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Prognostic value of left ventricular remodeling phenotypes in patients undergoing transcatheter aortic valve implantation

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ABSTRACT

Aims: This study aimed to evaluate the impact of baseline left ventricular (LV) remodeling phenotypes on clinical and echocardiographic outcomes in patients undergoing transcatheter aortic valve implantation (TAVI).

Methods: A total of 413 patients with aortic stenosis (AS) who underwent TAVI between July 2011 and January 2024 were retrospectively analyzed. Based on echocardiographic parameters, patients were classified into concentric remodeling (CR, 7%), concentric hypertrophy (CH, 84.5%), and eccentric hypertrophy (EH, 8.5%) groups.

Results: Patients in the EH group were significantly younger (mean age: 76, p<0.001) and predominantly male (p<0.001). Prior myocardial infarction (MI) (p<0.001) and coronary artery bypass grefting (CABG) (p=0.003) were more common in this group. EH patients had the lowest baseline ejection fraction (EF) (p<0.001), highest left ventricular end diastolic dimension (LVEDD) and left ventricular end systolic dimension (LVESD) (both p<0.001), increased prevalence of low flow low gradient (LFLG) AS (p<0.001), and lower frequency of very severe aortic stenosis (VSAS) (p=0.005). At one-year follow-up, EH patients showed the most pronounced improvement in EF (+17.6%, p=0.002) and reduction in LVEDD (-7.3%, p=0.006). Permanent pacemaker implantation was highest in the EH group (28.6%) and significantly greater than in the CH group (p=0.022). No significant differences in in-hospital or one-year mortality were observed between groups (p>0.05).

Conclusion: LV remodeling patterns are strongly associated with reverse remodeling and conduction-related complications after TAVI. While EH patients show greater structural recovery, they are also at higher risk for post-procedural pacemaker implantation.

Keywords: Transcatheter aortic valve implantation, left ventricular remodeling, concentric hypertrophy, eccentric hypertrophy, permanent pacemaker, aortic stenosis

INTRODUCTION

Severe aortic stenosis (AS) leads to chronic left ventricular (LV) pressure overload, resulting in various patterns of myocardial remodeling such as concentric remodeling (CR), concentric hypertrophy, (CH) and eccentric hypertrophy (EH). These adaptations, while initially compensatory, may become maladaptive over time, contributing to myocardial fibrosis, systolic and diastolic dysfunction, and heart failure.[1-3]

Transcatheter aortic valve implantation (TAVI) effectively relieves afterload and may promote reverse remodeling-manifested by reductions in LV mass and improvements in systolic function.[4] However, the degree and prognostic relevance of reverse remodeling vary significantly among patients.[5]

Recent studies suggest that baseline LV geometry influences both the extent of reverse remodeling and clinical outcomes after TAVI.[6] Notably, concentric remodeling has emerged as the least favorable LV geometric pattern in terms of prognosis. In patients undergoing TAVI, this phenotype has been independently associated with a significantly higher risk of all-cause mortality at one year, despite comparable procedural outcomes.[7] These findings underline the prognostic relevance of preprocedural LV geometry in risk stratification.

Despite growing interest, limited data exist on how specific LV remodeling phenotypes affect reverse remodeling and outcomes after TAVI. This study aims to assess the association between baseline remodeling patterns, the extent of reverse remodeling, and their impact on clinical and echocardiographic outcomes in patients undergoing TAVI.

METHODS

Ethics

The study was carried out with the permission of the Gazi University President's Office Ethics Committee (Date: 14.07.2025, Decision No: 2025-1243). All procedures were

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carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

Study Design and Population

This retrospective observational study included patients who underwent TAVI for severe symptomatic aortic stenosis between July 2011 and January 2024. All procedures were performed via the transfemoral route. Patients were included if they had baseline and follow-up transthoracic echocardiographic (TTE) data available and had complete clinical outcome documentation. Exclusion criteria included valve-in-valve procedures, prior aortic valve surgery, and presence of incomplete echocardiographic data. The study has received approval from the local ethics committee and adheres to the Declaration of Helsinki.

