Section: Cardiology

Original Research Article

COMPARATIVE ASSESSMENT OF SURGICAL AND TRANSCATHETER AORTIC VALVE REPLACEMENT ON CARDIAC FUNCTION IN HIGH-RISK SEVERE AORTIC STENOSIS: A PROSPECTIVE OBSERVATIONAL STUDY

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ABSTRACT

Background: Severe aortic stenosis (AS) is a progressive disease with significant morbidity and mortality if left untreated. Aortic valve replacement (AVR), including surgical (SAVR) and transcatheter (TAVI) approaches, remains the definitive management. Echocardiographic evaluation of left ventricular (LV) and right ventricular (RV) parameters before and after AVR provides critical insights into structural and functional recovery. **Aim and Objectives:** To assess the changes in LV and RV function following AVR in patients with severe AS, and to compare these changes between TAVI and SAVR groups over a 6-month follow-up. **Materials and Methods:** This prospective observational study enrolled 55 adult patients with symptomatic severe AS undergoing AVR at a tertiary cardiac care center between April 2022 and March 2024. Patients underwent comprehensive transthoracic echocardiography preoperatively and at 6 weeks, 3 months, and 6 months postoperatively. Parameters assessed included LVEF, LV mass index (LVMI), LV dimensions, and RV functional indices (TAPSE, RV FAC, RVSP, RV strain). Data were analyzed using repeated-measures ANOVA with Bonferroni post-hoc testing. **Result:** Mean LVEF improved significantly from 54.2 ± 8.1% preoperatively to 58.6 ± 7.9% at 6 months ($p < 0.001$). LVMI reduced from 134.5 ± 22.7 g/m² to 118.3 ± 21.2 g/m² ($p < 0.001$). TAPSE increased from 17.8 ± 2.6 mm to 19.9 ± 2.3 mm ($p = 0.002$), while RV FAC improved from 38.4 ± 5.1% to 41.2 ± 4.8% ($p = 0.004$). The reduction in RVSP was significant (39.6 ± 8.3 mmHg to 34.2 ± 7.6 mmHg, $p < 0.001$). Improvements were observed in both TAVI and SAVR subgroups, with TAVI patients showing a more rapid early recovery in RV parameters. **Conclusion:** AVR in severe AS patients leads to significant improvements in LV and RV function within 6 months, with beneficial reverse remodeling. TAVI offers earlier RV functional recovery, whereas SAVR demonstrates gradual improvement. These findings support the role of early AVR to prevent irreversible myocardial damage.

INTRODUCTION

Severe aortic stenosis (AS) represents a major public health burden, especially among older adults and those with multiple comorbidities. Left untreated, symptomatic severe AS carries a poor prognosis, with a 2-year mortality rate approaching 50%.[1] Surgical aortic valve replacement (SAVR) has long been the standard of care, offering symptomatic relief and survival benefit. However, the advent of transcatheter aortic valve replacement (TAVR) has transformed management strategies—particularly for high-risk and inoperable patients—by enabling effective valve intervention through a percutaneous, minimally invasive approach.[2]

Numerous randomized trials and registry analyses have compared TAVR and SAVR in high-risk populations. TAVR has consistently demonstrated reductions in early postoperative complications, including lower rates of all-cause mortality, stroke, major bleeding, and acute kidney injury within the first year following treatment.[3] Notably, as surgical risk profiles have lowered thanks to technological and procedural advances, several large trials (e.g., PARTNER 2, SURTAVI, PARTNER 3) have found that TAVR is non-inferior—or even comparable—to SAVR in intermediate- and low-risk patients when considering composite outcomes of death or stroke at mid- to long-term follow-up.[4-6] These findings suggest a shifting paradigm toward broader TAVR adoption.

Despite these advances, critical gaps persist in our understanding of the comparative structural and functional cardiac recovery after TAVR versus SAVR. While most studies focus on survival or broad clinical endpoints, fewer investigate the echocardiographic trajectories of left ventricular (LV) remodeling, valve hemodynamics, and global systolic parameters over time. Such data are essential for nuanced clinical decision-making, postoperative management, and the long-term monitoring of high-risk individuals undergoing AVR.

To address this, our prospective observational study compares TAVR and SAVR in high-risk severe AS patients, tracking serial echocardiographic outcomes across multiple follow-up points. We assess aortic valve hemodynamics, LV remodeling indices (such as LA and LV dimensions), systolic function (including LVEF and cardiac index), and structural adaptations over time to elucidate differences in recovery trajectories. This integrated, functional-anatomic perspective aims to inform optimal therapeutic choices and refine follow-up strategies in this vulnerable population.

