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Original Article

Long-term results of percutaneous balloon valvuloplasty of congenital aortic stenosis in adolescents and young adults



Neeraj Awasthy^{a,*}, Ria Garg^b, S. Radhakrishnan^c, Savitri Shrivastava^d

^a Consultant, Department of Pediatrics and Congenital Heart Diseases, Fortis Escorts Heart Institute, Okhla road, Delhi 110025, India

^b Fellow Department of Cardiology, Fortis Escorts Heart Institute, Okhla road, Delhi 110025, India

^c Director and HOD, Department of Pediatrics and Congenital Heart Diseases, Fortis Escorts Heart Institute, Okhla road, Delhi 110025, India

^d Director, Department of Pediatrics and Congenital Heart Diseases, Fortis Escorts Heart Institute, Okhla road, Delhi 110025, India

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ABSTRACT

Balloon aortic valvuloplasty (BAV) is a well accepted modality of treatment in congenital aortic stenosis in all age groups. Although in infants and children it is the modality of choice, in adolescents and young adults, it is of debatable efficacy.

Aim: To evaluate long-term results of aortic valvuloplasty particularly in adolescent and adults (>12 years) and compare the outcome in other age groups that are <1 year and between 1 and 11 years.

Setting: Tertiary referral center.

Patients: 165 consecutive patients treated at the median age of 9 years (1 day to 64 years). The follow-up was up to 14 years (median 3 years). The whole cohort was divided into 3 age-based subgroups: Group A (<1 year) $n = 45$, Group B (1 year–11 years) $n = 52$, and Group C (>12 years) $n = 68$. The characteristics of each subgroup were mutually compared.

Intervention: Percutaneous balloon valvuloplasty with mean (SD) balloon to annulus ratio of 0.93.

Main outcome measures were repeat BAV, significant aortic regurgitation (AR), and aortic valve replacement/repair.

Results: The incidence of significant AR from the whole cohort was 9.9% (8% moderate, 1.9% severe); $n = 16$. Group A = significant AR 9.5% (7.1% moderate, 2.4% severe), Group B = significant AR 11.3% (9.4% moderate, 1.9% severe), and Group C = significant AR 9% (7.5% moderate, 1.5% severe); p value = 0.99 (Group C vs Group A) and 0.92 (Group C vs Group B).

Repeat BAV rate was 13.3% ($n = 22$ out of 165 patients). Group A – $n = 5$ (11.9%), Group B – $n = 10$ (18.2%), and Group C – $n = 7$ (10.3%). p Value = 0.78 (C vs A) and 0.19 (C vs B).

Surgery in follow-up was needed in $n = 4$ (2.4%), none in Group A, 2 patients in Group B (3.6%), and 2 patients in group C (2.9%). Patients were followed up for a period of 14 years;

* Corresponding author.

E-mail address: n_awasthy@yahoo.com (N. Awasthy).

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Group A = up to 8 years, Group B = up to 13 years, and Group C = up to 14 years. Mean survival probability after the procedure was 8 years (Group A = 6.5 years, Group B = 8.1 years, and Group C = 9.9 years), and p value = 0.49 (A vs B), 0.23 (B vs C), and 0.4 (A vs C).

Conclusion: There is no statistical difference in the long-term outcome in the adults and adolescents as compared to the children; thus BAV remains an obvious treatment of choice with good long-term outcome.

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1. Introduction

Efficacy of balloon aortic valvuloplasty (BAV) is well documented in children with congenital aortic stenosis with good short-term results¹⁻³ and increased incidence of restenosis, as well as severe aortic insufficiency reinterventions in mid-term follow-up.^{4,5} Long-term results have shown 20% restenosis rate and a 21% incidence of significant aortic insufficiency 2-12 years after the procedure.⁶ The data regarding the outcomes of BAV in grown-up patients are scarce.

2. Material and methods

The purpose of our study was to evaluate long-term results of percutaneous BAV in a large cohort of patients and comparing the results of BAV in adults and adolescents with different age groups of the similar population.

