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Original Article

Management of Small Aortic Root during Aortic Valve Replacement

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Abstract

Background: Concomitant aortic root enlargement (ARE) increases the risk of aortic valve replacement (AVR). The objectives of this study were to identify the patients who needed aortic root enlargement and compare the outcomes and the risk of adding ARE to AVR.

Methods: We retrospectively reviewed 62 patients who underwent isolated mechanical aortic valve replacement between 2017 and 2019. We divided the patients into two groups: group A included patients with small aortic root who had AVR with one of the different surgical strategies for small aortic annulus (n= 32) and group B, which included patients with a normal aortic annulus and underwent conventional AVR (n= 30). Group A was further sub-divided based on the surgical strategy into 4 categories; patients who had supra-annular implantation of size 19 mm St. Jude prosthetic valve (n= 11; 34.4%), Nicks procedure (n= 13 40.6%), Manougian procedure (n= 4; 12.5%), Konno procedure (n= 4; 12.5%).

Results: Group A patients were significantly younger (26.16 ± 11.49 vs. 34.63 ± 8.9 years; p< 0.001) and had lower body weight (55.09 ± 21.41 vs. 69.80 ± 19.20; p= 0.01). Group A had significantly smaller valves (p = 0.03), and total cardiopulmonary bypass (148.65 ± 44.09 vs. 97.46 ± 20.90 minutes; p<0.001) and aortic cross-clamp times (118.13 ± 36.70 vs. 78.06 ± 16.01 minutes; p < 0.001) were significantly longer in group A. There was no significant difference in operative complications between groups. Among patients with small aortic root; Konno procedure had the longest bypass time (236.3 ± 19.70 minutes; p<0.001); cross-clamp time (192.5 ± 22.2 minutes; p <0.001); mechanical ventilation (4.75 ± 0.50 hours; p<0.001) and intensive care unit stay (6.50 ± 0.57 days; p <0.001). Patients with supra-annular implantation of the St. Jude valve had a significantly higher postoperative pressure gradient (14.64 ± 6.84 mmHg; p= 0.02). No difference in procedure complications was observed among aortic root enlargement procedures.

Conclusion: Patients who had aortic root enlargement procedure were younger, with lower weight and body surface area. Surgical procedures used to manage small aortic root had comparable early results, and no technique was superior to the others.

KEYWORDS
Aortic valve replacement; Patient-prosthetic mismatch; Aortic root enlargement

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Introduction

Aortic valve replacement (AVR) remains the standard procedure for the management of severe aortic valve diseases. AVR is associated with low morbidity and mortality, and it decreases the left ventricular (LV) volume and pressure overload and subsequently enhances ventricular remodeling and improves patient survival [1].

Patients with a small aortic root are prone to patient-prosthetic mismatch (PPM) after AVR, particularly in those with large body surface area (BSA). PPM was defined when the effective prosthetic valve area, after valve implantation, was less than that of a normal valve [2]. This definition has evolved into a prosthetic valve effective orifice area (EOA) indexed to body surface area of 0.85cm2/m2 or less (iEOA) [3].

Several techniques have been evolved to enlarge the small aortic root at the time of aortic valve replacement to accommodate a larger valve [4-7]. Newer strategies and surgical options have been developed, including homograft, autograft (Ross procedure), and most recently implanting stentless or sutureless valves.

The objectives of this study were to identify the patients who had small aortic root and needed aortic root enlargement and compare the outcomes and the risk of adding aortic root enlargement (ARE) to AVR.

Patients and Methods:

After approval of the Institutional Review Board, a single-center retrospective cohort study was conducted in the period between 2017 and 2019. We included all patients who underwent isolated mechanical aortic valve replacement in a university hospital during the study period with no specific age range nor valve pathology.

We excluded patients who had associated other cardiac pathology, including other valve affection or coronary artery disease, patients with a concomitant procedure (double valve replacement, coronary artery bypass grafting, or Bentall operation), patients who had AVR with a tissue valve and patients presented with native valve infective endocarditis.

We define small aortic root as aortic annulus diameter less than 21 mm measured with transthoracic echocardiography preoperatively [8].

Patients population

We enrolled 62 patients and divided them into two groups: group (A) included patients with small aortic root (< 21 mm) (n= 32), and group (B) included patients with aortic annulus ≥ 21mm who underwent conventional AVR (n= 30).
Group A was further sub-divided based on the surgical strategy used for aortic root enlargement into four categories a) supra-annular implantation with size 19 mm St. Jude prosthetic valve (n= 11; 34.4%), b) Nicks procedure (n= 13, 40.6%), c) Manouguian procedure (n= 4; 12.5%), d) Konno procedure (n= 4; 12.5%).

