of 612 patients who underwent TAVI, 213 were included in this study (82 ± 9 years old, 42% men). Although no significant size or function changes were seen for right cardiac chambers at follow-up, significant improvements were seen for ejection fraction (EF) and LS in both the LV and left atrium (LA) ($p < 0.05$ for both). The absolute percentage of LV and LA function improvement was higher for LS than for EF ($p < 0.05$). Women had smaller LV and right ventricular (RV) size, whereas parameters of LV and RV function were higher. All 1-year remodeling parameters were similar for men and women. Conventional LV remodeling parameters (LV mass) failed to improve 1 year after TAVI. However, novel strain-derived parameters of size and function showed remodeling of left chambers but not of RV or right atrium. The degree of LV and LA remodeling by LS is almost twice that of EF. Remodeling was similar for both genders. **(Am J Cardiol 2019;124:253−261)**

Transcatheter aortic valve implantation (TAVI) is an option for patients with severe aortic stenosis (AS) who are inoperable or at high and intermediate surgical risk.[1−3] Cardiac chamber adaptation to high left ventricular (LV) afterload due to AS develops gradually including LV hypertrophy, stiffness,[4,5] diastolic, and systolic heart failure, leading to chamber dilatation and death.[6,7] Echocardiography is the most widely used modality to evaluate chamber quantification after TAVI. Longitudinal strain (LS) detects subtle changes in LV function that precede those of ejection fraction (EF)[8,9] and is associated to cardiovascular outcomes.[8,10−13] LV reverse remodeling is expected after TAVI,[14−19] but previous reports were limited to classic parameters: mass, volumes, and EF. Sparse data exist about the effect of TAVI on LS of the left atrium[16,20] and right ventricle.[21−23] A detailed gender comparison including LS has not been reported to date. We sought to assess echocardiographically the post-TAVI remodeling process of 4 cardiac chambers by classic and novel parameters, and to explore gender differences.

Methods

Consecutive patients with severe symptomatic AS who were at high or extreme surgical risk and underwent TAVI at MedStar Washington Hospital Center from May 2007 to March 2014 were considered for the present study. Patients were included if an echocardiogram at baseline (0 to 4 months before) and 1-year postprocedure were both available for LV speckle tracking echocardiography (STE) analysis. Sinus rhythm during the echocardiographic acquisition was an inclusion criterion, and the presence of a pacemaker or poor-quality image were considered exclusion criteria. In all echocardiograms, the goal was to perform STE analysis for the 4 cardiac chambers. The local Institutional Review Board approved this study, and informed consent was obtained from each patient.

Prespecified clinical, procedural, and laboratory data were prospectively collected for all patients during screening, on admission, immediately postprocedure, and during follow-up. Data collection at baseline included demographic information, medical history, clinical data, basic laboratory tests, and Society of Thoracic Surgeons (STS) scores. Long-term follow-up was standardized according to our hospital valve team practices and included a 12-month follow-up visit with clinical and transthoracic

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echocardiographic evaluations. Clinical events were adjudicated by an independent cardiologist, who determined the nature of the event.

All transthoracic echocardiograms were prospectively acquired and analyzed by board-certified echocardiographers following a standard protocol as recommended by the American Society of Echocardiography.[24] Among others, conventional echocardiographic parameters (Xcelera, Philips, Netherlands) included LV outflow tract (pulse-wave Doppler) and aortic velocities (continuous-wave Doppler), their derived gradients and aortic valve area. LV mass was calculated using the based linear cube formula and indexed to body surface area as recommended by current guidelines.[24]

In addition to the conventional echocardiographic measurements, volumetric and myocardial deformation analyses were performed according to the recommendation of the American Society of Echocardiography and European Association of Cardiovascular Imaging.[9,24,25] Analyses were performed retrospectively using a commercially available semi-automated algorithm with a dedicated application for each ventricle, whereas a single atrial analysis tool was used for both atria (cardiac performance analysis on TOMTEC-Arena, TomTec imaging systems. Unterschleissheim, Germany). LV analysis included the 4-, 3-, and 2-chamber views, right ventricular (RV) analysis was performed in the RV focused view, and left and right atrial tracings were performed in the 4-chamber view (Figure 1). The first steps of analysis involved manual definition of the end-diastolic and end-systolic frames. Then, 2 mitral or tricuspid annular points were marked in each of the views, and an additional point was placed to mark either the ventricular apex for ventricular analysis, or the most distal point on the atrial roof for the atrial analysis. The endocardial border was automatically generated and then tracked throughout the cardiac cycle using speckle tracking technology. Manual corrections were performed interactively to optimize boundary position as necessary. RV LS was defined as recommended by guidelines, including the free wall and excluding the septal component, as the latter is mostly affected by the left ventricle.[9,24,25] Myocardial deformation-derived curves were generated, and peak LS was recorded for each chamber (Figure 2).

Continuous variables are expressed as mean ± SD or median and compared with 2 sample *t* test. Categorical variables are expressed as numbers and percentages and compared with Chi-square test or Fisher exact test as appropriate. Delta changes of volumetric and strain parameters from baseline to 1 year of follow-up were determined using paired Student's *t* test or Wilcoxon signed-rank test as appropriate. Changes over time were defined as a delta change of >±5% from the baseline value. Cox regression analysis was performed to assess association of LV global LS with 1-year mortality.