All the patients who underwent balloon aortic valvotomy from May 2005 to May 2014 were included in the study (Table 1). For ease of analysis, the whole cohort of patients was divided into three mutually exclusive groups: Group A: up to 1 year of age, Group B: 1-11 years of age, and Group C: 11 years and above.

Peak-to-peak gradient for the ease of analysis was divided into <50 mmHg and >50 mmHg for the ease of statistical analysis, as per the recommendations. All the patients had a complete clinical and echocardiographic examination before the valvuloplasty.

2.1. Echocardiography

Aortic valve gradient was assessed by continuous and pulsed Doppler from a subcostal, apical, jugular, and right subclavicular

approach, and the highest gradient measured was accepted. Peak instantaneous gradient was calculated from maximum flow velocity and mean gradient by a time-velocity integral. Aortic regurgitation (AR) was assessed by color flow mapping and pulsed Doppler and scored on a five-grade scale: grade 1-4 (1 - no regurgitation; 2 - mild; 3 - moderate; 4 - severe, reverse diastolic flow in the abdominal aorta). Left ventricular ejection fraction (LVEF) was calculated using Simpson's rule in apical 4-chamber view. LVEF = 55% was taken as normal. The aortic annulus diameter and the morphology of the aortic valve were assessed by means of two-dimensional imaging from the parasternal long- and short-axis views.

2.2. Valvuloplasty

Informed consent to undergo the procedure was signed by parents or patients as appropriate. The risks of the procedure and long-term issues of AR and restenosis were explained. The valvuloplasty was performed from the percutaneous femoral arterial approach in all but 5 patients. In 1 neonate (Group A), carotid cut-down was used, as femoral access was not feasible. In 3 patients in Group B and 1 patient in Group C, transseptal puncture was done to cross the aortic valve as aortic valve could not be crossed retrogradely. Echocardiography measurements of the aortic annulus were used to decide the balloon diameter. The chosen balloon diameter was 90% or equal to the aortic valve annulus. If adequate results were not obtained, then the balloon with biggest diameter was used with an attempt not to exceed 100% of annular diameter. Also the calcified aortic valve of the elderly was excluded and not taken for BAV.

2.3. Follow-up

The patients were followed up by clinical examination and complete echocardiographic evaluation a day after the

Table 1 – The demographic profile of the 3 groups of patients showing the age (in years) and weight (in kilogram), with their mean, standard deviation.

Variables	Age groups			Total (Group A + B + C)
	Group A (<1 year)	Group B (1-11 years)	Group C (12 years and above)	
n	45	52	68	165
Mean ± Standard deviation	Age (years)	0.115 ± 0.2	6.885 ± 2.8	20.6 ± 9.7
	Weight (kilograms)	4.0 ± 1.8	12.4 ± 10.3	43.6 ± 18.8
Median (range, kg)	Age (years)	0.0	7.0	18.5
	Weight (kilograms)	3.3 (2.2-10.2)	8.7 (2.3-43)	40.0 (9-87)

procedure, at discharge from the hospital, a month after discharge, and later at six month to yearly intervals according to the residual findings. The follow-up period ranged from 6 months to 14 years (median 3 year). Total patients lost to follow-up were $n = 34$ (20.6%); Group A $n = 4$ (12.9%), Group B $n = 9$ (20.9%), and Group C $n = 21$ (35%). All others had a complete clinical and echocardiographic evaluation in our outpatient clinic. Thus, follow-up data were available for 131 (79.3%) patients. In the patients lost to follow-up, the last available echocardiographic data were used for analyses, and in the patients who required surgery, the last echocardiography data before surgery were used.

