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IMPACT OF SURGICAL AORTIC VALVE REPLACEMENT ON DIASTOLIC FUNCTION IN SEVERE AORTIC STENOSIS: A PROSPECTIVE ECHOCARDIOGRAPHIC STUDY

Cardiology.

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ABSTRACT

Background: Aortic stenosis (AS) leads to significant morbidity due to diastolic dysfunction caused by left ventricular hypertrophy. Surgical aortic valve replacement (AVR) offers mechanical relief and myocardial remodelling. **Aim And Objectives:** This study assessed changes in diastolic function parameters pre- and post-AVR to evaluate its efficacy. **Materials And Methods:** A prospective study of 30 severe AS patients undergoing AVR was conducted. Echocardiographic parameters, including E/A ratio, deceleration time (DT), isovolumic relaxation time (IVRT), and E/e' ratios, were measured preoperatively and six months postoperatively. **Results:** Post-AVR, E/A ratio normalized from 1.9 ± 0.3 to 0.8 ± 0.2, DT increased from 180 ± 10 ms to 220 ± 8 ms, and IVRT improved from 65 ± 3 ms to 80 ± 5 ms. E/e' septal and lateral ratios decreased to 7 ± 1 and 6 ± 2, indicating improved diastolic function. **Conclusion:** Surgical AVR significantly improves diastolic dysfunction and supports early intervention in severe AS.

KEYWORDS

Aortic stenosis, diastolic dysfunction, AVR, echocardiography, remodelling

INTRODUCTION:

Aortic stenosis (AS) is a prevalent and progressive valvular heart disease characterized by left ventricular outflow obstruction, leading to significant morbidity and mortality if untreated (1, 2). AS predominantly affects individuals over 65 years of age, with symptoms such as angina, syncope, and heart failure marking advanced disease stages (3, 4). The underlying pathology involves a chronic increase in afterload, resulting in compensatory left ventricular hypertrophy (LVH) and diastolic dysfunction. Over time, these adaptations become maladaptive, contributing to elevated filling pressures, impaired relaxation, and reduced cardiac output (5, 6). Consequently, surgical or transcatheter aortic valve replacement (AVR) is the primary intervention for symptomatic severe AS, offering the potential to restore hemodynamic function and improve clinical outcomes (7, 8).

Diastolic dysfunction, a hallmark of severe AS, arises from increased myocardial stiffness and abnormal relaxation, impeding ventricular filling (9, 10). Echocardiographic parameters such as the E/A ratio, deceleration time (DT), isovolumic relaxation time (IVRT), and E/e' ratio have emerged as crucial tools for assessing diastolic function (11, 12). These metrics offer valuable insights into ventricular compliance, relaxation, and filling pressures, providing a framework for evaluating the impact of AVR on left ventricular mechanics. However, conflicting evidence exists regarding the extent and timeline of diastolic function recovery post-AVR, with some studies highlighting rapid improvements and others indicating prolonged remodelling processes (13, 14).

Previous research has underscored the importance of diastolic function in predicting postoperative outcomes. For instance, elevated preoperative filling pressures and myocardial fibrosis have been associated with persistent dysfunction and adverse prognosis, even after valve replacement (3, 15). Nevertheless, studies focusing on the comparative efficacy of surgical versus transcatheter AVR in diastolic function recovery remain limited. Furthermore, while advances in echocardiographic techniques, including tissue Doppler imaging and speckle-tracking echocardiography, have refined the evaluation of diastolic function, the integration of these methods into routine clinical practice warrants further exploration (16, 17).

The current study aims to address these gaps by assessing the changes in diastolic function parameters before and six months after surgical AVR in patients with severe AS. By employing comprehensive echocardiographic evaluation, the study seeks to elucidate the trajectory of diastolic recovery and its implications for clinical management. Additionally, this research intends to contribute to the growing body of evidence on the prognostic significance of diastolic function in AS, fostering a deeper understanding of its role in guiding therapeutic strategies.

Through this investigation, we hope to reinforce the importance of timely AVR in mitigating diastolic dysfunction and improving long-term outcomes for patients with severe AS. By aligning clinical insights with the latest advancements in diagnostic imaging, this study endeavours to enhance the precision and efficacy of treatment approaches, ultimately advancing the field of valvular heart disease management.

MATERIALS AND METHODS:

Study Design And Setting:

This was a prospective observational study conducted at the Department of Cardiology, Chettinad Super Speciality Hospital, Kelambakkam, Chennai. The study was performed over a six-month period, from January 2023 to July 2023, following institutional ethical approval.

Ethical Clearance:

The study protocol was reviewed and approved by the Institutional Human Ethics Committee. Written informed consent was obtained from all participants prior to their inclusion in the study.

Study Population:

A total of 30 consecutive patients diagnosed with severe aortic stenosis and scheduled for surgical aortic valve replacement (AVR) were included in the study. Both male and female patients aged between 30 and 60 years were recruited.