Statistical analysis was performed with SAS version 9.4 (SAS Institute Inc., Cary, North Carolina) and a p value <0.05 was considered significant.

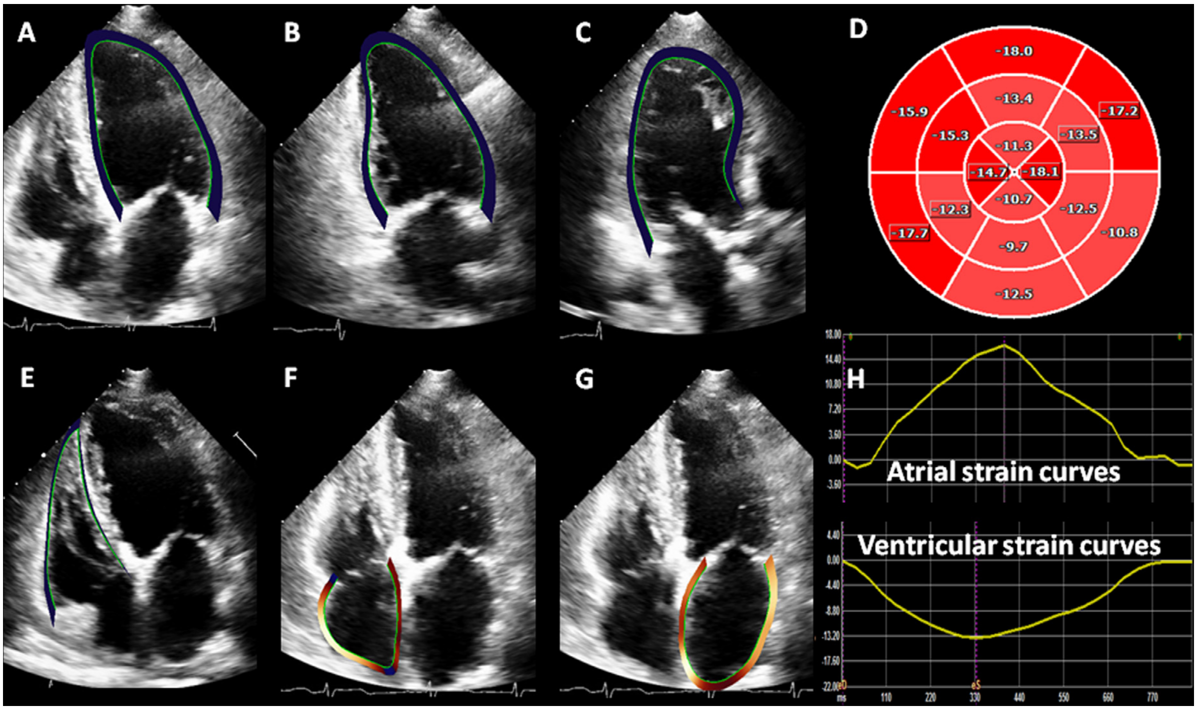

Figure 1. Representative example of 4 cardiac chambers size and function. Speckle tracking analyses (2D-CPA, TomTec) of the left ventricle are performed in 4-, 2-, and 3-chamber views, from which volumes, ejection fraction, and global longitudinal strain are derived (A-C). In addition, a bull's-eye plot of myocardial deformation is created (D). Right ventricular analysis is performed in the right ventricular focused view (E). Tracings of the RV include both the free-wall and septum, but only the free-wall represents right ventricular strain analysis, as the septal component is expressed as part of the left ventricular analysis. Right and left atrial size and function analysis are performed in the 4-chamber view (F and G). Representative longitudinal strain curves throughout the cardiac cycle are shown (H), both for atrial (top) and ventricular (bottom) chambers. Of note, whereas atrial longitudinal strain analysis generates positive values, those for ventricular chambers are negative.