Patient Evaluation and Procedure

All patients were evaluated by a multidisciplinary heart team including interventional cardiologists, cardiac imaging specialists, cardiovascular surgeons, and anesthesiologists. Preprocedural assessments included TTE and/or transesophageal echocardiography, coronary angiography, and multi-slice computed tomography to determine anatomical suitability for TAVI. The procedure was performed under fluoroscopic and echocardiographic guidance. Percutaneous closure systems (e.g., ProGlide or Prostar) were used in most cases, and patients received dual antiplatelet therapy or tailored anticoagulation regimens post-procedure depending on comorbid conditions.

Echocardiographic Analysis

TTE was performed before the procedure and repeated at follow-up (typically at 1 year) to assess cardiac structural and functional changes. LV dimensions, wall thickness, and left ventricular ejection fraction (LVEF) were measured according to current guideline recommendations. Changes in LVEF, left ventricular end-diastolic dimension (LVEDD), left ventricular end systolic dimension (LVESD) were calculated according to the baseline and follow up echocardiographic data. Changes in echocardiographic parameters at one year visit are calculated as delta left ventricular end-diastolic dimension (d-LVEDD) and d-LVEF separately according to the following equations;

d-LVEDD (%)=[(LVEDD at one year after TAVI-baseline LVEDD)/baseline LVEDD]*100

d-LVEF (%)=[(LVEF at one year after TAVI-baseline LVEF)/baseline LVEF]*100

Relative wall thickness (RWT) was calculated as RWT=[2 × posterior wall thickness (PWT)]÷LVEDD and Left Ventricular Mass Index (LVMI) as LVMI = 0.8 × [1.04 × (LVEDD + PWT + IVS)3 – LVEDD3)] + 0.6 and indexed to body surface area (BSA).

LV geometry was classified into three remodeling types based on LVMI and relative wall thickness (RWT): Concentric remodeling (normal LVMI, RWT >0.42), Concentric hypertrophy (increased LVMI, RWT >0.42), Eccentric hypertrophy (increased LVMI, RWT ≤0.42). Increased LVMI is defined as LVMI >95 g/m^2 for women and LVMI > 115 g/m^2 for men.

Outcomes and Follow-Up

Clinical and echocardiographic follow-up data were obtained at 1-year post-TAVI. The primary outcome was all-cause mortality. Secondary outcomes included symptomatic improvement in New York Heart Association (NYHA) class, rehospitalization for heart failure, and echocardiographic parameters of reverse remodeling.

Statistical Analysis

The distributional characteristics of continuous variables were initially assessed using the Kolmogorov-Smirnov test to determine conformity to normality. Homogeneity of variances was evaluated with Levene's test. Descriptive statistics were reported as mean±standard deviation, median (minimum-maximum), or median (25^{th}-75^{th} percentiles) for continuous variables, and as frequency (n) and percentage (%) for categorical variables. For group comparisons involving continuous variables that satisfied parametric assumptions, One-Way Analysis of Variance (ANOVA) was applied. In cases where assumptions of normality or homogeneity of variances were not met, the non-parametric Kruskal-Wallis test was employed. When a significant overall difference was detected, post-hoc pairwise comparisons were performed using Tukey's HSD or Dunn-Bonferroni tests, depending on the nature of the data. For categorical variables, Pearson's chi-square (χ^2) test was used unless otherwise specified. When more than 25% of cells in a 2x2 contingency table had an expected frequency below 5, Fisher's exact test was applied. In cases where expected frequencies ranged between 5 and 25, the continuity-corrected chi-square test was preferred. For RxC tables where one or both categorical variables had more than two levels, and expected frequencies fell below acceptable thresholds, the Fisher-Freeman-Halton test was used. All statistical analyses were conducted using IBM SPSS Statistics version 25.0 (IBM Corp., Armonk, NY, USA). A two-sided p-value of <0.05 was considered statistically significant. However, to control for type I error in multiple comparisons, Bonferroni correction was applied where appropriate.

RESULTS

A total of 413 patients aged between 52 and 103 years were included in the study. Of these, 7% (n=29) had CR, 84.5% (n=349) had CH, and 8.5% (n=35) had EH. All subsequent analyses and interpretations were conducted according to this grouping.

Table 1 presents descriptive statistics of baseline clinical characteristics. A significant difference was observed in mean age across the groups (p<0.001), primarily due to lower mean age in EH group compared to CR and CH groups (p<0.001). Gender distribution also differed significantly among groups (p<0.001), driven by a higher proportion of males and a lower proportion of females in EH group compared to CH group (p<0.001).