Preoperative assessment

We evaluated all patients clinically, calculated the body surface area (BSA), and performed preoperative echocardiography. According to the patients' BSA and the measurement of the aortic annulus, the surgery was planned as conventional isolated AVR or with concomitant aortic root enlargement procedure.

Operative data

All Patients had operation through a median sternotomy, then the thymus was dissected, and aortocaval cannulation was performed. Cardiopulmonary bypass was established, and the patients were initially cooled to 32 °C. Cooled saline cardioplegia was used in all patients. Aortotomy incision was done according to the preoperative plan, and the aortic valve and annulus were further evaluated. Aortic leaflets were excised using both surgical blade and scissor, and calcification was removed using the Rongeur. After complete removal of the valve, a valve sizer was applied to measure the aortic annulus.

According to the size of the annulus intraoperatively, the surgery was commenced as planned, or the plan was changed according to

Table 1: Baseline data of the studied groups. (Continuous variables are presented as mean± standard deviation and categorical variables as number and percent)

	Group A (n= 32)	Group B (n= 30)	*P*
Age (year)	26.16 ± 11.49	34.63 ± 8.9	< 0.001
Female	16 (50%)	18 (60%)	0.42
Weight (kg)	55.09 ± 21.41	69.80 ± 19.20	0.01
Height (cm)	159.03 ± 15.15	161.93 ± 8.67	0.97
Body surface area (m2)	1.5438 ± 0.33	1.7240 ± 0.20	0.06
Aortic annulus (mm)	2.01 ± 0.18	2.32 ± 0.19	< 0.001
Pressure gradient (mmHg)	77.19 ± 16.12	52.85± 13.3	< 0.001

surgeon preference. All patients were managed with one of the following procedures: conventional annular implantation of the prosthetic valve, supra-annular implantation of size 19 mm Saint-Jude mechanical valve, Nicks operation, Manouguian operation, or Konno-Rastan operation.

Supra-annular bioprosthesis was placed above the aortic annulus. This was achieved by suturing the valve from the ventricular side to the aortic side with the Teflon pledges seated below the prosthetic valve. In Nicks technique, the aortotomy was continued to the aortic annulus and crossed the middle of the non-coronary cusp across the aortic ring, and then the surgeon decided either to partially open the annulus or continued the incision as far as the origin of the mitral valve. Then a teardrop patch of the autologous pericardium was applied to close the defect [4].

In the Manouguian procedure, the aortic incision extends into the commissure between the non-coronary and the left coronary sinus through the interleaflet triangle, across the annulus of the mitral valve into the midportion of the valve's anterior leaflet, and posteriorly on the roof of the left atrium, after that a big diamond-shaped autologous pericardium was used to fill that defect and enlarge the annulus This operation was performed when greater enlargement of the left ventricular outflow tract diameter was required. The degree of enlargement was related to the depth of incision into the anterior leaflet [7].

In the Konno-Rastan procedure, the aortotomy incision was performed anteriorly and vertically extending to the right ventricular outflow tract (RVOT), then the interventricular septum was opened, we used two different patches for this procedure (a bovine pericardial patch and autologous pericardial patch) [5,6].

Postoperative assessment

Postoperative bleeding, re-exploration, duration of mechanical ventilation, and total ICU stay were recorded. Before discharge, the patients had an echocardiographic examination to evaluate the function of the implanted valve, cardiac function, the pressure gradient across the prosthetic valve, and the presence of pericardial collection.

Statistical Analysis

All the data were collected in a Microsoft excel file. SPSS version 23.0 (IBM Corp, Chicago, IL, USA) was used for data analysis. Quantitative data were described as mean ± standard deviation, and numbers with percentages described qualitative data. The Chi-square test was used for comparing independent categorical variables. Mann Whitney U test and Kruskal Wallis test were performed for the numerical variables. P-value of less than 0.05 was considered significant.

Results

Group A patients were significantly younger (26.16 ± 11.49 vs. 34.63 ± 8.9 years; p< 0.001) and had lower body weight 55.09 ± 21.41 vs. 69.80 ± 19.20 kg; p= 0.01). Group A had a significantly higher gradient and smaller aortic annulus (p <0.001). (Table 1)

The primary valve lesion in group A was isolated aortic stenosis (AS) (n=18; 56.3%), AS associated with either moderate or severe aortic regurge (AR) (n= 9; 28.2%) or with subaortic membrane (n= 3; 9.4%), and one case presented with isolated aortic regurge (3.1%). In group B the primary lesion was mixed AS and AR (66.7%), isolated AS (20.0%), and isolated AR (13.3%).