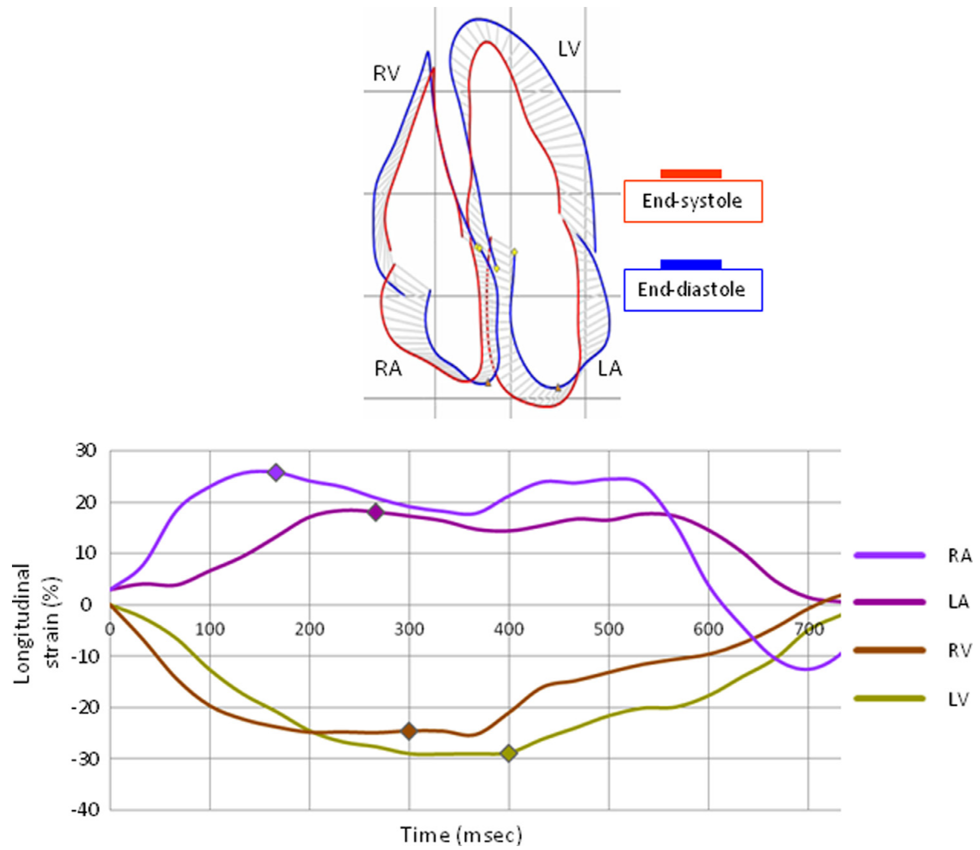

Figure 2. Example of 4-chamber strain analysis. Top: Superimposed end-diastolic (blue) and end-systolic (red) endocardial borders for the 4 cardiac chambers. Bottom: Example of myocardial deformation-derived curves. Peak longitudinal strain was recorded for each chamber. LA = left atrium; LV = left ventricle; RA = right atrium; RV = right ventricle. Figure generated with assistance from Berthold Klas (TOMTEC). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Results

A total of 612 consecutive patients who underwent TAVI at our institution from 2007 to 2014 had a baseline echocardiogram available and were considered for this analysis. Figure 3 details the flow chart of inclusion for

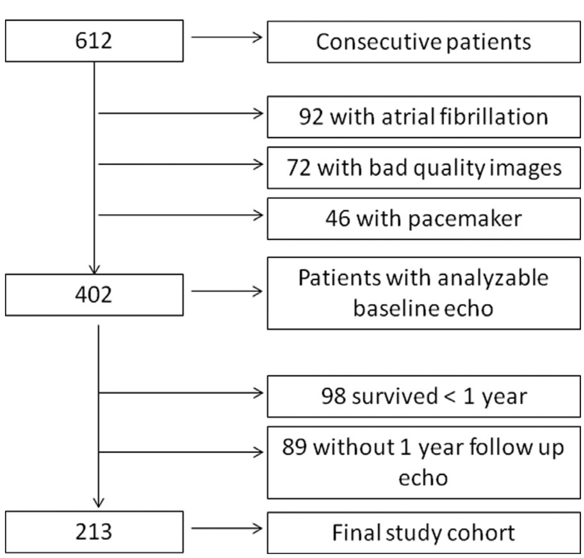

Figure 3. Flow chart of inclusion criteria of the study.

this study. Ninety-two patients were excluded because of atrial fibrillation, 72 for the presence of a pacemaker, and 46 for poor-quality images precluding speckle tracking analysis of the left ventricle. Of the remaining 402 patients who had a qualifying baseline echocardiogram, only 213 had a 1-year follow-up echo in normal sinus rhythm and, accordingly, represent our study cohort for this analysis (35% of the entire TAVI cohort). Feasibility of speckle tracking analysis of the left cardiac chambers was higher than right chambers, and that of the ventricles was higher than the atria: LV was 100%, LA 88%, RV 77%, and right atrium (RA) 68%.

From the 402 patients with baseline analyzable echocardiograms, at 1-year follow-up, 304 were alive and 98 had died. No significant differences were seen between survivors and nonsurvivors regarding age, race, and most of the clinical co-morbidities except that survivors had a higher body mass index, higher prevalence of hypertension and hyperlipidemia, and lower STS scores (Table 1, left columns). In addition, survivors had higher transaortic valve mean gradient and LV mass (Table 2, left columns). LV EF and global LS were similar between survivors (60 ± 12% and −20.3 ± 5%, respectively) and nonsurvivors (60 ± 13% and −19.9 ± 5%, respectively, $p = 0.45$). To evaluate whether baseline LV global LS was associated with mortality, an unadjusted Cox regression analysis