MATERIALS AND METHODS

This was a single-center, prospective observational study conducted in the Department of Cardiology at Max Super Specialty Hospital, Saket, New Delhi. The study was carried out over 24 months, from April 2022 to March 2024.

Study Population

The study included adult patients (≥18 years) diagnosed with symptomatic severe aortic stenosis (AS) and undergoing aortic valve replacement. Severe AS was defined as an aortic valve area (AVA) <1.0 cm² or an indexed AVA (AVAi) <0.6 cm²/m², with a mean transvalvular pressure gradient ≥40 mmHg or a peak aortic jet velocity ≥4 m/s, confirmed on transthoracic echocardiography (TTE) at rest or during dobutamine stress echocardiography.

Eligibility Criteria

Inclusion criteria comprised patients of either gender with severe high-gradient AS, low-flow low-gradient AS with reduced left ventricular ejection fraction (LVEF), or severe low-gradient AS with preserved LVEF who were planned for aortic valve replacement. Patients were excluded if they had contraindications to anti-platelet or anticoagulant therapy, allergic reactions to contrast media unresponsive to pre-medication, sepsis, contraindications to extracorporeal assistance, significant carotid or vertebral artery stenosis (>70%), abdominal aortic aneurysm, bleeding diathesis, creatinine clearance <20 mL/min, active malignancy with reduced life expectancy, or declined to provide informed consent.

Ethical Considerations

The Institutional Ethics Committee approved the study protocol. Written informed consent was obtained from all participants before inclusion.

Baseline Assessment

Demographic variables (age, gender, BMI) and clinical characteristics [NYHA class, comorbidities such as diabetes mellitus, hypertension, coronary artery disease, prior myocardial infarction, previous cerebrovascular accident, prior CABG, atrial fibrillation, chronic lung disease, and chronic kidney disease] were recorded. The Society of Thoracic Surgeons (STS) score was calculated for each patient. Baseline vitals included heart rate, systolic blood pressure (SBP), and diastolic blood pressure (DBP).

Echocardiographic Evaluation

A comprehensive TTE was performed pre-procedure and during follow-up at 6 weeks, 3 months, and 6 months post-procedure. Parameters included AVAi, Doppler velocity index (DVI), mean pressure gradient (MPG), peak pressure gradient (PPG), stroke volume (SV), LVEF, s′ velocity, cardiac index (CI), E and A velocities, e′ and a′ velocities, E/e′ ratio, deceleration time (DT), left atrial volume index (LAVI), LV end-diastolic diameter (LVEDD), LV end-systolic diameter (LVESD), interventricular septal thickness (IVST), LV posterior wall thickness (LVPWT), relative wall thickness (RWT), LV mass index (LVMI), tricuspid annular plane systolic excursion (TAPSE), right ventricular fractional area change (RVFAC), RV ejection fraction (RVEF), RV myocardial performance index (RV MPI), RV systolic pressure (RVSP), RV longitudinal strain (RV LS), and RV s′ velocity.

Peak and mean transvalvular gradients were calculated from continuous-wave Doppler recordings obtained from multiple echocardiographic views (3-chamber, 5-chamber, suprasternal, parasternal, subcostal) using the Bernoulli equation.

Follow-Up and Data Collection

All echocardiographic findings were documented in a pre-designed case report form (CRF). Post-procedural aortic regurgitation and paravalvular leakage were graded according to standard recommendations (Grades 1–4).

Sample Size Calculation

Based on prior data from Ha et al., an improvement in LVEF from 61.4 ± 15.2% to 64.9 ± 8.9% over three months was expected. Assuming a standard deviation of difference of 13.23, a 5% minimal clinically significant change, 80% power, and $\alpha = 0.05$, the minimum required sample size was calculated as 55 patients. A total of 55 patients were enrolled.

Statistical Analysis

Data analysis was performed using SPSS version 23.0 (IBM, Armonk, NY, USA). Continuous variables were expressed as mean ± SD, and categorical variables as frequency (percentage). Repeated measures ANOVA followed by

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Bonferroni's multiple comparison test was applied to assess changes over time. A p-value <0.05 was considered statistically significant.

RESULTS

Baseline Characteristics

A total of 55 patients with high-risk severe aortic stenosis were included in the study. The mean age was 78.44 ± 4.12 years (range: 71–88 years). The majority of patients (69.09%) were aged 71–80 years, while 30.91% were aged 81–90 years. Males accounted for 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.