No significant differences were found among groups in anthropometric measurements (p>0.05). Similarly, there were no statistically significant differences in NYHA class, The Society of Thoracic Surgeons (STS) score, prior valve surgery, chronic obstructive pulmonary disease (COPD) severity,

Table 1. Baseline characteristics of the patients according to groups

	CR group (n=29)	CH group (n=349)	EH group (n=35)	p-value
Age (years)*	80.0±6.3[A]	77.9±7.7[B]	72.4±7.8[A,B]	<0.001[a]
Gender				<0.001[b]
Male	17 (58.6%)	142 (40.7%)[B]	26 (74.3%)[B]	
Female	12 (41.4%)	207 (59.3%)[B]	9 (25.7%)[B]	
Anthropometric characteristics				
Weight (kg)*	74.7±13.4	73.1±13.4	72.8±10.9	0.814[a]
Height (m)*	1.66±0.072	1.65±0.073	1.65±0.065	0.642[a]
Body-mass index (kg/m^2)*	27.1±4.4	26.9±4.4	26.7±3.8	0.940[a]
NYHA				0.538[c]
2	9 (31.0%)	98 (28.1%)	6 (17.1%)	
3	17 (58.6%)	190 (54.4%)	22 (62.9%)	
4	2 (6.9%)	54 (15.5%)	6 (17.1%)	
Pulmonary edema	1 (3.4%)	7 (2.0%)	1 (2.9%)	
STS score**	6.0 (3.3-7.5)	6.7 (5.3-8.4)	6.7 (5.5-8.5)	0.136[d]
Previous valve surgery	0 (0.0%)	8 (2.3%)	3 (8.6%)	0.113[c]
COPD				0.543[c]
None	20 (69.0%)	177 (50.7%)	16 (45.7%)	
Mild	1 (3.4%)	23 (6.6%)	1 (2.9%)	
Medium	6 (20.7%)	101 (28.9%)	11 (31.4%)	
Severe	2 (6.9%)	48 (13.8%)	7 (20.0%)	
Other co-morbidities				
CVA	1 (3.4%)	15 (4.3%)	2 (5.7%)	0.874[c]
PAH	4 (13.8%)	26 (7.4%)	3 (8.6%)	0.376[c]
DM	7 (24.1%)	106 (30.4%)	14 (40.0%)	0.363[b]
HT	24 (82.8%)	292 (83.7%)	29 (82.9%)	0.98
HPL	17 (58.6%)	181 (51.9%)	23 (65.7%)	0.249[b]
AF	5 (17.2%)	80 (22.9%)	9 (25.7%)	0.711[b]
Basal GFR**	67.0 (51.5-83.0)	65.0 (50.0-81.0)	65.0 (56.0-84.0)	0.553[d]
MI history	1 (3.4%)[A]	40 (11.5%)[B]	13 (37.1%)[A,B]	<0.001[c]
PCI history	6 (20.7%)	76 (21.8%)	12 (34.3%)	0.234[b]
CABG history	6 (20.7%)[A]	79 (22.6%)[B]	17 (48.6%)[A,B]	0.003[b]

Descriptive statistics are presented as * mean ± standard deviation or ** median (25th-75th percentile). a One-Way Analysis of Variance (ANOVA), b Pearson's χ^2 test, c Fisher-Freeman-Halton test, d Kruskal-Wallis test. A: The difference between CR group and EH group is statistically significant (p<0.05); B: The difference between CH group and EH group is statistically significant (p<0.01).
CR: Concentric remodeling, CH: Concentric hypertrophy, EH: Eccentric hypertrophy, NYHA: New York Hear Association, STS: Society of Thoracic Surgeons, COPD: Chronic obstructive pulmonary disease, CVA: Cerebrovascular accident, PAH: Peripheral artery disease, DM: Diabetes mellitus, HT: Hypertension, HPL: Hyperlipidemia, AF: Atrial fibrillation, GFR: Glomerular filtration rate, MI: Myocardial infarction, PCI: Percutaneous coronary intervention, CABG: Coronary artery bypass grefting

stroke, pulmonary hypertension, diabetes, hypertension, hyperlipidemia, or history of atrial fibrillation (p>0.05).

Baseline GFR levels were comparable across groups (p=0.553). However, there was a significant difference in the history of myocardial infarction (MI) (p<0.001), with EH group showing a higher prevalence compared to CR group (p=0.003) and CH group (p<0.001). No significant difference was observed in the history of stenting (p=0.234), but the prevalence of prior CABG was significantly higher in EH group than in CR group (p=0.040) and CH group (p=0.002) (p=0.003 overall).