In the follow-up of the patients, the echocardiographic records were reviewed for the determination of Doppler gradients, need for repeat balloon aortic valvotomy, and need for surgery (AVR). The outcome parameters of the study were repeat BAV, need for surgery, and significant AR (grade 3 and 4), as detailed above. The outcome parameters were analyzed in the three groups with respect to age, balloon aortic annulus ratio, Z score, weight of the patient, LV dysfunction at the time of the presentation, pregradient of the catheterization, and associated lesions (bicuspid aortic valve, unicuspid aortic valve, associated lesions, such as ventricular septal defect (VSD), atrial septal defect (ASD), patent ductus arteriosus (PDA), coarctation of aorta, presence of mitral regurgitation (MR), and mitral stenosis (MS)). Improvement of LV function was analyzed in the patients with decreased LV function and possible factors that could have contributed were looked at.

2.4. Statistical analysis

SPSS version 17 was used for statistical analysis. Continuous variables are presented as mean \pm SD and categorical variables are presented as percentages. Differences between continuous variables were assessed by Student t test. Paired tests were analyzed by paired Student t test. Categorical variables were compared using the chi-square test or Fisher exact test as indicated. Significance was set at $p < 0.05$. Cumulative survival curves were constructed using the Kaplan-Meier method and compared by the log-rank test. The Cox proportional hazard regression method was used to examine the univariable association of clinical, catheterization, and echocardiographic variables with event-free survival. Multivariable associations within these same groups were also evaluated. All continuous variables were measured in their original scale.

3. Results

There were a total of $n = 165$ patients over the period; Group A $n = 45$ (27.2%), Group B $n = 52$ (31.5%), and Group C $n = 68$ (41.2%). All the patients were analyzed with respect to the three subgroups (A, B, and C) (Table 1).

In Group A, the mean age at the time of valvuloplasty was 1.2 months (range 0–1 years). There were 22% newborns under 4 weeks of age (13.3% of the total cohort and 48% of the total Group A cohort). Group B included patients of 1–11 years of age, $n = 52$ (31.5%); the mean age at the time of valvuloplasty was 6.8 years (range = 1–11 years). Group C included patients of ≥ 12 years $n = 68$ (41.2%); the mean age at the time of valvuloplasty was 20.6 years (range = 12–24 years) (Table 1).

Balloon-annulus ratio (bar) and Z scores of annulus are elaborated in Table 2.

3.1. Catheter gradient

The immediate change in peak-to-peak catheter gradient was compared in three subgroups (cut-off peak-to-peak gradient 50 mmHg). For Group A, 94.3% ($n = 42/45$) patients had a gradient change, while 5.7% ($n = 2$) of the patients had gradient that continued to be more than 50 mmHg. In follow-up, out of the 5.7% ($n = 2$) patients, 1 underwent repeat BAV. For Group B, 93.2% ($n = 48/52$) patients had a gradient change, while 6.8% ($n = 3$) of the patients had gradient that continued to be more than 50 mmHg. For Group C, 88.1% ($n = 59/68$) patients had a gradient change, while 11.9% ($n = 7$) of the patients had gradient that continued to be more than 50 mmHg. In follow-up, out of the 7 patients, 2 had repeat BAV. p Value for Group B vs A is 0.51, and Group C vs A is 0.47. The percentage fall in gradient for each group was as follows: Group A had a change of $57.6\% \pm 20.6\%$ in mean gradient; Group B had a change of $61.6\% \pm 22.1\%$ in mean gradient; Group C had a change of $64.2\% \pm 20.4\%$ in mean gradient. There was no significant difference of p value between the three groups (A vs B < 0.0001 , B vs C < 0.0001 , A vs C < 0.001).

3.1.1. LV dysfunction

LV dysfunction at the time of presentation was present in 66.7% of patients in Group A ($n = 28$), 40.7% in Group B ($n = 22$), and 10.9% in Group C ($n = 7$). This accounted for 35.5% of the whole cohort of BAV patients.

Follow-up for each subgroup A, B, and C will be discussed with respect to three outcome parameters: repeat BAV, need

Table 2 – Table showing the balloon-annulus ratio and Z scores for the 3 groups of patients: A, B, and C. (For the whole group BAR = 0.76–1.08 (mean 0.93 \pm 0.24).