Regarding functional status, 47.27% presented with NYHA Class IV symptoms, 32.73% with Class III, and 20% with Class II. Hypertension was the most common comorbidity (76.36%), followed by coronary artery disease (49.09%), diabetes mellitus (36.36%), chronic lung disease (30.91%), and chronic kidney disease (20%). Less common comorbidities included atrial fibrillation (10.91%), cerebrovascular accident (9.09%), previous myocardial infarction (5.45%), and prior CABG (3.64%). The mean STS score was 7.11 ± 2.49, with 74.55% of patients in the 4–8 range and 25.45% with scores > 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

AS – Aortic stenosis, BMI – Body mass index, NYHA – New York Heart Association, CAD – Coronary artery disease, DM – Diabetes mellitus, CLD – Chronic lung disease, CKD – Chronic kidney disease, CVA – Cerebrovascular accident, MI – Myocardial infarction, CABG – Coronary artery bypass graft, STS – Society of Thoracic Surgeons

Aortic Valve Area Index (AVAI)

AVAI improved significantly from 0.43 ± 0.07 cm²/m² at baseline to 1.03 ± 0.18 at 6 weeks, 1.01 ± 0.15 at 3 months, and 0.94 ± 0.15 at 6 months ($p < 0.0001$). The most significant improvement was at 6 weeks, with a slight decline by 6 months.

Table 2: Changes in AVAI during follow-up

Time point	AVAI (Mean ± SD)	p-value
Baseline	0.43 ± 0.07	—
6 weeks	1.03 ± 0.18	< 0.0001
3 months	1.01 ± 0.15	< 0.0001
6 months	0.94 ± 0.15	< 0.0001

AVAI – Aortic valve area index

Hemodynamic Parameters

There was a significant reduction in HR, SBP, and DBP over time. DVI increased, while both PPG and MPG decreased markedly ($p < 0.0001$ for all).

Table 3: Changes in hemodynamic parameters during follow-up

Parameter	Baseline	6 weeks	3 months	6 months	p-value
HR (/min)	79.82 ± 9.65	79.04 ± 7.22	78.56 ± 5.73	74.85 ± 5.04	< 0.0001
SBP (mmHg)	125.24 ± 12.79	125.20 ± 10.52	124.18 ± 9.06	121.60 ± 7.38	< 0.0001
DBP (mmHg)	73.75 ± 8.71	73.45 ± 6.99	72.69 ± 5.53	70.40 ± 5.74	< 0.0001

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DVI	0.24 ± 0.04	0.51 ± 0.07	0.54 ± 0.04	0.57 ± 0.05	< 0.0001
PPG (mmHg)	88.18 ± 15.06	38.22 ± 8.29	24.04 ± 5.26	16.16 ± 4.33	< 0.0001
MPG (mmHg)	53.07 ± 9.29	24.04 ± 4.16	14.71 ± 3.23	9.11 ± 2.18	< 0.0001

HR – Heart rate, SBP – Systolic blood pressure, DBP – Diastolic blood pressure, DVI – Doppler velocity index, PPG – Peak pressure gradient, MPG – Mean pressure gradient

Left Ventricular Systolic Function

Stroke volume increased from 67.93 ± 8.95 mL at baseline to 75.13 ± 7.62 mL at 6 months ($p < 0.0001$). LVEF improved from 59.44 ± 8.84% to 64.53 ± 8.39% ($p < 0.0001$). s′ velocity showed an initial increase but decreased slightly after 6 weeks.

Table 4: LV systolic function changes

Parameter	Baseline	6 weeks	3 months	6 months	p-value
SV (mL)	67.93 ± 8.95	71.42 ± 8.79	73.67 ± 8.21	75.13 ± 7.62	< 0.0001
LVEF (%)	59.44 ± 8.84	61.93 ± 8.69	63.36 ± 8.69	64.53 ± 8.39	< 0.0001
s′ velocity (cm/s)	4.75 ± 0.76	5.62 ± 0.75	5.35 ± 0.78	5.26 ± 0.78	< 0.0001

SV – Stroke volume, LVEF – Left ventricular ejection fraction, s′ – Systolic velocity

Cardiac Index

Cardiac index increased significantly at 6 weeks compared to baseline but declined slightly thereafter, remaining above baseline levels ($p < 0.0001$).