Table 1
Baseline characteristics

Variable	Entire cohort (n = 402)	Dead (n = 98)	Alive (n = 304)	Entire cohort p value	Paired (n = 213)	Paired females (n = 123)	Paired males (n = 90)	Paired patients p value
Age (years)	83 ± 8	84 ± 7	83 ± 8	0.30	82 ± 9	83 ± 8	81 ± 9	0.03
Race								
Black	52 (13%)	11 (11%)	43 (14%)	0.46	32 (15%)	22 (18%)	9 (10%)	0.11
White	342 (85%)	87 (89%)	255 (84%)	0.24	177 (83%)	98 (80%)	77 (86%)	0.28
Other	8 (2%)	0 (0%)	6 (2%)	1.00	4 (2%)	3 (2%)	4 (4%)	0.52
Body mass index (Kg/m^2)	27 ± 6	26 ± 6	28 ± 6	<0.01	28 ± 6	28 ± 7	28 ± 5	0.31
Hypertension	378 (94%)	90%	96%	0.03	204 (96%)	116 (94%)	88 (98%)	0.31
Diabetes Mellitus	137 (34%)	30%	36%	0.25	75 (35%)	44 (36%)	31 (34%)	0.79
Hyperlipidemia	318 (79%)	72%	82%	0.04	175 (82%)	98 (80%)	77 (85%)	0.13
Chronic lung disease	137 (33%)	37%	32%	0.39	62 (29%)	30 (24%)	32 (36%)	0.06
Chronic Renal failure	197 (49%)	56%	46%	0.11	99 (46%)	49 (40%)	50 (55%)	0.03
Prior percutaneous coronary intervention	125 (31%)	31%	31%	0.93	61 (29%)	28 (23%)	33 (37%)	0.03
Prior bypass surgery	125 (31%)	29%	32%	0.67	72 (34%)	21 (17%)	51 (57%)	<0.01
Prior myocardial infarction	80 (20%)	25%	18%	0.13	33 (16%)	16 (13%)	17 (19%)	0.11
NYHA III/IV (%)	88%	93%	87%	0.12	181 (85%)	103 (84%)	78 (87%)	0.51
Prior valvuloplasty	32%	35%	31%	0.59	61 (29%)	39 (32%)	22 (24%)	0.20
STS score	9.0 ± 4.6	9.8 ± 4.8	8.7 ± 4.5	0.04	8.8 ± 4.7	9.4 ± 4.7	8.0 ± 4.5	0.04
BNP (pg/ml)	540 ± 673	665 ± 825	495 ± 607	0.21	503 ± 580	560 ± 695	414 ± 323	0.18

Results are shown by mean and SD, or number and percentage of patients when appropriate.
BNP = brain natriuretic peptide; NYHA = New York Heart Association; STS = Society of Thoracic Surgeons (STS) score.

was performed. This analysis showed that no association was found between baseline LV global LS and 1-year mortality (hazard ratio 1.02 [confidence interval 0.98 to 1.06]; p = 0.41).

Evaluation of left and right cardiac chamber remodeling at 1 year included 213 patients with both baseline and follow-up analyzable echocardiograms: Patients were 82 ± 9 years old, 42% were male, and their body mass index was 28 ± 6. Table 1, right columns show baseline characteristics and comparisons in genders: Women were older and had higher STS scores, and fewer had renal failure, peripheral vascular disease, prior coronary intervention, or bypass surgery. Baseline conventional echocardiographic characteristics are presented in Table 2, right columns. Women had smaller LV outflow tract diameter and higher mean transaortic valve gradient than men did. Although aortic valve area and LV mass were smaller for women, these differences became nonsignificant after being indexed for body surface area (aortic valve area index and LV mass index).

Baseline speckle tracking-derived echocardiographic comparisons between genders are shown in Table 3. Women had smaller LV indexed volumes (end-diastolic volume index (EDVi) and end-systolic volume index (ESVi)) and higher EF than men, whereas global LS and indexed stroke volume were similar between genders. LA

Table 2
Conventional echocardiographic characteristics at baseline

Variable	Entire cohort (n = 402)	Dead (n = 98)	Alive (n = 304)	Entire cohort p value	Paired (n = 213)	Paired females (n = 123)	Paired males (n = 90)	Paired patients p value
Aortic insufficiency > moderate	0 (0%)	0 (0%)	0 (0%)	1.0	0 (0%)	0 (0%)	0 (0%)	1.0
Mitral regurgitation > moderate	4 (1.1%)	0 (0%)	4 (1.4%)	0.58	2 (1%)	1 (0.9%)	1 (1.3%)	1.0
Tricuspid regurgitation > moderate	5 (1.4%)	1 (1.1%)	4 (1.4%)	1.0	3 (1.5%)	2 (1.7%)	1 (1.2%)	1.0
Pulmonary artery systolic pressure (mm Hg)	45 ± 16	46 ± 17	45 ± 16	0.56	45 ± 17	46 ± 18	43 ± 16	0.27
Aortic valve area (cm^2)	0.66 ± 0.13	0.66 ± 0.14	0.66 ± 0.13	0.97	0.67 ± 0.13	0.64 ± 0.13	0.71 ± 0.12	<0.01
Aortic valve area index (cm^2/m^2)	0.37 ± 0.07	0.38 ± 0.08	0.36 ± 0.07	0.07	0.37 ± 0.07	0.37 ± 0.08	0.37 ± 0.06	0.50
Mean gradient (mm Hg)	49 ± 13	46 ± 13	50 ± 13	0.049	49 ± 14	52 ± 15	46 ± 11	<0.01
LVOT diameter (mm)	1.95 ± 0.2	1.94 ± 0.2	1.96 ± 0.2	0.57	1.96 ± 0.2	1.89 ± 0.2	2.05 ± 0.2	<0.01
Mitral annulus calcification above moderate	144 (36%)	32 (33%)	112 (37%)	0.54	65 (35%)	49 (45%)	16 (21%)	<0.01
LVEDd (mm)	4.4 ± 0.7	4.4 ± 0.7	4.5 ± 0.7	0.29	4.5 ± 0.7	4.3 ± 0.6	4.7 ± 0.7	<0.001
LVESd (mm)	3.1 ± 0.8	3.0 ± 0.8	3.1 ± 0.9	0.52	3.1 ± 0.9	2.8 ± 0.8	3.4 ± 0.9	<0.001
LV mass (grams)	209 ± 71	192 ± 68	214 ± 72	0.04	214 ± 60	200 ± 53	235 ± 64	<0.01
LV mass index (grams/m^2)	115 ± 33	108 ± 32	117 ± 34	0.09	119 ± 31	116 ± 30	122 ± 32	0.27

Results are shown by mean and SD, or number and percentage of patients when appropriate.
LV = left ventricular; LVEDd = LV end-diastolic diameter; LVESd, LV end-systolic diameter; LVOT = LV outflow tract.