Age groups	Balloon-annulus ratio		n	Z-score	
	Mean	Median		Mean	Median
<1 Year (Group A)	0.98 \pm 0.45	0.88	34	0.77 \pm 0.1	0.73
1–11 Years (Group B)	0.89 \pm 0.11	0.92	46	1.05 \pm 0.3	1.0
≥ 12 Years (Group C)	0.91 \pm 0.06	0.93	59	1.68 \pm 0.26	1.68
Total	0.93 \pm 0.24	0.92	139	1.25 \pm 0.46	1.26

Table 3 – The distribution of aortic insufficiency (AR) with their grading, repeat BAV and surgery for the 3 groups of patients: A, B, and C.

Complications		Age groups			Total (Group A + B + C)
		Group A (<1 year)	Group B (1–11 years)	Group C (12 years and above)	
AR (n and % within each age group)	1 (None)	15 (35.7%)	22 (41.5%)	21 (31.3%)	58 (35.8%)
	2 (Trace)	6 (14.3%)	7 (13.2%)	10 (14.9%)	23 (14.2%)
	3 (Mild)	17 (40.5%)	18 (34%)	31 (44.8%)	65 (40.1%)
	4 (Moderate)	3 (7.1%)	5 (9.4%)	5 (7.5%)	13 (8%)
	5 (Severe)	1 (2.4%)	1 (1.9%)	1 (1.5%)	3 (1.9%)
	Total	42	53	67	162
Follow-up (n and % within each age group)	Repeat BAV	5 (11.9%)	10 (18.2%)	7 (10.3%)	22 (13.3%)
	Surgery	0.0 (0.0%)	2 (3.6%)	2 (2.9%)	4 (2.4%)

for surgery, and AR (Table 3). Further, the three outcome parameters would be discussed, including the factors influencing each parameter in the three subgroups (A, B, and C), viz. age, balloon aortic annulus ratio, Z score, weight of the patient, LV dysfunction at the time of the presentation, predilatation gradient, peak-to-peak gradient of the catheterization, and associated lesions (bicuspid aortic valve, unicuspid aortic valve, VSD, ASD, PDA, coarctation of aorta, presence of MR and MS).

3.2. Repeat BAV

Repeat BAV was required in 5 patients in Group A (11.9%), 10 patients in Group B (18.2%), and 7 patients in Group C (10.3%). p Value = 0.78 for (Group A vs C), and p = 0.196 for (Group B vs C) (Table 3).

Of those requiring repeat BAV, 15.8% (n = 9) patients had LV dysfunction at the time of presentation (Table 4). Of these, 44.4% (n = 4) were in Group A, 44.4% (n = 4) were in Group B, and 11.1% (n = 1) were in Group C. These patients continued to have LV dysfunction in follow-up.

All the patients taken for BAV had no significant AR (ranging from grade 1–2) preprocedure. Group A had grade 1 – 40.1% and grade 2 – 59.9%. Group B had grade 1 – 38.4% and grade 2 – 61.7%. Group C had grade 1 – 42.1% and grade 2 – 79.7%.

Balloon-annulus ratio for those undergoing repeat BAV was 1.09 (\pm 0.6) as compared to patients who did not have repeat BAV, who had BAR of 0.92 (\pm 0.05).

3.3. Gradient change

Mean predilatation gradient was 70 ± 31 mmHg and post-dilatation gradient was 30.8 ± 22 mmHg in the patients who

underwent repeat BAV, as compared to those who did not have repeat BAV, who had a mean predilatation gradient of 85 ± 30.5 mmHg and postdilatation gradient of 23 ± 15.5 mmHg. Thus, those who had significant change in gradient from pre- to postdilatation had less chance of repeat BAV than those who had less change in gradient.

For Group A, 94.3% (n = 42/45) of the patients had predilatation gradient >50 mmHg that decreased to post-dilatation gradient <50 mmHg, while 5.7% (n = 2) of the patients had gradient that continued to be more than 50 mmHg. In follow-up, out of these 2 patients, 1 had repeat BAV.