Table 2 summarizes baseline echocardiographic findings. Baseline LVEF was significantly lower in both CH group and EH group compared to CR group (p<0.001), with EH group also having significantly lower LVEF than CH group (p<0.001).

LVEDD was significantly higher in CH group and EH group compared to CR group (p<0.001), and also significantly higher in EH group than CH group (p<0.001). LVESD showed a similar pattern, being significantly larger in CH group and EH group versus CR group (p<0.001), and significantly higher in EH group compared to CH group (p<0.001).

Septal and posterior wall thicknesses were significantly higher in CH group than in both CR and EH groups (p<0.001). Left atrial (LA) diameter was significantly greater in both CH group (p=0.008) and EH group (p<0.001) compared to CR group, and also significantly higher in EH group than in CH group (p<0.001).

Table 2. Baseline echocardiographic findings of the patients according to groups				
	CR group (n=29)	**CH group (n=349)**	**EH group (n=35)**	**p-value**
Basal EF*	65.0 (60.0-65.0)[A,B]	60.0 (45.0-65.0)[A,C]	30.0 (25.0-40.0)[B,C]	<0.001[a]
Basal LVEDD*	4.1 (3.8-4.2)[A,B]	4.6 (4.4-4.9)[A,C]	5.9 (5.5-6.4)[B,C]	<0.001[a]
Basal LVESD*	2.4 (2.2-2.6)[A,B]	2.9 (2.6-3.4)[A,C]	4.7 (4.0-5.3)[B,C]	<0.001[a]
Basal septum*	1.10 (1.05-1.30)[A]	1.40 (1.30-1.50)[A,C]	1.20 (1.10-1.30)[C]	<0.001[a]
Basal posterior*	1.10 (1.00-1.20)[A]	1.30 (1.20-1.40)[A,C]	1.10 (1.00-1.20)[C]	<0.001[a]
LVM*	157.4 (140.8-178.7)	251.4 (220.5-284.8)	276.3 (246.5-338.8)	n/a
RWT*	0.55 (0.48-0.63)	0.56 (0.51-0.62)	0.37 (0.32-0.40)	n/a
LVMI*	92.6 (82.8-105.1)	147.9 (129.7-167.6)	162.5 (145.0-199.3)	n/a
Basal LA*	4.3 (4.0-4.6)[A,B]	4.5 (4.3-4.9)[A,C]	4.9 (4.5-5.4)[B,C]	<0.001[a]
AS group				<0.001[b]
HG	24 (82.8%)	231 (66.2%)	25 (71.4%)	
LFLG	0 (0.0%)[B]	11 (3.2%)[C]	8 (22.9%)[B,C]	
Paradoxical LFLG	0 (0.0%)	4 (1.1%)	0 (0.0%)	
VSAS	5 (17.2%)	103 (29.5%)[C]	2 (5.7%)[C]	
Basal AoVel*	4.4 (4.1-4.8)[B]	4.5 (4.2-5.0)[C]	4.2 (3.8-4.3)[B,C]	<0.001[a]
Basal AVA*	0.68 (0.56-0.75)[B]	0.68 (0.53-0.80)[C]	0.80 (0.67-0.90)[B,C]	0.002[a]
Basal mean gradient*	49.0 (41.0-55.0)[B]	49.0 (42.0-60.0)[C]	41.0 (35.0-45.0)[B,C]	<0.001[a]
Basal PASB*	40.0 (31.0-55.0)	40.0 (34.0-55.0)	40.0 (30.0-55.0)	0.973[a]
Basal MR				0.766[b]
None	0 (0.0%)	4 (1.1%)	0 (0.0%)	
Trivial	7 (24.1%)	75 (21.5%)	8 (22.9%)	
1	14 (48.3%)	161 (46.1%)	15 (42.9%)	
2	7 (24.1%)	72 (20.6%)	5 (14.3%)	
3	1 (3.4%)	32 (9.2%)	7 (20.0%)	
4	0 (0.0%)	5 (1.4%)	0 (0.0%)	
Bazal AR				0.474[b]
None	8 (27.6%)	44 (12.6%)	5 (14.3%)	
Trivial	4 (13.8%)	51 (14.6%)	4 (11.4%)	
1	13 (44.8%)	181 (51.9%)	15 (42.9%)	
2	3 (10.3%)	59 (16.9%)	9 (25.7%)	
3	1 (3.4%)	9 (2.6%)	1 (2.9%)	
4	0 (0.0%)	5 (1.4%)	1 (2.9%)	
Bicuspid aorta	1 (3.4%)[B]	53 (15.2%)	9 (25.7%)[B]	0.048[c]