Table 3
Comparison by gender of baseline, 1-year follow-up, and change overtime (%Delta) of size and function parameters of all 4 cardiac chambers by speckle tracking echocardiographic analysis

Variable		Baseline			1-Year post-TAVR			%Delta		
		Female	Male	p Value	Female	Male	p Value	Female	Male	p Value
LV	EDVi (ml)	57 ± 20	68 ± 28	<0.01	55 ± 20	70 ± 27	<0.01	1 ± 35	8 ± 37	0.57
	ESVi (ml)	22 ± 13	31 ± 19	<0.01	20 ± 11	29 ± 17	<0.01	3 ± 51	5 ± 45	0.81
	EF (%)	63 ± 11	58 ± 12	<0.01	66 ± 10	61 ± 11	<0.01	8 ± 18	7 ± 20	0.99
	SVi (ml)	35 ± 10	37 ± 12	0.10	36 ± 12	41 ± 13	0.01	6 ± 32	17 ± 47	0.52
	Global LS (%)	−21 ± 5	−20 ± 5	0.14	−23 ± 4	−21 ± 4	<0.01	14 ± 21	11 ± 17	0.18
LA	EDVi (ml)	28 ± 14	26 ± 11	0.20	26 ± 15	23 ± 10	0.04	1 ± 44	7 ± 47	0.30
	ESVi (ml)	50 ± 19	47 ± 15	0.26	48 ± 19	44 ± 16	0.14	3 ± 39	3 ± 36	0.61
	EF (%)	45 ± 11	45 ± 9.9	0.56	47 ± 12	49 ± 10	0.16	8 ± 24	14 ± 33	0.24
	SVi (ml)	−21 ± 8	−21 ± 8	0.70	−22 ± 9	−21 ± 8	0.86	10 ± 49	11 ± 51	0.26
	LS (%)	19 ± 5	20 ± 6	0.09	21 ± 6	23 ± 6	0.18	19 ± 26	18 ± 30	0.34
RV	EDAi (cm^2)	11 ± 3	12 ± 3	0.04	11 ± 3	13 ± 4	0.05	4 ± 27	4 ± 34	0.86
	ESAi (cm2)	5.6 ± 2	6.9 ± 3	<0.01	5.5 ± 2	7.0 ± 3	<0.01	6 ± 37	4 ± 42	0.79
	FAC (%)	51 ± 10	44 ± 9	<0.01	52 ± 8	46 ± 10	<0.01	5 ± 24	6 ± 26	0.78
	FW LS (%)	−27 ± 7	−24 ± 7	<0.01	−28 ± 5	−24 ± 6	<0.01	6 ± 26	8 ± 28	0.61
RA	EDVi (ml)	15 ± 9	18 ± 11	0.09	15 ± 10	19 ± 12	0.03	9 ± 56	16 ± 56	0.81
	ESVi (ml)	27 ± 13	30 ± 15	0.19	28 ± 14	32 ± 15	0.11	10 ± 49	13 ± 49	0.73
	EF (%)	44 ± 13	42 ± 15	0.22	46 ± 13	40 ± 15	0.03	2 ± 112	8 ± 51	0.49
	SVi (ml)	−12 ± 6	−12 ± 6	0.93	−13 ± 7	−13 ± 7	0.98	13 ± 111	22 ± 77	0.48
	LS (%)	28 ± 8	24 ± 8	<0.01	29 ± 8	24 ± 7	<0.01	7 ± 35	7 ± 42	0.97

EDVi = end-diastolic volume index; EDAi = end-diastolic area index; EF = ejection fraction; ESAi = end-systolic area index; ESVi = end-systolic volume index; FAC = fractional area change; FW = free wall; LA = left atrial; LS = longitudinal strain; LV = left ventricular; RA = right atrial; RV = right ventricular; SVi = stroke volume index; TAVR = transcatheter aortic valve replacement.

indexed dimensions and functional parameters (EF and LS) were similar for men and women. Similarly, RV dimensions were smaller and RV functional parameters (fractional area change and LS) were higher in women, whereas LS was the only RA parameter higher in women (indexed volumes and EF were similar).

There were no significant changes from baseline to 1-year follow-up on LV mass (214 ± 60 and 209 ± 58 g, respectively, $p = 0.09$) or LV mass index (119 ± 31 and 116 ± 31 g/m^2, $p = 0.09$).

Although no significant size or function changes were seen for right cardiac chambers at follow-up (Fig. 4), significant improvements were seen for EF and LS in both the LV and LA ($p < 0.01$ for both; Fig. 5). The improvement in both LV and LA EF resulted from a decrease in their minimum size (end-systole for the LV and end-diastole for the LA) with no change in their maximum size (end-diastole for LV and end-systole for LA). The percentage of LV and LA function improvement was higher for LS than for EF: % delta of LV EF improved 7 ± 19% and LV global LS 13 ± 20%, % delta of LA EF improved 11 ± 29% and LA LS 19 ± 27%, ($p < 0.05$ for both chambers, Table 4).