For Group B, 93.2% (n = 48/52) of the patients had pregradient >50 mmHg that decreased to postgradient <50 mmHg, while 6.8% (n = 3) of the patients had peak gradient that continued to be more than 50 mmHg. In follow-up, none of these 3 patients had a repeat BAV or surgery.

For Group C, 88.1% (n = 59/68) of the patients had pregradient >50 mmHg that decreased to postgradient <50 mmHg, while 11.9% (n = 8) of the patients had gradient that continued to be more than 50 mmHg. In follow-up, out of these 7 patients, 2 had repeat BAV.

p value = 0.476 for (Group A vs C), and p = 0.510 for (Group B vs C).

All the patients requiring repeat BAV or surgery had features of effort intolerance.

3.4. Aortic insufficiency (Table 3)

AR was divided into 4 groups, 1–4 (1 – none, 2 – mild, 3 – moderate, 4 – severe), for the ease of outcome analysis.

Group A had 9.5% incidence of significant AR (7.1% moderate n = 3, 2.4% severe n = 1), while most patients had no AR (35.7%, n = 16) or mild AR (55%, n = 25).

Table 4 – The profile of patients with ventricular dysfunction (left ventricular ejection fraction <55% measured in apical four chamber view by Simpsons method) in follow-up.

Follow-up (n and % within each age group)	Follow-up \times LV_dysfunction		LV_dysfunction		Total
			1 (Present)	2 (Absent)	
			Count	Count	
Follow-up (n and % within each age group)	1 (Repeat BAV)	Count	9 (15.8%)	13 (12.6%)	22 (13.8%)
	2 (Surgery)	Count	2 (3.5%)	2 (1.9%)	4 (2.5%)

Table 5 – The survival for the 3 groups of patients (see also Kaplan–Meier curve).

Duration of follow-up	2 Years	4 Years	6 Years	8 Years	10 Years	12 Years	14 Years
Age groups							
<1 Year	86%	78.5%	70.8%	45%			
1–11 Years	79.3%	63.6%	56%	50.2%	41.8%	20.2%	
≥12 Years	92.3%	89.9%	86.2%	52.9%	44%	31%	0%

Survival table showing cumulative proportion surviving at the time.

Group B had 11.3% incidence of significant AR (9.4% moderate $n = 5$, 1.9% severe $n = 1$), while most patients had no AR (41.5%, $n = 22$) or mild AR (47.2%, $n = 18$).

Group C had 9.9% incidence of significant AR (7.5% moderate $n = 5$, 1.5% severe $n = 1$), while most patients had no AR (32%, $n = 22$) or mild AR (59.7%, $n = 40$).

p value = 0.99 for (Group A vs C), and $p = 0.92$ for (Group B vs C).

The bicuspid aortic valve was compared and was not observed to have impact on the degree of AR or falling gradient. The maximum impact observed was when the postgradient was reduced significantly; probably the significant change in gradient was at the cost of significant AR.

3.5. Relation between significant AR and balloon annulus

Ratio in Group A, the mean balloon–annulus ratio for patients having significant AR is 0.8, in Group B it is 0.94, and in Group C it is 0.91. Thus, there was statistically no difference between the BAR and AR. This was not an age-dependent variable. And thus, balloon size was not an attributable cause of significant aortic insufficiency when compared between the groups.

Also a strong correlation existed with the presence of associated risk factors for AR. Presence of PDA (63.7%) and coarctation of aorta (25%) were invariably associated with the presence of significant AR.

Surgery (Tables 3 and 5) in follow-up was observed in 2.4% ($n = 4$), none in Group A, 2 patients in Group B (3.6%), and 2 patients in Group C (2.9%), and it was observed over a follow-up period of Group A = 0–8 years, Group B = up to 13 years, and Group C = up to 14 years. Mean survival probability after the procedure was 8.9 years (Group A = 6.5 years, Group B = 8.1 years, and Group C = 9.9 years). p Value = 0.49 (A vs B), 0.23 (B vs C), and 0.4 (A vs C) (Figs. 1 and 2).

