

Original Research Article

Effect of aortic valve replacement on left ventricular systolic function, left ventricular mass index reduction and clinical outcome in early post-operative period in patients with aortic stenosis

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ABSTRACT

Background: Aortic stenosis (AS) causes chronic left ventricular pressure overload, resulting in ventricular hypertrophy, remodeling and progressive impairment of ventricular function. Aortic valve replacement (AVR) relieves the pressure overload, but the extent of early ventricular recovery remains clinically important. This study evaluated early changes in left ventricular ejection fraction (LVEF), left ventricular mass (LVM), left ventricular mass index (LVMI), relative wall thickness (RWT), hemodynamic parameters and functional status following surgical AVR.

Methods: This prospective observational study included 40 adult patients with AS who underwent isolated surgical AVR at the National Institute of Cardiovascular Diseases and Hospital, Dhaka, Bangladesh, from July 2017 to June 2018. Preoperative and early postoperative echocardiographic parameters were compared. Clinical outcomes included NYHA functional class, aortic valve pressure gradient, ICU stay and postoperative complications.

Results: The mean age was 39.23 ± 12.41 years; 25 (62.5%) patients were male and 15 (37.5%) were female. Mean LVEF increased significantly from $46.30 \pm 7.07\%$ preoperatively to $50.83 \pm 6.06\%$ postoperatively ($p=0.001$). Mean LVM decreased from 407.92 ± 157.05 g to 304.49 ± 132.73 g ($p=0.001$), while LVMI decreased from 220.32 ± 102.58 to 160.57 ± 86.94 ($p=0.001$). The mean aortic valve pressure gradient decreased from 54.59 ± 4.41 to 12.37 ± 6.60 mmHg ($p<0.0001$). NYHA functional class improved from 2.83 ± 0.38 to 1.07 ± 0.25 ($p<0.001$). RWT decreased from 0.4738 ± 0.074 to 0.4227 ± 0.086 ($p<0.003$). One patient (2.5%) developed prosthesis-patient mismatch and one (2.5%) developed paravalvular leakage. Two deaths were reported during the study period.

Conclusions: Surgical AVR was associated with significant early improvement in left ventricular systolic function, regression of left ventricular mass and LVMI, reduction in transvalvular pressure gradient, and improvement in functional status within four weeks. These findings suggest that relief of aortic obstruction is associated with early favorable ventricular remodeling in patients with AS.

Keywords: Aortic stenosis, Aortic valve replacement, Left ventricular function, Echocardiography

INTRODUCTION

Aortic stenosis (AS) is a common and progressive valvular heart disease characterized by narrowing of the aortic valve orifice, resulting in obstruction of left ventricular (LV) outflow and chronic pressure overload.^{1,2} As the stenotic obstruction progresses, the left ventricle adapts by developing concentric hypertrophy to maintain systolic function and reduce ventricular wall stress despite increasing afterload.³ Although initially compensatory, persistent pressure overload may eventually result in impaired ventricular relaxation, diastolic dysfunction, myocardial fibrosis and deterioration of systolic function.^{4,5}

The relationship between ventricular pressure, chamber dimensions and myocardial wall stress can be explained by the Laplace principle, according to which wall stress is directly related to intracavitary pressure and ventricular radius and inversely related to wall thickness.⁶ Thus, increased wall thickness initially provides an important compensatory mechanism by limiting wall stress. However, prolonged severe AS may exceed the adaptive capacity of the myocardium, leading to progressive ventricular dysfunction and heart failure.

Left ventricular hypertrophy is clinically important because increased LV mass and abnormal ventricular geometry are associated with adverse cardiovascular outcomes and mortality.^{7,8} Consequently, regression of LV hypertrophy after correction of the valvular obstruction is considered an important component of reverse ventricular remodeling.

Aortic valve replacement (AVR) relieves the fixed LV outflow obstruction and substantially reduces LV afterload. This facilitates reverse remodeling, characterized by regression of myocardial hypertrophy and improvement in ventricular function. Previous studies have demonstrated significant reductions in LV mass and improvements in ventricular performance following AVR, although the magnitude and timing of recovery vary according to preoperative ventricular function, severity and duration of pressure overload, myocardial fibrosis and prosthetic valve hemodynamics.^{9,10}

Echocardiography provides a practical, non-invasive method for assessing these changes. Left ventricular ejection fraction (LVEF) evaluates global systolic function, while LV mass (LVM) and LV mass index (LVMI) quantify ventricular hypertrophy. Relative wall thickness (RWT) provides additional information regarding ventricular geometry, while the transvalvular pressure gradient reflects the hemodynamic effect of valve replacement.¹¹ Assessment of these parameters together can provide a comprehensive evaluation of early reverse ventricular remodeling.