Valve size 19 mm was the most commonly used valve in group A (n= 19); 11 patients had supra-annular implantation, and eight patients had Nicks operation. In group B, 12 patients (40%) had size 19 mm valve,12 patients (40%) had a size 21mm valve, and six patients (20%) had size 23 mm valve. Group A had significantly longer total cross-clamp and bypass times (p< 0.001). (Table 2)

Table 2: Operative data of the studied groups. (Continuous variables are presented as mean± standard deviation)

Variables	Group A (n= 32)	Group B (n= 30)	*P*
Valve size (mm)	19.81 ± 0.99	20.60 ± 1.53	0.03
Cross-clamp time (minutes)	118.13 ± 36.70	78.06 ± 16.01	< 0.001
CPB time (minute)	148.65 ± 44.09	97.46 ± 20.90	<0.001

CPB: cardiopulmonary bypass

Postoperatively, group A had a significantly longer duration of mechanical ventilation and intensive care unit stay (p= 0.02). There was no difference in the postoperative transvalvular pressure gradient and bleeding between both groups. Operative mortality was reported in one patient in group A who underwent supra-annular implantation of St. Jude 19mm valve. (Table 3)

Subgroup analysis of patients in group A revealed that two patients (15.4%) in the Nicks subgroup had intraoperative bleeding, one patient (7.7%) had a valve break, and two had unfitted valves (15.4%). Each of the Manouguian and St. Jude 19mm subgroups had an unfitted valve in one patient. (Table 4) Heart block occurred in one patient in the Nicks subgroup (7.7%), and one patient in the Konno subgroup (25%), hemolysis occurred in one patient in the Nicks group (7.7%), and renal failure occurred in one patient (9.1%) of ST. Jude 19mm.

The subgroup St. Jude size 19mm had the lowest bypass and cross-clamp times followed by Nicks procedure, then Manouguian procedure while Konno procedure had the highest time. There was no statistically significant difference between Nick and Manouguian procedures, but there was a significant difference between both and the other two groups (p-value<0.001). (Table 4) Patients with supra-annular implantation of the St. Jude valve had a significantly higher postoperative pressure gradient (14.64 ± 6.84 mmHg; p= 0.02). No difference in procedure complications was observed among aortic root enlargement procedures.

Discussion

The small aortic root presents a technical challenge during aortic valve replacement. There are different options for valve replacement; however, in our study, we included patients with mechanical prosthetic valves only because it is the most common type of prostheses used in our center. Patients with suspected small aortic root need to be addressed preoperatively by accurate measurement of the aortic annulus using transesophageal echocardiography (TEE) or multi-slice computed tomography (MSCT), which are not done routinely in our center.

In a study by Hisata and associates, they described AVR in small Asian patients and concluded that patients with small aortic root were older with a female predominance. In our study, sex distribution was comparable among the two groups with no significant difference [9]. Patients with small aortic roots in our research were younger and had lower body weight, which is different from what was reported in other studies, and this could be contributed to the dominance of rheumatic pathology in our population [9]. Aortic stenosis was the most common valve lesion associated with small aortic root [10], which is consistent with our results, and patients in group A had a significantly higher preoperative pressure gradient across the valve [1].

Table 3: Postoperative data of the studied group. (Continuous variables are presented as mean± standard deviation and categorical variables as number and percent)

	Group A (n= 32)	Group B (n= 30)	*P*
Mechanical ventilation (hour)	3.42 ± 1.04	3.01 ± 1.23	0.02
ICU stay (days)	4.37 ± 1.28	3.73 ± 1.14	0.02
Postoperative pressure (mmHg)	11.94 ± 5.33	11.60 ± 3.74	0.78
Postoperative bleeding	5 (15.6%)	2 (6.7%)	0.42
Re-exploration	1 (3.1%)	2 (6.7%)	0.60
Operative mortality	1 (3.1%)	0	1.00

ICU: intensive care unit

In a study by Kulik and colleagues, the aortic cross-clamp time was about 10 mins more in the group with AVR and ARE [11]. In our study, both cross-clamp and total bypass times were longer in group A (the cross-clamp was 40 minutes longer, and bypass time was 51 minutes longer). This is attributed to the additional procedure performed to AVR, and our times were longer than what was reported in the literature because of the relatively small number of patients performed in our center.

We did not find a significant difference between the two groups regarding the postoperative complications; however, group A had slightly more bleeding. These results showed that aortic root enlargement strategies carried no added risk when compared to conventional AVR surgery. Several studies had evaluated the risk of aortic root enlargement surgeries, and the results were controversial [12,13]. Rocha and associated in the analysis of 7039 patients found that surgical enlargement of the aortic root was not associated with increased risk of mortality or adverse events and that surgical ARE is a safe adjunct to AVR [14].