4. Discussion

Our study presents a single institution's experience with 165 consecutive patients with congenital aortic stenosis treated by percutaneous balloon valvuloplasty with the aim to compare the outcomes in three subsets of patients with hypothesized different outcomes as per age, and these subsets of patients were subsequently followed up for long-term outcomes up to 14 years. The institution is a tertiary care referral center for a large subset of population of the country. In all the patients who underwent valvuloplasty, it was the initial method used.

4.1. The study design discussed

The purpose of having divided the patients into three groups was essentially to compare the outcomes of Group C

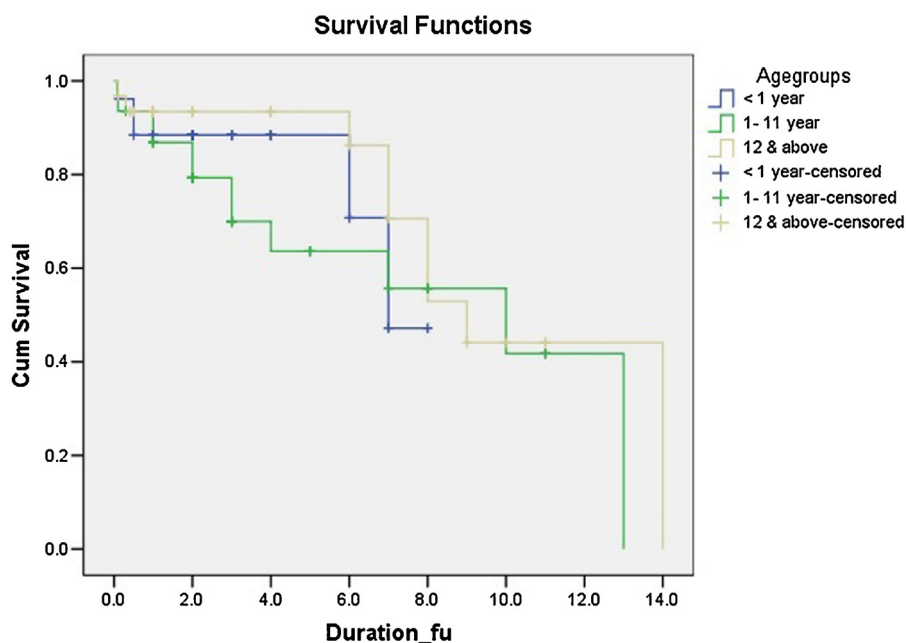


Fig. 1 – Kaplan–Meier curve showing the follow-up of the 3 subsets of patients A, B, and C as per the age group. + sign as labeled by the term “censored” signifies the events: either repeat BAV or surgery.