On paired comparisons of baseline and 1-year follow-up on a patient-by-patient basis (Table 4, right columns), there were more patients with improving than patients with worsening LA and LV dimensions, EF, and LS (changes defined as relative delta >5%). Global LS was more sensitive to detecting improvement (60% of cases improved LV LS and 64% improved LA LS), whereas lower percentages of cases had improvement of LA and LV function as determined by EF (51% for LV and 56% for LA). In contrast, RA and RV parameters showed similar numbers of cases improving and worsening.

Changes at 1 year were consistently similar for both genders, as all echocardiographic changes were similar in women and men (Table 3).

Discussion

The findings of our analysis are unique as, for the first time, 4-cardiac-chamber STE analyses in a TAVI population are reported. Our study has 4 main novel findings: First, that baseline LV global LS was not associated with 1-year mortality in this population; second, that TAVI results in remodeling and improvement in function of the left cardiac chambers (LV and LA), but not of the right chambers (RV and RA); third, that remodeling after TAVI was better detected with speckle tracking strain analysis than with conventional parameters such as LV mass; and fourth, that there are gender disparities on LV and RV size and function, but remodeling affects men and women similarly.

Four-cardiac-chamber remodeling 1 year after TAVI was reflected by improvement in left cardiac chambers function indices (EF and LS). The improvement in LV and LA EF could be secondary to enhanced contractility rather than their capacitance: The maximal volumes for each chamber did not change at 1-year follow-up (EDV for the LV and ESV for the LA); only the smaller volumes did (LV ESV and LA EDV). Furthermore, the functional improvement was volume independent, as shown by the myocardial deformation LV and LA strain analyses. Importantly, the degree of percent delta change for LV and atrial chambers by LS is almost twice that of EF. This finding can be explained by the superior capability of myocardial deformation analysis to detect subtle changes (more sensitive than EF[8]). Recently, Treibel et al explained

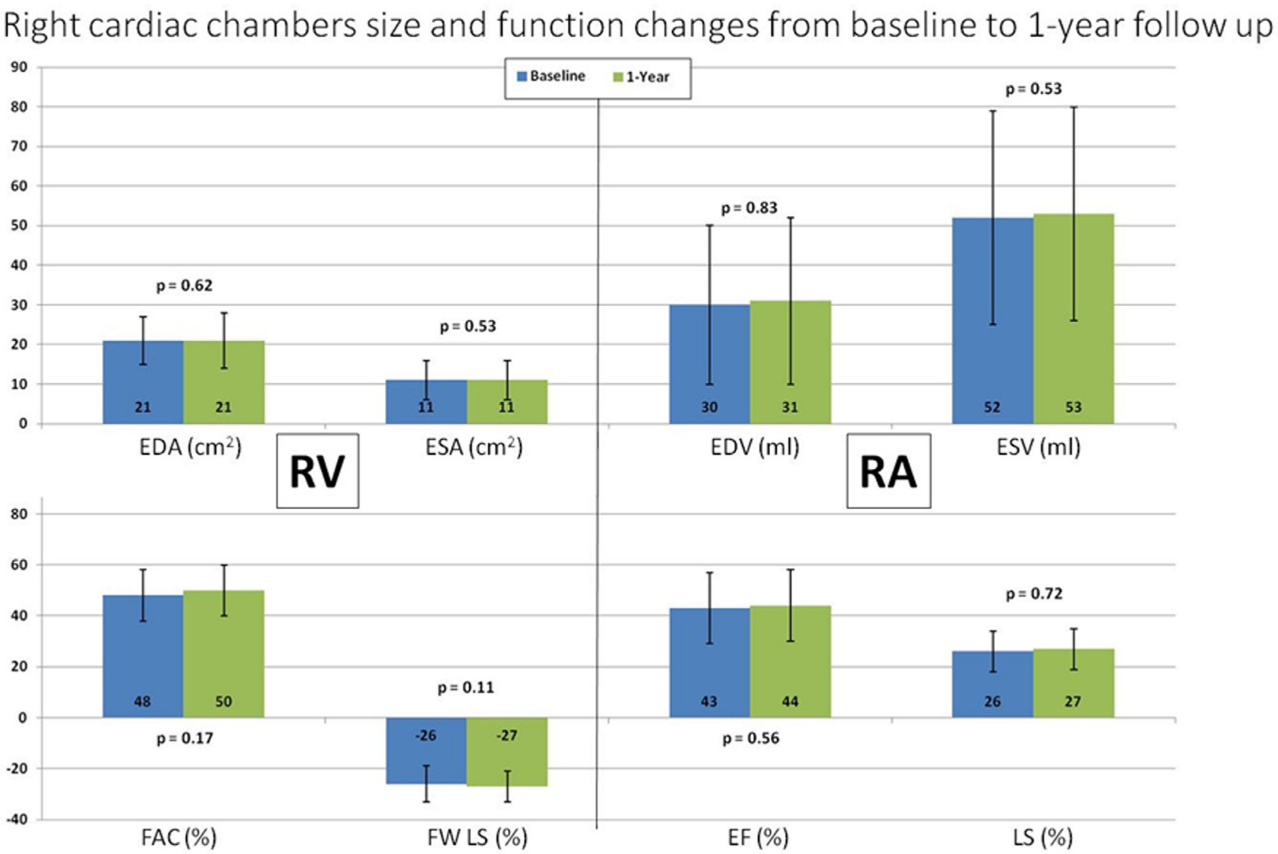

Figure 4. Size (top) and function (bottom) changes from baseline to 1 year of follow-up for both the right ventricle (left) and atrium (right). EDA = end-diastolic area; EDV = end-diastolic volume; EF = ejection fraction; ESA = end-systolic area; ESV = end-systolic volume; FAC = fractional area change; FW = free wall; LS = longitudinal strain; RA = right atrium; RV = right ventricle.