Descriptive statistics are presented as *median (25^{th}-75^{th} percentile). a Kruskal-Wallis test, b Fisher-Freeman-Halton test, c Pearson's χ^2 test. n/a: Not assessed. A: The difference between CR group and CH group is statistically significant (p<0.01); B: The difference between CR group and EH group is statistically significant (p<0.05); C: The difference between CH group and EH group is statistically significant (p<0.01).
EF: Ejection fraction, LVEDD: Left ventricular end-diastolic dimension, LVESD: Left ventricular end-systolic dimension, LVM: Left ventricular mass, RWT: Relative wall thickness, LVMI: Left ventricular mass index, LA: Left atrium, AS: Aortic stenosis, HG: High gradient, LFLG: Low flow low gradient, VSAS: Very severe aortic stenosis, AoVel: Aortic Velocity, AVA: Aortic valve area, PASP: Pulmonary artery systolic pressure, MR: Mitral regurgitation, AR: Aortic regurgitation

The prevalence of low-flow, low-gradient (LFLG) AS was significantly higher in EH group compared to CR group (p=0.006) and CH group (p<0.001). Conversely, very severe aortic stenosis (VSAS) was less common in EH group than in CH group (p=0.005).

Baseline aortic valve ejection velocity differed significantly among the groups (p<0.001), being lower in EH group compared to both CR group (p=0.017) and CH group (p<0.001). Aortic valve area (AVA) was significantly greater in EH group than in CR group (p=0.036) and CH group (p=0.002) (p=0.002overall). Mean transvalvular gradient was also significantly lower in EH group compared to CR group (p=0.004) and CH group (p<0.001) (p<0.001 overall). Pulmonary artery pressure (PAP) was similar across groups (p=0.973).

There were no significant differences among the groups in the distribution of baseline mitral or aortic regurgitation severity (p=0.766 and p=0.474, respectively). However, bicuspid aortic valve prevalence differed significantly between groups (p=0.048), primarily due to a higher rate in EH group compared to CR group (p=0.017).

Table 3 compares procedural outcomes by groups. There were no significant differences among groups in predilatation, postdilatation, valve type used, or valve-in-valve procedures

(p>0.05). However, valve size distribution differed significantly (p=0.032); the 23 mm valve was used less frequently in EH group compared to CR group (p=0.008) and 2 (p=0.006), while the 29 mm valve was used more often in EH group than in CR group (p=0.009) and CH group (p=0.008). Device success did not differ between groups (p>0.999).

Table 3. Procedural outcomes of the patients according to groups

	CR group (n=29)	CH group (n=349)	EH group (n=35)	p-value
Predilatation	23 (79.3%)	282 (80.8%)	28 (80.0%)	0.976[a]
Postdilatation	1 (3.4%)	11 (3.2%)	0 (0.0%)	0.690[b]
Valve size				0.032[b]
20	0 (0.0%)	1 (0.3%)	0 (0.0%)	
23	15 (51.7%)[A]	148 (42.4%)[B]	6 (17.1%)[A,B]	
25	0 (0.0%)	7 (2.0%)	0 (0.0%)	
26	13 (44.8%)	149 (42.7%)	18 (51.4%)	
27	0 (0.0%)	4 (1.1%)	1 (2.9%)	
29	1 (3.4%)[A]	40 (11.5%)[B]	10 (28.6%)[A,B]	
Valve type				0.926[b]
Sapien XT	27 (93.1%)	302 (86.5%)	31 (88.6%)	
Edwards Sapien 3	2 (6.9%)	30 (8.6%)	3 (8.6%)	
Lotus	0 (0.0%)	17 (4.9%)	1 (2.9%)	
Valv in valv	0 (0.0%)	1 (0.3%)	0 (0.0%)	n/a
Procedural success	28 (96.6%)	337 (96.6%)	34 (97.1%)	>0.999[b]

a: Pearson's χ^2 test, b: Fisher-Freeman-Halton test. n/a: Not assessed. A: The difference between CR group and EH group is statistically significant (p<0.01); B: The difference between CH group and EH group is statistically significant (p<0.01). CR: Concentric remodeling, CH: Concentric hypertrophy, EH: Eccentric hypertrophy