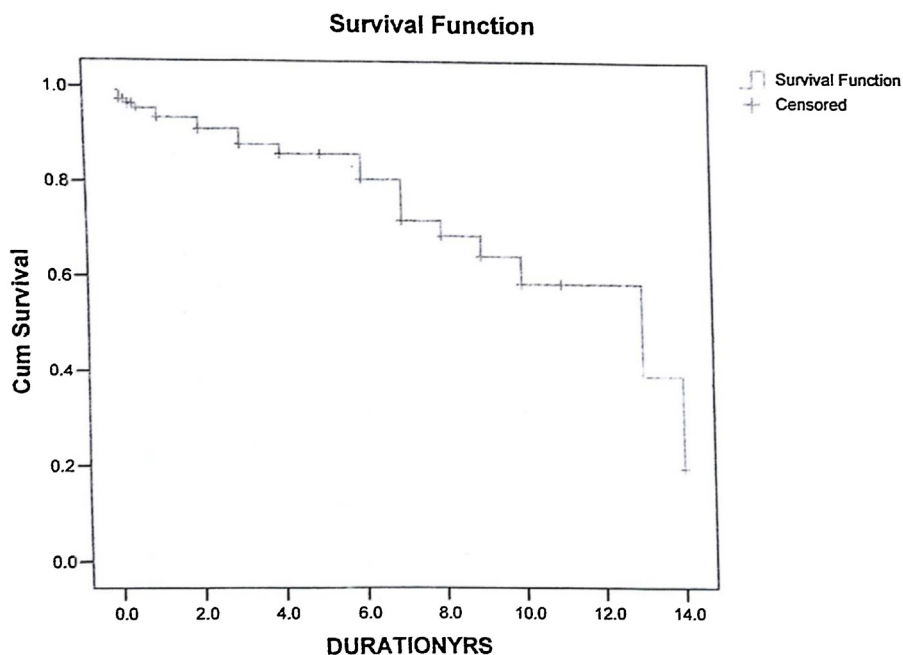


Fig. 2 – Kaplan–Meier curve showing the follow-up of the 3 subsets of patients as a single cohort. Mean (SEM) survival probability, 14.4 years after the procedure, was 0.89 (0.02) and mean (SEM) probability of surgery-free survival was 0.50 (0.08). + sign as labeled by the term “censored” signifies the events: either repeat BAV or surgery.

(i.e. patients above 11 years of age) with those of the Group A and Group B. BAV remains the procedure of choice for the infants in Group A and Group B. The same is essentially because of the need of a more invasive repeated surgical procedure whenever performed in this particular age group. There is in general high degree of inclination for surgical intervention in young and adolescents age groups (Group C), having achieved a larger annulus size and less chance of a repeated surgery for the valve mismatch. Also, few would consider that BAV is just a bridge to surgery to buy time. The inclination for the surgical group stems from the popular thinking that most of the patients of the aortic valve disease would end up on the surgical table. Thus, Group C remains a subject of contention between the surgical proponents and interventional cardiologist. The present study was essentially planned with this aim to reevaluate the outcomes of this group of patients with those in other age groups, and to look at their long-term outcome.

4.2. Why the division into age groups

There are a number of studies that have evaluated the patients from 0 years to adult age who underwent BAV as a single cohort.^{10,11} Also there are a number of studies that discuss the advantages of using the procedure in patients who are unsuitable for surgical correction^{12–14} with good long-term outcome. There is still a lack of available literature that exclusively looks at young adult and adolescents, with the aim to evaluate the outcomes of BAV, in an age group that is otherwise suitable for aortic valve replacement in view of generally adequate annulus size with or without Konnos. A few studies showed high incidence of surgery after BAV.^{12,13}

In the present study, all the patients were enlisted and subsequently analyzed retrospectively with respect to the presentation of the patients and risk factors. Risk factors compared in the study for each group was ventricular dysfunction at the time of presentation, degree of aortic insufficiency at the time of presentation, and associated risk factors because of sick presentation of these subgroups of patients. LV dysfunction was present in 44.4% of Group A patients as compared to only 11.1% in Group C, as Group A always represents a sicker group of patients. So although the need of repeated BAV correlated with the ventricular dysfunction, statistically it did not impact the difference in long-term outcome when compared for all the three groups (p value = 0.751 for patients undergoing repeat BAV with and without LV dysfunction). Also, in consistent with the observed studies, the ventricular dysfunction improved significantly in all the age groups after BAV.¹⁵ Pedersen et al. have demonstrated the same even in the elderly population.^{16,17} All the patients in the present study underwent BAV using low-profile Tyshak II balloon, which have shown good results in various studies.¹⁸ Retrograde technique was used in most of the patients, while in 8 patients antegrade transseptal technique was also used.¹⁹ Innoue was used in none of our patients for BAV till data were analyzed. Rapid ventricular pacing²⁰ was used as a protocol in all of our patients in Group C and a few in Group B.

Aortic insufficiency was divided into 4 grades as per the standard recommendations. Significant AR (i.e. grade 3 or 4), i.e. moderate or severe AR, was observed in 9.9% of the total cohort of our patients with no statistical difference between the three groups, p value = 0.99 (C vs A) and 0.92 (C vs B). Interestingly, the valve morphology did not impact the degree

of AR in any of our subgroups (a observation seen in few other studies),^{10,11} but we believe this is because of the presence of even distribution of the bicuspid aortic valve patients in all the three groups, making the difference between them statistically insignificant. Associated lesions, such as PDA (27% of AR) and coarctation (25% of AR), were observed to have strong association with the presence of significant AR in our study.

