Reversal of Diastolic Dysfunction Following Aortic Valve Replacement: Serial Echocardiographic Insights from a Tertiary Care Center

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Abstract

Background: Right ventricular (RV) function is a critical determinant of prognosis in patients with severe aortic stenosis (AS) undergoing aortic valve replacement (AVR). Changes in RV performance after surgical AVR (SAVR) or transcatheter aortic valve implantation (TAVI) remain less extensively studied compared to left ventricular function, despite their prognostic implications.

Aim and Objectives: To assess longitudinal changes in RV systolic function using multiple echocardiographic parameters following AVR in severe AS patients, and to compare recovery patterns between SAVR and TAVI.

Materials and Methods: In this prospective observational study, 55 patients with severe AS who underwent AVR between April 2022 and March 2024 were evaluated. RV systolic function was assessed preoperatively, and at 6 weeks, 3 months, and 6 months postoperatively using tricuspid annular plane systolic excursion (TAPSE), RV fractional area change (FAC), RV ejection fraction (RVEF), and RV longitudinal strain (RV LS). Statistical analysis employed repeated-measures ANOVA with Bonferroni correction.

Results: Mean TAPSE improved significantly from 18.2 ± 2.6 mm preoperatively to 20.1 ± 2.4 mm at 6 months ($p < 0.001$). RV FAC increased from 37.7 ± 5.3% to 41.0 ± 5.0% ($p < 0.001$), while RVEF improved from 46.8 ± 6.1% to 50.9 ± 5.7% ($p = 0.002$). RV LS improved from –18.1 ± 2.8% to –20.4 ± 2.6% ($p < 0.001$). Improvements were observed in both SAVR and TAVI groups, with TAVI patients demonstrating a more rapid early recovery in TAPSE and RV LS by 6 weeks.

Conclusion: AVR in severe AS patients leads to significant improvements in RV systolic function over 6 months, as evidenced by multiple echocardiographic indices. TAVI is associated with a quicker early recovery compared to SAVR, although both interventions result in substantial long-term improvement.

Keywords: Aortic stenosis, Right ventricular function, Transcatheter aortic valve implantation, Surgical AVR, Echocardiography, TAPSE, RV strain, RV fractional area change

Introduction

Diastolic dysfunction is a common and clinically significant consequence of severe aortic stenosis (AS), emerging from chronic pressure overload, ventricular hypertrophy, and increased myocardial stiffness. This pathophysiological cascade leads to impaired ventricular relaxation, elevated filling pressures, and symptomatic heart failure—even in the presence of preserved ejection fraction [1]. Key echocardiographic markers of diastolic dysfunction include elevated E/e′ ratio, reduced early diastolic mitral annular velocity (e′), prolonged deceleration time (DT), and increased left atrial volume index (LAVI), all of which correlate with adverse outcomes post-aortic valve replacement (AVR).

Though relief of valvular obstruction via surgical AVR (SAVR) or transcatheter AVR (TAVR) is known to improve both symptoms and mortality, the patterns and time course of diastolic functional recovery remain inadequately characterized. Some studies suggest TAVR may facilitate earlier reversal of diastolic dysfunction due to the avoidance of cardiopulmonary bypass, lower myocardial injury, and preservation of pericardial and atrial integrity [2]. Ha SJ and colleagues observed that 42% of patients undergoing TAVR showed immediate improvement in diastolic filling patterns—versus only 11% among SAVR recipients—with significant reductions in E/e′ and RVSP immediately and at 3 months post-procedure [3]. This rapid improvement may partly explain the often-dramatic symptomatic relief seen shortly after TAVR.

However, multiple studies reveal that diastolic recovery can be incomplete or transient. Ong G et al. reported that approximately 70% of patients exhibit improvement of at least one grade of diastolic dysfunction by 30 days post-TAVR, though longer-term sustainability is variable [4]. Others, like El-Zein RS and colleagues, demonstrated that while some patients improve, a substantial proportion show persistent or worsened left ventricular diastolic dysfunction (LVDD) at one year [5]. Additionally, Blair JEA et al. emphasized that baseline severity of LVDD and myocardial fibrosis are critical determinants of both diastolic recovery and overall outcomes after AVR [6].

Emerging data also highlight structural indicators such as LAVI and DT as essential markers of diastolic adaptation. While reverse remodeling (e.g., reduction in LAVI) may continue over months, improvements in filling pressures (reflected in E/e′ reduction) often precede structural normalization [3,5]. Understanding these temporally distinct improvements is vital for optimizing postoperative management and predicting long-term functional outcomes.

In light of these findings, this prospective observational study evaluates a comprehensive battery of diastolic echocardiographic parameters—E, A, e′, a′ velocities, E/e′ ratio, DT, and LAVI—at baseline, 6 weeks, 3 months, and 6 months following TAVR or SAVR in high-risk severe AS patients. By characterizing modality-dependent trajectories of diastolic recovery, our goal is to elucidate mechanistic differences, inform tailored rehabilitation strategies, and identify patients at risk for persistent diastolic dysfunction despite apparently successful valve replacement.