Although ventricular remodeling may continue for months or years after AVR, meaningful physiological changes may occur within the early postoperative period. However, data regarding the magnitude of very early changes in LV structure and function remain limited, particularly in resource-constrained cardiac surgical settings.

Therefore, this study evaluated changes in LVEF, LVM, LVMI, RWT, aortic valve pressure gradient and New York Heart Association (NYHA) functional class during the first four weeks following isolated surgical AVR for AS, with the aim of characterizing the early structural, functional, hemodynamic and clinical response to surgical relief of LV outflow obstruction.

METHODS

Study design and setting

This prospective observational study was conducted in the Department of Cardiac Surgery, National Institute of Cardiovascular Diseases and Hospital (NICVD), Sher-e-Bangla Nagar, Dhaka, Bangladesh, from July 2017 to June 2018.

The study population consisted of adult patients admitted for isolated surgical AVR because of AS. A purposive/convenience sampling technique was used. Forty patients fulfilling the study criteria were enrolled.

Inclusion and exclusion criteria

Patients aged 18 years or older with AS who underwent isolated surgical AVR were eligible for inclusion. Patients with concomitant coronary artery disease, narrow aortic root, recent myocardial infarction or clinical heart failure were excluded.

The study protocol was submitted to and approved by the Ethical Review Committee of NICVD. Written informed consent was obtained from each participant or an appropriate relative. Patient confidentiality was maintained throughout the study, and participants were informed of their right to withdraw from the study.

Clinical and echocardiographic assessment

Demographic variables, including age, sex and body surface area (BSA), were recorded. The presence of hypertension and baseline NYHA functional class was documented.

All patients underwent preoperative and postoperative two-dimensional and M-mode transthoracic echocardiography. Echocardiographic assessment was performed using a Vivid S5 GE Healthcare echocardiography system. The parameters assessed included LVEF, left ventricular dimensions, LVM, LVMI, RWT and aortic valve pressure gradient.

Postoperative clinical and perioperative variables included intensive care unit (ICU) stay, inotropic support, prosthesis-patient mismatch (PPM) and paravalvular leakage (PVL).

Surgical technique

All patients underwent isolated surgical AVR through standard median sternotomy under general anesthesia. Cardiopulmonary bypass was established using ascending aortic and two-stage single venous cannulation. Moderate hemodilution and moderate systemic hypothermia (28–32°C) were used.

Myocardial protection was achieved with intermittent antegrade St. Thomas cardioplegia administered directly into the coronary ostia. An oblique aortotomy was performed above the aortic annulus. The native valve was completely excised, and calcification was removed when present.

Mechanical prosthetic valves were implanted in all patients using interrupted mattress sutures with pledgets. The pledgets were positioned in the supra-annular position. The aortotomy was closed with polypropylene sutures. Following completion of the operation, patients were transferred to the cardiac ICU in an intubated and mechanically ventilated state and subsequently weaned according to their clinical condition.

Outcome measures

The primary echocardiographic outcomes were changes in LVEF, LVM and LVMI between the preoperative and early postoperative assessments. Secondary outcomes included changes in RWT, mean aortic valve pressure gradient and NYHA functional class, as well as ICU stay and postoperative complications.

Left ventricular geometry was categorized using RWT and LVMI into four patterns: 1) Normal geometry; 2) Concentric remodeling; 3) Concentric hypertrophy; and 4) Eccentric hypertrophy.

Statistical analysis

Continuous variables were expressed as mean±standard deviation, and categorical variables were presented as frequencies and percentages. Preoperative and postoperative continuous variables were compared using the paired Student's t-test. Categorical variables were compared using the chi-square test or Fisher's exact test when appropriate. A p value <0.05 was considered statistically significant.

Statistical analyses were performed using SPSS version 25.0 (IBM/SPSS Inc., Chicago, IL, USA).

RESULTS

A total of 40 patients who underwent isolated aortic valve replacement for aortic stenosis were included in the analysis. The mean age was 39.23±12.41 years. There were 25 (62.5%) male and 15 (37.5%) female patients. The mean body surface area was 1.56±0.12 m², and hypertension was present in 25 (62.5%) patients (Table 1).

Table 1: Baseline demographic and clinical characteristics of the study population.