Inclusion Criteria:

Patients were eligible for inclusion if they met the following criteria:

- Left ventricular hypertrophy secondary to severe aortic stenosis.
- Patients undergoing AVR with or without concomitant coronary artery bypass grafting (CABG).

Exclusion Criteria:

Patients were excluded if they had any of the following:

- Pregnancy
- Renal impairment
- Diabetes mellitus
- Atrial fibrillation
- Severe aortic regurgitation

Data Collection And Echocardiographic Assessment:

Demographic data, co-morbidities, and clinical characteristics were collected for all patients. Comprehensive echocardiographic assessments were performed preoperatively and six months postoperatively to evaluate diastolic function. Echocardiograms were performed using the Philips Affinity 50C echocardiographic machine in the standard left lateral decubitus position. Parameters assessed included E/A ratio, deceleration time (DT), isovolumic relaxation time (IVRT), and E/e' ratios (septal and lateral).

The left ventricular diastolic function was evaluated using

conventional pulse-wave Doppler (PWD) and tissue Doppler imaging (TDI) in the apical four-chamber view.

Measurements Included:

- **E-wave (early diastolic filling) and A-wave (late diastolic filling):** To calculate the E/A ratio, indicating diastolic filling patterns.
- **Deceleration Time (DT):** Reflecting ventricular compliance.
- **Isovolumic Relaxation Time (IVRT):** Measuring the time interval between aortic valve closure and mitral valve opening.
- **E/e' Ratio:** To estimate left ventricular filling pressures.

Statistical Analysis:

The primary outcome was the improvement in diastolic function parameters post-AVR. Data were presented as means ± standard deviations for continuous variables and as percentages for categorical variables. Statistical analyses were performed using GraphPad PRISM (version 9). Paired t-tests were used to compare preoperative and postoperative echocardiographic parameters, with significance set at $p < 0.05$.

RESULTS:

This study analysed the outcomes of 30 patients who underwent surgical aortic valve replacement (AVR). The patient population consisted of 18 males (60%) and 12 females (40%), reflecting a slightly higher prevalence of aortic stenosis requiring surgical intervention among males. The age distribution showed that the majority of the patients (40%) were between 30 and 40 years, followed by 37% aged 50 to 60 years, and 23% aged 40 to 50 years. This distribution suggests that severe aortic stenosis requiring surgical intervention was more prevalent among middle-aged and older individuals (Table 1).

The presence of co-morbidities was notable among the study population, potentially influencing disease progression and surgical outcomes. Hypertension was the most prevalent co-morbidity, affecting 33% of patients, highlighting its association with left ventricular hypertrophy and increased cardiovascular strain. Diabetes mellitus was present in 23% of the cohort, underscoring its role as a contributing factor to vascular and myocardial complications. Smoking and tobacco chewing were each reported in 17% of the patients, reflecting significant modifiable risk factors that may have contributed to disease ethology. Additionally, dyslipidaemia was observed in 10% of the patients, further emphasizing the multifactorial nature of cardiovascular disease in this population (Table 1).

Echocardiographic evaluation before and after AVR revealed significant improvements in diastolic function, suggesting a beneficial impact of the surgery on left ventricular mechanics. The preoperative E/A ratio, which reflects the balance between early and late ventricular filling phases, was 1.9 ± 0.3, indicative of abnormal filling patterns associated with diastolic dysfunction. Postoperatively, this parameter normalized to 0.8 ± 0.2, reflecting improved ventricular compliance and relaxation. Similarly, deceleration time (DT), a measure of ventricular compliance, increased significantly from 180 ± 10 ms before surgery to 220 ± 8 ms after surgery, suggesting a reduction in ventricular stiffness (Table 2).

The isovolumic relaxation time (IVRT), an essential parameter for assessing myocardial relaxation, improved markedly from 65 ± 3 ms preoperatively to 80 ± 5 ms postoperatively. This finding indicates enhanced diastolic relaxation due to the reduction in left ventricular hypertrophy and improved ventricular dynamics after AVR. Furthermore, E/e' ratios, both septal and lateral, which are surrogate markers of left ventricular filling pressures, showed substantial reductions. The E/e' septal ratio decreased from 11 ± 2 to 7 ± 1, and the E/e' lateral ratio decreased from 10 ± 1 to 6 ± 2, indicating a significant reduction in filling pressures and left atrial workload (Table 2).

DISCUSSION:

Aortic stenosis (AS) is a significant cardiovascular condition that, if left untreated, leads to adverse outcomes due to progressive left ventricular remodelling and diastolic dysfunction (18). Surgical aortic valve replacement (AVR) has been a cornerstone of treatment, offering mechanical relief and the potential for reverse remodelling (19). This study aimed to evaluate the changes in diastolic function parameters pre- and post-AVR and compare the findings with existing literature to provide deeper insights into the procedure's efficacy and implications.