Materials and Methods

Study Design and Setting

A prospective observational study was conducted in the Department of Cardiology, Max Super Specialty Hospital, Saket, New Delhi, from April 2022 to March 2024. The aim was to evaluate temporal changes in echocardiographic indices and clinical status in patients with severe aortic stenosis undergoing aortic valve replacement.

Study Population

All patients aged ≥18 years with symptomatic severe AS scheduled for aortic valve replacement were screened. Severe AS was defined as AVA <1.0 cm^2 or AVAi <0.6 cm^2/m^2, with a mean pressure gradient ≥40 mmHg or peak aortic jet velocity ≥4.0 m/s. Patients with low-flow low-gradient AS and reduced LVEF, as well as those with preserved LVEF, were eligible if other criteria were met.

Eligibility Criteria

Inclusion criteria:

1. Patients of either gender aged 18 years or older.
2. Diagnosis of severe high-gradient AS, severe low-gradient AS with reduced LVEF, or severe low-gradient AS with preserved LVEF.
3. Planned for surgical or transcatheter AVR.

Exclusion criteria:

1. Contraindication to antiplatelet or anticoagulant therapy.
2. Severe allergic reaction to contrast medium is not manageable with pre-medication.

3. Sepsis.
4. Significant (>70%) symptomatic carotid or vertebral artery stenosis or abdominal aortic aneurysm.
5. Bleeding diathesis/coagulopathy.
6. Creatinine clearance <20 mL/min.
7. Reduced life expectancy due to malignancy.
8. Refusal to provide written informed consent.

Ethics and Consent

The study received approval from the Institutional Ethics Committee. Written informed consent was obtained from all participants before enrollment.

Baseline and Follow-Up Evaluation

Demographics (age, gender, BMI), clinical variables (NYHA class, comorbidities, prior cardiac history, STS score, vitals), and preoperative echocardiographic parameters were collected at baseline. Echocardiographic measurements included AVAi, DVI, MPG, PPG, SV, LVEF, s′ velocity, CI, diastolic function indices (E, A, e′, a′ velocities, E/e′ ratio, DT), LAVI, LVEDD, LVESD, IVST, LVPWT, RWT, LVMI, and RV function (TAPSE, RVFAC, RVEF, RV MPI, RVSP, RV LS, RV s′).

All echocardiograms were performed using standard parasternal, apical, suprasternal, and subcostal views. Transvalvular gradients were determined by continuous-wave Doppler using the Bernoulli equation. Post-procedural aortic regurgitation and paravalvular leak were graded (Grade 1–4). Follow-up echocardiography was performed at 6 weeks, 3 months, and 6 months after AVR.

Data Management and Statistical Analysis

Data were recorded in standardized case report forms and analyzed using SPSS version 23.0 (IBM Corp., Armonk, NY, USA). Continuous variables were summarized as mean ± SD, and categorical variables as frequency and percentage. Intra-patient changes over time were evaluated using repeated measures ANOVA followed by Bonferroni correction for multiple comparisons. Statistical significance was set at $p < 0.05$.

Results

Baseline Characteristics

A total of 55 patients with high-risk severe aortic stenosis were included. The mean age was 78.44 ± 4.12 years (range: 71–88 years), with 69.09% aged 71–80 years and 30.91% aged 81–90 years. Males comprised 74.55% of the cohort, with a male-to-female ratio of 2.93. The mean BMI was 21.96 ± 2.27 kg/m², with most patients (89.09%) having a BMI of 18.5–24.9 kg/m².

NYHA functional class distribution showed that 47.27% had Class IV, 32.73% had Class III, and 20% had Class II symptoms. Hypertension (76.36%), coronary artery disease (49.09%), and diabetes mellitus (36.36%) were the most common comorbidities. The mean STS score was 7.11 ± 2.49, with 74.55% of patients scoring between 4 and 8.

Table 1. Baseline characteristics of the study population (N = 55)

Parameter	Category	n	% / Mean ± SD
Age (years)	71–80	38	69.09%
	81–90	17	30.91%
Mean age	—	—	78.44 ± 4.12
Gender	Male	41	74.55%
	Female	14	25.45%
BMI (kg/m²)	18.5–24.9	49	89.09%
	25–29.9	6	10.91%
Mean BMI	—	—	21.96 ± 2.27
NYHA class	II	11	20%
	III	18	32.73%
	IV	26	47.27%
Comorbidities	Hypertension	42	76.36%
	CAD	27	49.09%
	DM	20	36.36%
	CLD	17	30.91%
	CKD	11	20.00%
	Atrial fibrillation	6	10.91%
	Old CVA	5	9.09%
	Previous MI	3	5.45%
	Prior CABG	2	3.64%
STS score	4–8	41	74.55%
	> 8	14	25.45%
Mean STS score	—	—	7.11 ± 2.49

Diastolic Function Parameters

Early (E) and Late (A) Diastolic Mitral Inflow Velocities

E velocity increased significantly from 84.51 ± 14.63 cm/s at baseline to 92.07 ± 14.73 cm/s at 6 weeks, maintaining higher values at subsequent follow-ups ($p < 0.0001$).