Variables	Value
Age (years), mean±SD	39.23±12.41
Male, N (%)	25 (62.5)
Female, N (%)	15 (37.5)
Body surface area (m²), mean±SD	1.56±0.12
Hypertension, N (%)	25 (62.5)

Significant early improvement in left ventricular systolic function and regression of left ventricular hypertrophy was observed following AVR. The mean LVEF increased from 46.30±7.07% preoperatively to 50.83±6.06% at the postoperative assessment (p=0.001). Mean LVEF therefore improved by approximately 9.8%. A significant reduction in left ventricular mass was also observed, decreasing from 407.92±157.05 g preoperatively to 304.49±132.73 g postoperatively (p=0.001), representing an approximate 25% reduction. Similarly, LVMI decreased from 220.32±102.58 to 160.57±86.94 following AVR (p=0.001), corresponding to an approximate 27% reduction (Table 2).

Table 2: Comparison of left ventricular systolic function and ventricular mass before and after AVR (n=40).

Variables	Preoperative	Postoperative	P value
LVEF (%)	46.30±7.07	50.83±6.06	0.001
LV mass (g)	407.92±157.05	304.49±132.73	0.001
LVMI	220.32±102.58	160.57±86.94	0.001
LVEF (%)	46.30±7.07	50.83±6.06	0.001
LV mass (g)	407.92±157.05	304.49±132.73	0.001

The mean aortic valve pressure gradient decreased significantly from 54.59±4.41 mmHg before surgery to 12.37±6.60 mmHg postoperatively (p<0.0001). NYHA functional class improved from 2.83±0.38 preoperatively to 1.07±0.25 postoperatively (p<0.001).

Relative wall thickness also decreased significantly from 0.4738±0.074 to 0.4227±0.086 following AVR (p<0.003), indicating early regression of adverse left ventricular remodeling (Table 3).

Table 3: Comparison of hemodynamic, geometric and functional parameters before and after AVR (n=40).

Variables	Pre operative	Postoperative	P value
Mean aortic valve pressure gradient (mmHg)	54.59±4.41	12.37±6.60	<0.0001
NYHA functional class	2.83±0.38	1.07±0.25	<0.001
Relative wall thickness	0.4738±0.074	0.4227±0.086	<0.003

Following AVR, 25 (62.5%) patients required an ICU stay of less than 5 days, whereas 15 (37.5%) required an ICU stay of more than 5 days. Prosthesis-patient mismatch was reported in 1 (2.5%) patient, and postoperative paravalvular leakage was reported in 1 (2.5%) patient. Based on the reported postoperative left ventricular remodeling pattern, concentric hypertrophy was the most common geometry, observed in 79% of patients. Eccentric hypertrophy was present in 10%, concentric remodeling in 8%, and normal geometry in 3% of patients (Table 4).

Table 4: Early postoperative clinical outcomes and left ventricular remodeling pattern following AVR

Variables	N (%)
Postoperative ICU stay	
<5 days	25 (62.5)
>5 days	15 (37.5)
Postoperative complications	
Prosthesis-patient mismatch	1 (2.5)
Paravalvular leakage	1 (2.5)
Postoperative LV geometry	
Concentric hypertrophy	79
Eccentric hypertrophy	10
Concentric remodeling	8
Normal geometry	3

Overall, AVR was associated with significant early improvement in LVEF, marked reductions in LV mass and LVMI, substantial reduction in the transvalvular pressure gradient, and significant improvement in NYHA functional class. Early postoperative assessment also demonstrated a significant reduction in relative wall thickness, while concentric hypertrophy remained the predominant left ventricular remodeling pattern.

DISCUSSION

The principal finding of this study was that significant reverse ventricular remodeling was detectable within four weeks of surgical AVR. LVEF increased, while LVM,

LVMI and RWT decreased. These echocardiographic improvements were accompanied by a marked reduction in aortic valve pressure gradient and improvement in NYHA functional class, indicating early structural, hemodynamic and clinical recovery.

In our cohort, mean LVEF increased from 46.30% to 50.83%, representing an approximately 9.8% relative improvement. Early improvement in LV systolic function after AVR has previously been reported. Dahl et al. demonstrated that preoperative ventricular function influences postoperative outcomes in patients with severe AS, while Delgado et al showed that myocardial deformation may improve following surgical valve replacement even when conventional LVEF is preserved.^{12,13} These findings support the concept that relief of afterload can rapidly improve LV performance, although recovery may be incomplete in patients with advanced myocardial remodeling.