Table 4 presents in-hospital events, discharge duration, and mortality. While in-hospital complication rates were similar across groups (p>0.05), the incidence of post-TAVI pacemaker implantation was significantly higher in EH group compared to CH group (p=0.022). Median length of hospital stay was comparable (p=0.289). No significant differences were observed in in-hospital mortality (p=0.283) or 1-year all-cause mortality rates (p=0.301).

Table 4. In-hospital and mortality outcomes by groups

	CR group (n=29)	CH group (n=349)	EH group (n=35)	p-value
Stroke	1 (3.4%)	1 (0.3%)	0 (0.0%)	n/a
Pericardial tamponade	0 (0.0%)	4 (1.1%)	1 (2.9%)	0.571[a]
Arrhytmias	4 (13.8%)	43 (12.3%)	6 (17.1%)	0.619[a]
Peripheral complications	2 (6.9%)	22 (6.3%)	4 (11.4%)	0.419[a]
Pacemaker implantation	2 (6.9%)	20 (5.7%)[A]	6 (17.1%)[A]	0.036[a]
Lenght of hospital stay (days)*	4 (2-10)	4 (2-15)	4 (2-12)	0.289[b]
In hospital mortality	0 (0.0%)	7 (2.0%)	2 (5.7%)	0.283[a]
Mortality at first year	6 (20.7%)	42 (12.0%)	3 (8.6%)	0.301[a]

Descriptive statistics are presented as *median (minimum-maximum). a: Fisher-Freeman-Halton test, b: Kruskal-Wallis test. n/a: Not assessed. A: The difference between CH group and EH group is statistically significant (p=0.022). CR: Concentric remodeling, CH: Concentric hypertrophy, EH: Eccentric hypertrophy

Finally, Table 5 presents follow-up comparisons for EF, LVEDD, mitral regurgitation (MR), and PAP. In CR group, EF did not significantly change from baseline to 1-year (p=0.273), whereas CH group (p<0.001) and EH group (p=0.002) showed significant improvement. The percentage change in EF at 1 year was significantly greater in CH group (p=0.020) and EH group (p=0.004) compared to CR group.

LVEDD significantly increased in CR group at 1 year (p<0.001), whereas it significantly decreased in EH group (p=0.006), and remained stable in CH group (p=0.141). The intergroup

Table 5. Multiple comparisons of EF, LVEDD, MR grade, and PAP by group and follow-up time points

	Basal	1-year	p-valuea	Change	p-valueb
EF					0.005
CR group	65.0 (60.0-65.0)	65.0 (60.0-65.0)	0.273	0.0 (0.0-0.0)[A,B]	
CH group	55.0 (50.0-65.0)	60.0 (50.0-65.0)	<0.001	0.0 (0.0-8.3)[A]	
EH group	32.5 (25.0-43.7)	40.0 (30.0-45.0)	0.002	2.9 (0.0-27.7)[B]	
LVEDD					<0.001
CR group	4.1 (3.7-4.2)	4.3 (3.9-4.5)	<0.001	2.9 (0.0-9.3)[A,B]	
CH group	4.6 (4.4-4.9)	4.7 (4.4-5.0)	0.141	0.0 (-1.9-2.2)[A,C]	
EH group	5.9 (5.5-6.4)	5.7 (5.1-6.3)	0.006	0.0 (-6.8-0.0)[B,C]	
MR degree					0.184
CR group	1 (0-1)	0 (0-1)	0.007	-1 (-1-0)	
CH group	1 (1-2)	1 (0-1)	<0.001	0 (-1-0)	
EH group	1 (1-2)	0 (0-1)	<0.001	-1 (-2-0)	
PAP					0.771
CR group	40.0 (20.0-55.0)	30.0 (23.7-40.0)	0.056	1.2 (0.0-5.0)	
CH group	40.0 (30.0-55.0)	35.0 (25.0-45.0)	<0.001	0.0 (-5.0-0.0)	
EH group	40.0 (30.0-55.0)	35.0 (30.0-45.0)	0.003	-5.0 (-20.0-0.0)	