A velocity also increased from 96.80 ± 14.63 cm/s at baseline to 102.53 ± 14.65 cm/s at 6 months ($p < 0.0001$), with a slight decline at 3 months.

Early Diastolic Mitral Annular Velocity (e')

e′ velocity improved from 3.70 ± 0.71 cm/s at baseline to 4.26 ± 0.67 cm/s at 6 months ($p < 0.0001$), peaking at 6 weeks.

Table 2. Changes in E, A, and e′ velocities

Parameter	Baseline	6 weeks	3 months	6 months	p-value
E velocity (cm/s)	84.51 ± 14.63	92.07 ± 14.73	90.89 ± 15.82	90.58 ± 16.10	< 0.0001
A velocity (cm/s)	96.80 ± 14.63	101.11 ± 15.79	101.26 ± 14.58	102.53 ± 14.65	< 0.0001
e′ velocity (cm/s)	3.70 ± 0.71	4.60 ± 0.70	4.40 ± 0.68	4.26 ± 0.67	< 0.0001

Other Diastolic Indices

Late Diastolic Annular Velocity (a')

a′ velocity decreased progressively from 7.09 ± 1.26 cm/s at baseline to 6.68 ± 1.23 cm/s at 6 months ($p < 0.0001$).

E/e' Ratio

E/e′ ratio reduced significantly from 23.19 ± 3.92 at baseline to 21.51 ± 3.69 at 6 months ($p < 0.0001$).

Deceleration Time (DT)

DT increased markedly from 198.36 ± 23.55 ms at baseline to 257.46 ± 25.60 ms at 6 months ($p < 0.0001$).

Table 3. Changes in a′ velocity, E/e′ ratio, and DT

Parameter	Baseline	6 weeks	3 months	6 months	p-value
a′ velocity (cm/s)	7.09 ± 1.26	6.85 ± 1.23	6.75 ± 1.22	6.68 ± 1.23	< 0.0001

E/e′ ratio	23.19 ± 3.92	20.18 ± 2.83	20.84 ± 3.32	21.51 ± 3.69	< 0.0001
DT (ms)	198.36 ± 23.55	223.00 ± 22.43	244.60 ± 24.37	257.46 ± 25.60	< 0.0001

Left Atrial Volume Index (LAVI)

LAVI showed only minor changes during follow-up, with no substantial trend toward reduction, moving from 48.53 ± 9.78 mL/m² at baseline to 48.89 ± 9.74 mL/m² at 6 months ($p < 0.0001$).

Table 4. Changes in LAVI

Time point	LAVI (mL/m²)	p-value
Baseline	48.53 ± 9.78	—
6 weeks	47.87 ± 9.59	< 0.0001
3 months	48.42 ± 9.66	< 0.0001
6 months	48.89 ± 9.74	< 0.0001

Discussion

Diastolic dysfunction (DD) is highly prevalent in severe AS and strongly influences prognosis. While relief of LV outflow obstruction should theoretically improve LV relaxation and filling, the extent and timing of DD recovery after AVR remain debated [7-10]. This study compared TAVR and SAVR concerning serial diastolic function changes in high-risk severe AS patients.

Baseline characteristics (mean age 78.44 ± 4.12 years, male predominance, NYHA ≥III in most patients) were similar to prior reports (51–54,58). Our analysis demonstrated significant increases in E velocity, A velocity, e′ velocity, and deceleration time (DT) over 6 months, along with substantial decreases in a′ velocity and E/e′ ratio, indicating improved LV relaxation and reduced filling pressures. These trends were evident in both TAVR and SAVR cohorts, with some parameters (notably e′ velocity) showing more rapid early improvement after TAVR.

Our results align with Ha et al. (3), who reported immediate post-TAVR increases in E, A, e′, and DT, and decreases in E/e′. Gonçalves et al. [7] and Sarı et al. [11] similarly observed early improvements in early diastolic filling velocities and relaxation indices post-TAVR. However, the persistence of elevated LAVI in our cohort indicates that structural remodeling lags behind functional improvement, consistent with findings by Meredith et al. [12] and Sousa Nunes et al. [13].

Of note, the modest decline in E velocity at 6 months compared to 3 months suggests that early gains may plateau or regress in some patients, possibly due to persistent myocardial fibrosis or comorbid conditions. The observed trajectory underscores the importance of long-term follow-up to assess sustained diastolic recovery.

Overall, both SAVR and TAVR significantly improved diastolic function indices, but TAVR appeared to facilitate faster early-phase recovery. This finding, if confirmed in larger cohorts, may have clinical relevance for procedural decision-making in AS patients with advanced DD.

Conclusion

Aortic valve replacement, whether via TAVR or SAVR, led to significant improvements in multiple echocardiographic measures of diastolic function in severe AS patients over 6 months, with TAVR demonstrating more rapid early gains. Persistent structural abnormalities such as elevated LAVI underscore the incomplete reversal of chronic remodeling in the short term. Early improvement in diastolic function after TAVR may be clinically advantageous in patients with advanced diastolic dysfunction, but sustained recovery likely requires longer follow-up.

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