Table 4: Perioperative data of the study group based on surgical strategy. (Continuous variables are presented as mean± standard deviation and categorical variables as number and percent)

	Nicks (n= 13)	Manouguian (n= 4)	Konno (n= 4)	Supra-annular ST. Jude 19mm (n= 11)	*P*
Intraoperative event					
None	8 (61.5%)	3 (75%)	4 (100%)	10 (90.9%)	0.82
Bleeding	2 (15.4%)	0	0	0	
Valve break	1 (7.7%)	0	0	0	
Unfitted valve	2 (15.4%)	1 (25%)	0	1 (9.1%)	
Other complications					
None	11 (84.6%)	4 (100%)	3 (75%)	10 (90.9%)	0.74
Heart block	1 (7.7%)	0	1 (25%)	0	
Hemolysis	1 (7.7%)	0	0	0	
Renal failure	0	0	0	1 (9.1%)	
Total cross clamp (mm)	111.2 ± 14.30	145 ± 14.7	192.5 ± 22.2	89.5 ± 16	< 0.001
Bypass time (minute)	139.9 ± 17.7	183.8 ± 25	236.3 ± 19.70	114.4 ± 19.8	<0.001
Mechanical ventilation (hour)	3.30 ± 1.03	4 ± 0.81	4.75 ± 0.50	2.86 ± 0.77	< 0.001
ICU stay (days)	4.07 ± 0.75	4.50 ± 0.57	6.50 ± 0.57	3.90 ± 1.44	< 0.001
Post-operative pressure (mmHg)	12.25 ± 3.91	7.25 ± 1.25	8.50 ± 1.73	14.64 ± 6.84	0.02
Postoperative bleeding	2 (15.4%)	1 (25%)	0	2 (18.2%)	1.00
Re-exploration	1 (7.7%)	0	0	0	1.00
Operative mortality	0	0	0	1 (10%)	0.59

ICU: intensive care unit

Postoperative patient prosthesis mismatch (PPM) was evaluated by measuring the peak pressure gradient across the implanted prosthetic valve, and pressure above 30 mmHg indicates the presence of PPM [15]. In a study by Prifti and colleagues on the outcomes of the St. Jude 19mm mechanical valve, they found that this valve offers excellent postoperative clinical and hemodynamic performance in patients with small aortic annulus with an accepted transvalvular pressure gradient [16]. In our study we found no significant difference between the two groups regarding postoperative transvalvular pressure gradient and both groups fall in the safe zone with no prevalence of PPM in any group. All the cases of the study had a postoperative pressure gradient across the valve below 30 mmHg except one patient in group A. Our results are comparable to what is reported in the literature [16]. In a review by Bortolotti and coworkers comparing different surgical techniques of aortic root enlargement, they found that different ARE procedures are safe with good long-term results, and these findings were consistent with our results [17].

In our study, Nicks was performed in 13 patients (40.6%), out of which eight patients couldn't have a valve bigger than St. Jude size 19mm, while the remaining five patients had valve size 21 mm. The Manouguian and the Konno-Rastan subgroups had a size 21mm valve even in case of Konno procedures that were performed in teens with very small BSA.

There was no significant difference among the four strategies regarding intraoperative events. Two cases had bleeding after Nicks procedure, which was controlled on cardiopulmonary bypass. The valve did not fit during supra-annular implantation in 4 patients, 3 of these cases had root enlargement (2 had Nicks, and 1 had Manouguian), and in the fourth case, we removed the sutures and performed more extensive excision of the leaflet tissue, and supra-annular re-implantation was successful. Most of these events were related to either poor planning of surgery or the wrong decision to continue with the old plan.

As expected, the more the complexity of the surgery, the more time it takes; therefore, supra-annular implantation of St Jude size 19 mm had the least time, followed by Nicks, then Manouguian and finally by Konno procedure. The postoperative pressure gradient was measured with transthoracic echocardiography. The lowest pressure gradient was achieved in the Konno subgroup, and the highest was the supra-annular size 19 mm valve. This may be explained by the size of the implanted valve as in the Manouguian and Konno groups valve size 21 mm was used, while in the Nicks and the supra-annular groups' valve size 19 mm was the main size used. Although there was a significant difference between the four strategies, all of them had accepted pressure gradient with no difference in PPM.

These results support the idea that all the different surgical strategies mentioned in our study had accepted outcomes concerning early morbidity, mortality, and post-operative pressure gradient.

Study limitations

Limitations in the current study include small sample size, and surgery was performed by different surgical teams. The study is a retrospective analysis which could have selection bias. Transthoracic echocardiography was used to measure the annulus in all patients with interobserver variability. Additionally, not all options for management of small aortic root was evaluated in our study. Lastly, we applied one criterion for assessing the postoperative results and evaluating PPM, which is the transthoracic echocardiographic measurement of the pressure gradient across the prosthetic aortic valve.

Conclusion

Patients with younger age, lower weight, and AS are more likely to have a small aortic root. Aortic root enlargement strategies could be safe when combined with conventional aortic valve replacement with no additional operative risk. The results of aortic root enlargement techniques were comparable.

Conflict of interest: Authors declare no conflict of interest.

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