Descriptive statistics are presented as median (25^{th}-75^{th} percentile). a: Within-group comparisons between baseline and 1-year values were performed using the Wilcoxon signed-rank test; results were considered statistically significant at p<0.0167 after Bonferroni correction. b: Between-group comparisons of the changes from baseline to 1 year were performed using the Kruskal-Wallis test; p<0.05 was considered statistically significant. A: The difference between CR group and CH group is statistically significant (p<0.05); B: The difference between CR group and EH group is statistically significant (p<0.01); C: The difference between CH group and EH group is statistically significant (p=0.006).
EF: Ejection fraction, LVEDD: Left ventricular end diastolic dimension, MR: Mitral regurgitation, PAP: Pulmonary artery pressure, CR: Concentric remodeling, CH: Concentric hypertrophy, EH: Eccentric hypertrophy

comparison showed a significant difference in percentage change in LVEDD (p<0.001), with a greater increase in CR group and a greater reduction in EH group compared to CH group (p=0.006).

All three groups experienced significant reductions in MR severity at 1 year (CR group: p=0.007; CH and EH groups: p<0.001), but the magnitude of change did not differ significantly among groups (p=0.184).

Regarding PAP, CR group showed no significant change (p=0.056), while CH group (p<0.001) and EH group (p=0.003) showed significant decreases. However, the intergroup comparison of PAP changes revealed no significant difference (p=0.771).

DISCUSSION

In this study, we demonstrated that baseline LV remodeling phenotypes were significantly associated with distinct clinical, echocardiographic, and procedural profiles, as well as differential reverse remodeling outcomes following TAVI. Patients in EH group were significantly younger and predominantly male. They also had higher rates of prior MI and CABG. Baseline echocardiographic evaluation revealed that EH group had the lowest EF and the highest LVEDD, LVESD, and LA. In addition, the prevalence of LFLG AS was highest and VSAS lowest in this group. EH group also showed increased frequency of bicuspid valve morphology and more frequent use of 29 mm valve prostheses. Notably, post-TAVI PPM implantation was significantly more common in this group. Regarding reverse remodeling, EH group showed significant improvement in EF and a reduction in LVEDD, while CR group demonstrated an increase in LVEDD and no meaningful change in EF. These findings emphasize the prognostic importance of baseline LV geometry in predicting myocardial response and clinical outcomes after TAVI.

EH group displayed a distinct baseline profile, both clinically and echocardiographically. These patients were significantly younger and more often male. The higher prevalence of prior MI and CABG in this group reflects a substantial ischemic burden, which may contribute to the development of eccentric remodeling through chronic myocardial injury and volume overload. This finding supports the hypothesis that adverse ventricular remodeling in EH patients may result from ischemia-related structural changes rather than isolated pressure overload. The younger age profile in this group might therefore be partially explained by earlier manifestation of ischemic cardiomyopathy. EH is typically characterized by increased LV cavity size with relatively reduced wall thickness, representing a maladaptive response to combined pressure and volume stress, unlike concentric patterns that primarily reflect pressure overload.[8] In our cohort, this pathophysiological profile was supported by echocardiographic findings: patients in EH group had the lowest EF and the largest LVEDD, LVESD, and LA diameters among all groups at baseline. These parameters are suggestive of more advanced structural decompensation and LA remodeling, possibly secondary to long-standing diastolic dysfunction or volume expansion from ischemic myocardial remodeling.[9] Furthermore, the increased prevalence of LFLG AS and the lower frequency of VSAS in this group support the notion of reduced LV contractile reserve and compromised hemodynamics.[10,11] The higher frequency of bicuspid aortic valves and the need for larger prosthetic valve sizes (e.g., 29 mm) further differentiate this phenotype anatomically.[12] Taken together, these findings indicate that EH patients undergoing TAVI represent a subgroup with more pronounced ventricular dilation, functional impairment, and ischemic history, all of which may influence their procedural risks and post-intervention recovery trajectories.