differences between myocardial fibrosis characteristics that can affect reverse myocardial remodeling assessed by cardiac magnetic resonance.[26] Although not proven in our study, it is possible that patients who failed to improve in our study suffered from extensive fibrosis that precluded an improvement in myocardial function as a parameter of remodeling.

Interestingly, no remodeling would be found in our study following the classic definition by LV mass. Indeed, no remodeling was found in previous publications when this definition was implemented.[19,27] However, our results show that remodeling over time with myocardial deformation analysis occurs after 1-year follow-up. This suggests that myocardial deformation indices could be better parameters to assess LV remodeling than the classic definition. Our results further show what previous studies suggested in LS analyses of single chamber (LV), or left heart only (LV and LA), or with a lower number of patients.

Our data on echocardiographic differences by gender build on previous reports on gender diversity in normal hearts and in TAVI.[24,28–30] Women presented smaller baseline absolute volumes for all 4 cardiac chambers, with superior indices of left and RV function (both EF and LS). Most of these gender disparities were present also at 1-year follow-up. Importantly, the effect of TAVI in remodeling of the 4 cardiac chambers was similar in men and women.

Left cardiac chambers feasibility was higher than right chambers, and the ventricular feasibility was higher than that of the atria. These findings are not surprising, as LV echocardiographic assessment is one of the main focuses of clinically indicated studies, especially for TAVI. Accordingly, LV STE analysis was selected as an inclusion criterion for our study. Moreover, ventricular assessment is still considered a priority over the atria in clinically indicated echocardiograms, despite the clear importance of atrial evaluation. Our feasibility findings cannot be extrapolated to clinically indicated studies performed for indications different from AS or TAVI evaluation, as those were the cases in this cohort.

Our study has some limitations. First, this is a retrospective analysis of single-center cohort and, accordingly, extrapolation of our results could be affected by local bias. Still, our hospital has a similar population and treatments to the vast majority of other TAVI referral medical centers and, accordingly, our results are relevant to the overall TAVI community. Second, patients with poor-quality echocardiographic images were excluded from this analysis, thus limiting the generalizability of our findings. Morbidly obese patients and those with suboptimal images caused by other conditions such as lung disease may not be adequately represented in our cohort. Accordingly, our results cannot be extrapolated to consecutive patients or outpatients with a