A major finding was the reduction in LVM from 407.92±157.05 g to 304.49±132.73 g, corresponding to approximately 25% regression within four weeks. Similarly, LVMI decreased from 220.32±102.58 to 160.57±86.94, representing approximately 27% reduction. Previous studies have demonstrated significant regression of LV mass after AVR. Concistrè et al. reported significant LV mass regression after implantation of a sutureless aortic bioprosthesis, while studies evaluating normal LV mass have emphasized the importance of indexing LV mass to body size.^{14,15}

The magnitude of early regression observed in our study should be interpreted as the beginning of reverse remodeling rather than complete normalization. Regression of LV hypertrophy may continue for months after AVR. Sharma et al. reported sustained LV mass regression following valve replacement, while echocardiographic studies have demonstrated that changes in LV geometry and mass continue during longer-term follow-up.^{16,17} Therefore, the four-week follow-up in the present study probably captures only the initial phase of a longer remodeling process.

RWT also decreased from 0.4738±0.074 to 0.4227±0.086. RWT, when interpreted together with LVMI, helps characterize LV geometry and distinguish concentric hypertrophy from other remodeling patterns.¹⁸ The reduction observed in our cohort is consistent with regression of the concentric remodeling associated with chronic pressure overload. Rymuza et al. similarly reported that concentric hypertrophy is a frequent remodeling pattern in patients with severe AS and that LV geometry has clinical relevance.¹⁹

The marked reduction in mean aortic valve pressure gradient, from 54.59±4.41 to 12.37±6.60 mmHg, confirms effective relief of the preoperative obstruction. This hemodynamic improvement provides the principal physiological basis for the observed reduction in LV

afterload and subsequent ventricular remodeling. Early reduction in obstruction following AVR has also been associated with improvement in LV structure and function.²⁰

Clinical improvement paralleled the echocardiographic findings. Mean NYHA functional class improved from 2.83 ± 0.38 to 1.07 ± 0.25 . This substantial improvement indicates that the structural and hemodynamic benefits of AVR translated into meaningful symptomatic recovery. Bakkali et al also reported improvement in LV remodeling following AVR in patients with severe AS and LV dysfunction.²¹

The prognostic importance of LV mass and geometry should also be considered. Increased LV mass and abnormal geometry have been associated with cardiovascular morbidity and mortality.²² The regression observed after AVR may therefore have implications beyond short-term echocardiographic improvement. However, longer follow-up is required to determine whether early structural regression translates into improved long-term clinical outcomes.

Prosthesis-patient mismatch (PPM) is another factor that may influence postoperative remodeling. One patient in our cohort developed PPM. PPM can result in residual postoperative gradients and potentially limit LV mass regression. Ruel et al. demonstrated that PPM was particularly relevant in patients with pre-existing LV dysfunction and was associated with reduced LV mass regression and adverse clinical outcomes.²³ Appropriate prosthesis selection is therefore important for achieving optimal postoperative hemodynamic and remodeling outcomes.

The findings should also be considered in the context of contemporary AS management. Current guidelines emphasize AVR as the definitive treatment for severe symptomatic AS, with the choice between surgical and transcatheter approaches determined by clinical characteristics, surgical risk, anatomy and life expectancy.^{7,25} Although the present study evaluated only surgical AVR, the observed early reverse remodeling supports the physiological principle that removal of severe outflow obstruction can rapidly reduce LV pressure overload.

This study has several limitations. The sample size was small, with only 40 patients from a single cardiac surgery center, and purposive/convenience sampling may have introduced selection bias. Follow-up was limited to approximately four weeks, preventing assessment of long-term LV remodeling, functional recovery and survival. Furthermore, only patients undergoing isolated surgical AVR were included, limiting generalizability to combined procedures and transcatheter valve replacement. Finally, assessment was based primarily on conventional echocardiographic parameters without

myocardial strain or cardiac magnetic resonance assessment of myocardial fibrosis.

Despite these limitations, the study demonstrates that meaningful reverse ventricular remodeling can begin within the first month following surgical AVR. The simultaneous improvement in LVEF, reduction in LVM and LVMI, reduction in RWT and transvalvular gradient, and improvement in NYHA functional class indicate that AVR produces early beneficial changes in ventricular structure, function and clinical status.

CONCLUSION

Surgical AVR in patients with AS was associated with significant early improvement in left ventricular systolic function, regression of left ventricular mass and LV mass index, reduction in aortic valve pressure gradient and improvement in functional status within four weeks. These findings support the concept that relief of chronic pressure overload promotes early reverse ventricular remodeling. Patients with advanced ventricular dysfunction may have less complete recovery, emphasizing the importance of timely intervention before irreversible myocardial remodeling develops. Longer-term prospective studies with larger cohorts are required to determine the durability of these early changes and their relationship with long-term clinical outcomes.

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