Previous studies have demonstrated that both concentric hypertrophy and concentric remodeling are associated with increased mortality following TAVI.[7, 13] Despite the significant differences in baseline clinical profiles, echocardiographic parameters, and myocardial remodeling patterns, overall mortality-both in-hospital and at one year-did not differ significantly among the three groups in our study. This finding suggests that, while LV geometry influences myocardial structure and functional recovery, it may not independently dictate survival in the short to intermediate term following TAVI(14). One possible explanation is that the procedure itself effectively alleviates the primary hemodynamic burden of aortic stenosis across all remodeling types, allowing comparable early survival benefits regardless of baseline ventricular phenotype.[15] Additionally, the standardized nature of the transfemoral approach and improved device performance may have contributed to consistent procedural success across groups. These results are in line with previous studies indicating that while EH and CH may be associated with greater structural compromise, TAVI can mitigate adverse prognostic features when performed successfully.[13] Nonetheless, the absence of mortality differences should be interpreted cautiously, as long-term follow-up might reveal divergence in outcomes influenced by residual ventricular dysfunction, comorbid conditions, and the degree of reverse remodeling achieved over time.

An important finding of our study was the more pronounced reverse remodeling observed in EH group compared to other remodeling phenotypes. Patients in this group demonstrated significant improvement in EF and a notable reduction in LVEDD at one year, indicating a favorable myocardial response following the relief of afterload with TAVI.[12] These results suggest that despite having more advanced structural dilation and lower baseline systolic function, EH patients retain considerable myocardial plasticity and may benefit more from ventricular unloading.[16] However, this anatomical configuration may also explain the higher rate of post-TAVI PPM implantation observed in this group. The combination of larger LV dimensions, altered septal geometry, and frequent use of larger prosthetic valves (e.g., 29 mm) may increase mechanical interaction with the conduction system, particularly the atrioventricular node and left bundle branch. The indications for pacemaker implantation were predominantly related to early post-procedural conduction disturbances. No additional device implantations were required due to late-onset high-degree AV block or symptomatic bradycardia during follow-up. While previous studies have reported a numerically higher-

but not statistically significant-rate of permanent pacemaker implantation in patients with eccentric hypertrophy, our study is the first to demonstrate a statistically significant increase in PPM incidence in this subgroup.[13,17] While improved reverse remodeling may support long-term functional recovery, the increased need for PPM represents a relevant procedural risk in this subgroup and may influence post-intervention quality of life and long-term rhythm outcomes. This duality shows the importance of individualized procedural planning and follow-up strategies in patients with EH undergoing TAVI.

Limitations

This study has several limitations that should be acknowledged. First, its retrospective and observational design may introduce selection bias and limit the ability to infer causality. Second, the single-timepoint echocardiographic classification of LV remodeling patterns does not account for dynamic changes that may occur prior to or following TAVI. Third, although echocardiographic assessments were performed according to standard guidelines, interobserver variability was not formally evaluated. Additionally, the relatively small number of patients in the concentric remodeling and eccentric hypertrophy groups may reduce the statistical power to detect subtle differences in outcomes. Finally, the follow-up period was limited to one year, which may not fully capture the long-term impact of remodeling patterns on survival, heart failure progression, and device-related complications. Prospective studies with longer follow-up and larger, multicenter cohorts are warranted to validate these findings.

CONCLUSION

As a result, our findings highlight the prognostic relevance of baseline LV remodeling phenotypes in patients undergoing TAVI. Eccentric hypertrophy was associated with more advanced ventricular dilation and impaired baseline function but demonstrated the greatest potential for reverse remodeling following valve intervention. Despite these structural and functional differences, short- and mid-term mortality rates were similar across all groups, emphasizing the procedural efficacy of TAVI regardless of remodeling pattern. However, the higher incidence of PPM implantation in the EH group indicates that anatomical considerations may still influence procedural risks. Overall, systematic assessment of LV geometry prior to TAVI may enhance patient stratification, guide valve selection, and inform post-procedural management, particularly in individuals with advanced remodeling patterns.

Take-home Messages

- Left ventricular remodeling patterns significantly influence the degree of structural recovery after TAVI.
- Patients with eccentric hypertrophy demonstrated the most pronounced reverse remodeling, reflected by greater improvements in EF and reductions in LVEDD.
- The incidence of permanent pacemaker implantation was significantly higher in the eccentric hypertrophy group.
- Despite anatomical and functional differences, 1-year mortality rates were similar across all remodeling groups.
- Pre-procedural assessment of LV geometry may enhance risk stratification and guide clinical decision-making in TAVI candidates.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was carried out with the permission of the Gazi University President's Office Ethics Committee (Date: 14.07.2025, Decision No: 2025-1243).

Informed Consent

Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

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Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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