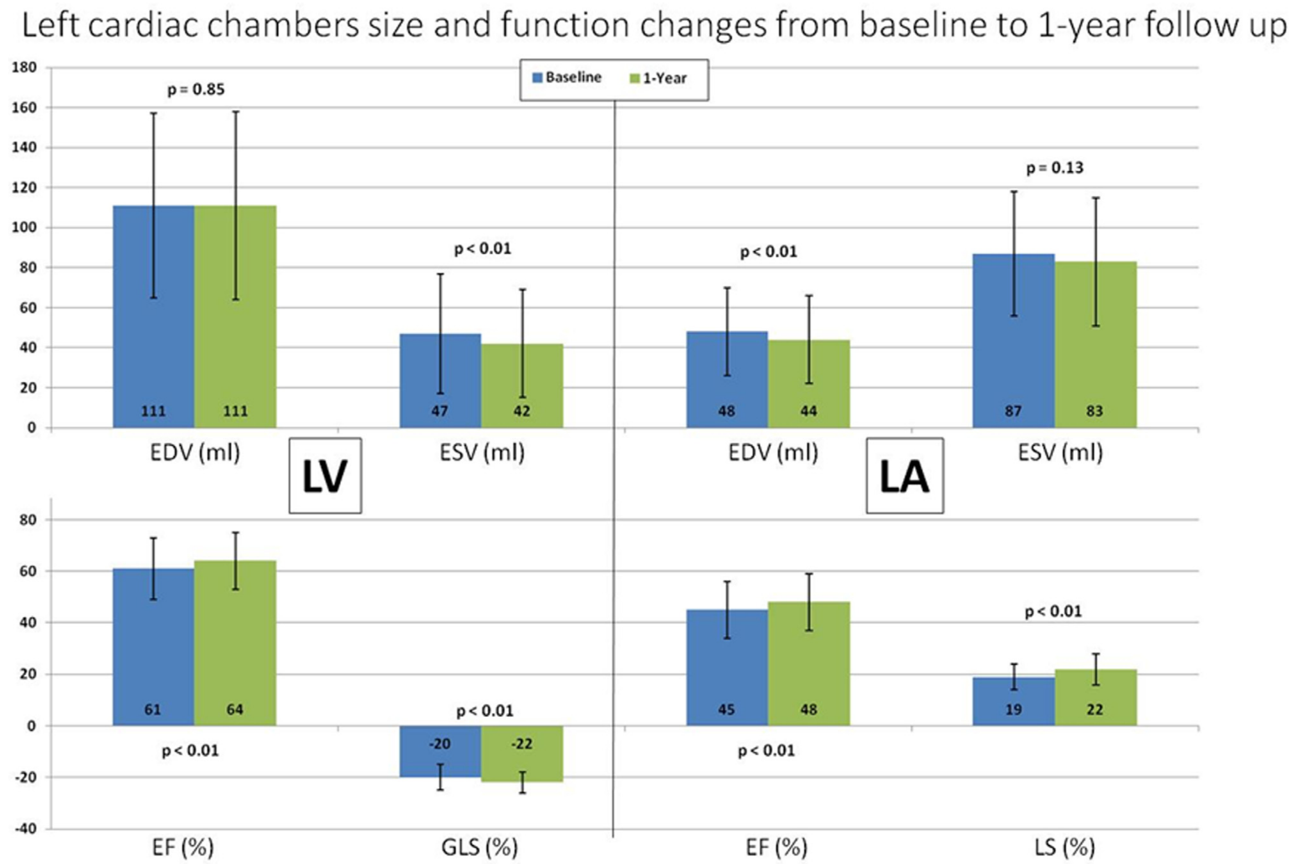

Figure 5. Size (top) and function (bottom) changes from baseline to 1-year follow-up for both the left ventricle (left) and atrium (right). EDV = end-diastolic volume; EF = ejection fraction; ESV = end-systolic volume; GLS = global longitudinal strain; LA = left atrium; , LS = longitudinal strain; LV = left ventricle.

Table 4
Cardiac remodeling of all 4 cardiac chambers by speckle tracking echocardiographic analysis

Variable		Baseline	1-Year post-TAVR	p Value	%Delta	% cases changed by ±5% (relative change) Worsened	No change	Improved
LV	EDVi (ml)	62 ± 24	61 ± 24	0.74	4 ± 36	46	10	44
	ESVi (ml)	26 ± 16	24 ± 15	<0.01	18 ± 48	39	11	50
	EF (%)	61 ± 12	64 ± 11	<0.01	7 ± 19	22	27	51
	SVi (ml)	36 ± 11	38 ± 13	0.02	11 ± 39	35	13	52
	Global LS (%)	−20 ± 5	−22 ± 4	<0.01	13 ± 20	9	31	60
LA	EDVi (ml)	27 ± 13	25 ± 13	<0.01	2 ± 45	38	9	53
	ESVi (ml)	49 ± 17	46 ± 18	0.07	7 ± 37	35	14	51
	EF (%)	45 ± 11	48 ± 11	<0.01	11 ± 29	31	13	56
	SVi (ml)	−21 ± 8	−22 ± 8	0.49	10 ± 50	48	10	42
	LS (%)	19 ± 5	22 ± 6	<0.01	19 ± 27	11	25	64
RV	EDAi (cm2)	12 ± 3	12 ± 3	0.62	5 ± 39	44	20	36
	ESAi (cm2)	6 ± 2	6 ± 2	0.76	4 ± 24	45	14	41
	FAC (%)	48 ± 10	50 ± 10	0.17	5 ± 25	40	20	40
	FW LS (%)	−26 ± 7	−27 ± 6	0.11	7 ± 26	47	12	41
RA	EDVi (ml)	17 ± 10	17 ± 11	0.99	11 ± 56	51	9	40
	ESVi (ml)	29 ± 14	29 ± 15	0.59	11 ± 49	46	14	40
	EF (%)	43 ± 14	44 ± 14	0.56	2 ± 94	42	16	42
	SVi (ml)	−12 ± 6	−13 ± 7	0.35	16 ± 99	45	7	48
	LS (%)	26 ± 8	27 ± 8	0.72	7 ± 30	35	20	45

Results are shown by mean and SD. Abbreviations as in Table 3.

wide range of image quality. Finally, this study only analyzed patients in sinus rhythm during imaging, excluding those in atrial fibrillation or with a pacemaker, who are a large proportion of patients post-TAVI.

In conclusion, our results are the first to evaluate remodeling of all 4 cardiac chambers post-TAVI. After 1 year, post-TAVI cardiac remodeling is reflected by improvement in left cardiac chambers function (EF and LS), whereas the degree of change by LS is almost twice that of EF. No size or function changes were noted for RV or RA, and remodeling was similar for both genders. Novel speckle tracking strain is more sensitive than conventional parameters to detect cardiac remodeling.

Disclosures

Federico M. Asch: Director of an academic core lab that has institutional contracts with Boston Scientific, Medtronic, St. Jude Medical/Abbott, Edwards Lifesciences, Biotronik, JenaValve and Livanova. Toby Rogers: Consultant: Medtronic; Proctor: Edwards Lifesciences. Ron Waksman − Advisory Board: Abbott Vascular, Amgen, Boston Scientific, Cardioset, Cardiovascular Systems Inc., Medtronic, Philips Volcano, Pi-Cardia Ltd.; Consultant: Abbott Vascular, Amgen, Biosensors, Biotronik, Boston Scientific, Cardioset, Cardiovascular Systems Inc., Medtronic, Philips Volcano, Pi-Cardia Ltd.; Grant Support: Abbott Vascular, AstraZeneca, Biosensors, Biotronik, Boston Scientific, Chiesi; Speakers Bureau: AstraZeneca, Chiesi; Investor: MedAlliance. All other authors report no relations that could be construed as a conflict of interest.

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