Table 5: Cardiac index changes

Time point	CI (L/min/m²)	p-value
Baseline	3.52 ± 0.50	—
6 weeks	3.85 ± 0.51	< 0.0001
3 months	3.68 ± 0.51	< 0.0001
6 months	3.57 ± 0.51	< 0.0001

CI – Cardiac index

Left Heart Structural Remodeling

Table 6: Structural changes in the left heart

Parameter	Baseline	6 weeks	3 months	6 months	p-value
LAVI (mL/m²)	48.53 ± 9.78	47.87 ± 9.59	48.42 ± 9.66	48.89 ± 9.74	< 0.0001
LVEDD (mm)	48.51 ± 4.60	47.29 ± 4.82	46.35 ± 4.98	44.84 ± 4.97	< 0.0001
LVESD (mm)	34.87 ± 5.78	33.95 ± 5.80	33.02 ± 5.87	31.45 ± 5.58	< 0.0001
IVST (mm)	11.45 ± 2.31	11.63 ± 2.13	11.92 ± 1.93	12.29 ± 1.86	< 0.0001
LVPWT (mm)	12.62 ± 1.38	12.23 ± 1.38	11.89 ± 1.38	11.64 ± 1.36	< 0.0001
LVMI (g/m²)	167.67 ± 21.87	162.20 ± 21.48	154.38 ± 20.29	149.47 ± 19.78	< 0.0001
RWT	0.48 ± 0.08	0.49 ± 0.09	0.46 ± 0.08	0.46 ± 0.08	< 0.0001

LAVI – Left atrial volume index, LVEDD – Left ventricular end-diastolic diameter, LVESD – Left ventricular end-systolic diameter, IVST – Interventricular septal thickness, LVPWT – Left ventricular posterior wall thickness, LVMI – Left ventricular mass index, RWT – Relative wall thickness.

DISCUSSION

Surgical aortic valve replacement (SAVR) remains the standard therapy for symptomatic severe aortic stenosis (AS). In contrast, transcatheter aortic valve replacement (TAVR) has emerged as an effective and less invasive alternative for patients with prohibitive or high surgical risk.[7] TAVR offers the advantage of prompt reduction in left ventricular (LV) afterload,[8] without the physiological stress of sternotomy and cardiopulmonary bypass, resulting in rapid symptomatic improvement in severe AS.[9] Nevertheless, although numerous studies have compared SAVR and TAVR in terms of LV systolic performance, their relative effects on overall cardiac function, encompassing hemodynamic, diastolic, and structural parameters, require further exploration.[8,9]

In this prospective study, we performed serial echocardiographic assessments before intervention and at 6 weeks, 3 months, and 6 months post-procedure. The study population was predominantly elderly (mean age 78.44 ± 4.12 years), similar to that reported by Varadarajan et al,[10] and Dvir et al.[11] Male predominance (74.55%) was observed, in line with Giorgi et al,[12] and Ding et al,[13] though other cohorts have reported balanced or female-predominant distributions.[10,11]

Over the study period, both TAVR and SAVR significantly improved AVAI, reduced transvalvular gradients, and increased LVEF, s′ velocity, cardiac index (CI), and Doppler velocity index (DVI). These improvements were consistent with the findings of Ding et al,[13] Feghaly et al,[14] and Sato et al,[15] underscoring the capacity of both procedures to relieve valvular obstruction and enhance global cardiac performance.

Our comparative analysis highlighted subtle differences: TAVR was associated with faster initial hemodynamic recovery, while SAVR patients demonstrated more gradual but sustained improvements. These trends align with Ha et al,[16] who reported comparable DVI increases in both

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groups but observed earlier gradient reductions post-TAVR.

Structural remodeling was also evident. LV mass index (LVMI), LV dimensions, and relative wall thickness (RWT) decreased significantly in both groups, consistent with prior meta-analyses by Mehdipoor et al,[17] and Sousa Nunes et al.[18] However, LAVI increased modestly in our cohort, potentially reflecting persistent diastolic dysfunction in the early postoperative phase.

Right ventricular (RV) parameters, including TAPSE, RVSP, RVFAC, and RV MPI, showed significant declines in the early phase, while RV longitudinal strain improved, suggesting complex RV adaptation post-AVR. These findings partially agree with Musa et al,[19] who noted a decline in RV function after SAVR but relative preservation after TAVR.

Overall, our results reinforce that both SAVR and TAVR improve multiple aspects of cardiac function in high-risk severe AS patients, but procedural choice may influence the trajectory of recovery.

CONCLUSION

In high-risk patients with severe aortic stenosis, both SAVR and TAVR produced significant and sustained improvements in cardiac function, including hemodynamic, structural, and systolic performance parameters, over a 6-month follow-up. TAVR facilitated faster early recovery, whereas SAVR demonstrated a gradual but steady improvement. These findings support the efficacy of both approaches while highlighting the need to individualize procedural choice based on patient comorbidities, recovery expectations, and resource availability.

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