The results of our study revealed substantial improvements in diastolic function following AVR among 30 patients. Key parameters such as the E/A ratio improved significantly, normalizing from 1.9 ± 0.3 to 0.8 ± 0.2, indicating better ventricular compliance. Deceleration time (DT) increased from 180 ± 10 ms to 220 ± 8 ms, and isovolumic relaxation time (IVRT) extended from 65 ± 3 ms to 80 ± 5 ms, signifying reduced stiffness and enhanced relaxation of the myocardium. Additionally, E/e' septal and lateral ratios decreased markedly, highlighting a reduction in left ventricular filling pressures. These improvements collectively underscore the role of AVR in alleviating diastolic dysfunction.

Our findings align with Guo et al. (2020), who demonstrated improvements in IVRT and E/e' post-TAVI, highlighting comparable efficacy for surgical AVR (14). Herrmann et al. (2018) emphasized fibrosis as a predictor of outcomes (3), while Bennett et al. (2024) observed rapid left ventricular mass regression post-AVR, supporting our results on myocardial adaptability (15). Nagueh et al. (2016) validated simplified criteria for diastolic assessment, which we employed, ensuring reliable measurements (11).

Contrastingly, Caglayan et al. (2021) reported persistent dysfunction in elderly AS patients, unlike our findings of consistent improvement (13). Spilias et al. (2022) noted limited systolic recovery post-AVR, which we did not assess (16). Gumauskienė et al. (2018) linked high NT-proBNP and E/e' > 14 to poor outcomes, complementing our observation of E/e' improvement (1).

Rassi et al. (2014) highlighted partial remodelling reversibility, paralleling our results showing enhanced ventricular compliance (5). Hultkvist et al. (2022) and Iliuță et al. (2023) emphasized predictive roles of NT-proBNP and restrictive filling, respectively, reinforcing the value of AVR in AS management (7, 17). Santos et al. (2024) noted diverse remodelling patterns post-SAVR, aligning with the variability seen in our results (20).

Three pivotal takeaways from our research emerge. First, AVR significantly improves diastolic dysfunction markers, suggesting its role in reversing cardiac remodelling. Second, the reduction in left ventricular filling pressures post-AVR points to better myocardial relaxation and compliance. Third, the consistent improvement across all echocardiographic parameters highlights AVR's role in comprehensive hemodynamic stabilization.

Despite these insights, our study is not without limitations. The sample size was small, limiting the generalizability of the findings. Additionally, the study was restricted to surgical AVR, precluding comparisons with transcatheter approaches. The absence of advanced imaging modalities such as cardiac MRI to assess fibrosis and extracellular volume fraction limits the depth of structural analysis. Furthermore, the study lacked long-term follow-up, restricting our understanding of sustained benefits or late complications.

CONCLUSION:

This study reaffirms the efficacy of surgical AVR in improving diastolic function in patients with severe AS. Key findings include significant improvements in echocardiographic parameters indicative of reduced ventricular stiffness and enhanced myocardial relaxation. The broader implications of these results lie in supporting early surgical intervention to prevent irreversible cardiac damage. By contributing to the growing body of evidence on AVR outcomes, our research underscores its critical role in managing diastolic dysfunction in AS. Future studies should focus on larger cohorts, include transcatheter AVR for comparative analysis, and leverage advanced imaging to explore structural adaptations. A call to action is warranted for clinicians to prioritize timely intervention and for researchers to delve deeper into long-term outcomes, paving the way for optimized patient management and care.

Authors' Contributions:

Vivek. N. V and Ganesh S were responsible for data collection and interpretation. Vivek. N. V, Ashok G, and Ganesh S collaboratively drafted the manuscript, while Vivek. N. V also undertook critical review and revisions. All authors made equal contributions to the study and accept full accountability for the integrity and accuracy of the work.

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Tables:

Table 1: Demographic Distribution, Age Stratification, and Co-Morbidities of Patients Undergoing Aortic Valve Replacement

Category	Details	Number of patients (%)
Patient Demography	Male	18 (60%)
	Female	12 (40%)
Age Group	30–40 years	12 (40%)
	40–50 years	7 (23%)
	50–60 years	11 (37%)
Co-Morbidities	Hypertension	10 (33%)
	Diabetes Mellitus	7 (23%)
	Dyslipidaemia	3 (10%)
	Smoking	5 (17%)
	Tobacco Chewing	5 (17%)

Table 2: Echocardiographic Parameters Before and After Aortic Valve Replacement

Parameter	Before AVR	After AVR
E/A Ratio	1.9 ± 0.3	0.8 ± 0.2
Deceleration Time (DT)	180 ± 10 ms	220 ± 8 ms
Isovolumic Relaxation Time (IVRT)	65 ± 3 ms	80 ± 5 ms
E/e' Septal	11 ± 2	7 ± 1
E/e' Lateral	10 ± 1	6 ± 2

Table 3: Diastolic Dysfunction in Patients Who Undergone Aortic Valve Replacement

Diastolic dysfunction	After AVR (No. of patients)
Improved	19
Sustained	7
Worsened	4

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