Our restenosis rate was comparable and aortic insufficiency rate and surgical rate were lower than many other reported studies.⁴⁻²⁰ O Reich et al.⁴ followed up over a period of 15 years showed restenosis rate of 16.7% ($n = 45$) and significant insufficiency in 22.3% ($n = 60$); surgery was needed in 20.1% ($n = 54$), and "valvuloplasty failure" occurred in 41.6% ($n = 112$) of patients. But we believe that they looked at the full cohort of patients from 0 to 23 years as a single subset, which is a wide spectrum of patients and probably the subgroups should be subdivided into age groups to evaluate the age-related discrepancies in evaluation (as done in our study).

Division into subgroups really helps to distinguish the impact of age on various subgroups. There are only a few studies that evaluate the patients on the age-related aspects. Balmer et al. in their cohort of 70 patients (up to 16 years of age) divided them into less than 3 months and more than 3 months, and showed that pressure gradient dropped significantly with the intervention and increased mildly at follow-up. Freedom from AR was initially lower in group <3 months (75% vs 90% after one month), but after two years, the difference between the two groups was not significant (50% vs 61%). Thus their observation is similar to our findings.

The issues that decide the long-term AR still remain controversial. In our study, though it was not intended to evaluate the risk factors for AR, we observed that neither the valve morphology nor the presence of bicuspid aortic valve was a significant risk factor for AR. Similar findings were shown by few other studies,¹⁰⁻¹⁴ although the associated lesions when present were found to have a statistically significant correlation with presence of AR.

Repeat BAV rate was 13.3% ($n = 22$ out of 165 patients). Repeat BAV was required in 5 patients in Group A (11.9%), 10 patients in Group B (18.2%), and 7 patients in Group C (10.3%). p Value = 0.78 for (Group C vs A), and 0.19 for (Group C vs B). Mean pregradient was 70 ± 31 mmHg and postgradient was 30.8 ± 22 mmHg in the patients who underwent repeat BAV, as compared to those who did not have repeat BAV, who had a mean pregradient of 85 ± 30.5 mmHg and postgradient of 23 ± 15.5 mmHg. Thus, those who had significant change in gradient from pre to post had less chance of BAV than those who had less change in gradient. Change in gradient was 57.6% for Group A, 61.7% for Group B, 64.2% for Group C, and 61.7% for the whole cohort of patients. Significant decrease in gradients have been shown by many other studies.^{4-8,10,11} Similarly, as others,⁴⁻²⁰ we have obtained an effective reduction of gradient by valvuloplasty but the gradient on average did not increase over the follow-up period. In our study, there was a statistically significant reduction in gradient in each of the three subgroups but there was no statistical difference between the change in gradients between the three groups of patients A, B, and C and hence the BAV procedure is equally efficacious in all the three with no statistical difference between the subgroups.

Higher incidence of surgery than our group has been shown in various studies. 15%, $n = 42$, of their 272 patients of Maskatia et al. underwent aortic valve surgery. Our subgroup of patients had no statistical difference between the three groups with 5 patients undergoing surgery in the whole cohort. Of the patients who underwent the surgery, i.e. aortic valve replacement, indication was the same as in their study, i.e. significantly increased aortic insufficiency. Understandably, none of the patients with significant residual AS underwent surgery as these are always considered for a repeated BAV. None of our patients warranted AVR because of associated cardiac surgery for other valve replacement. None of the patients in group 1 underwent a surgery in follow-up, and probably they still have not achieved that age that makes them a suitable candidate for AVR, although we agree that none of them required an aortic valve repair as well. In spite of this, the difference between the groups was not statically significant. Also, as compared to other studies, we had a lot of patients who did not warrant surgery. This could imply improved Indian results with BAV as compared to other subgroups of patients. The lost to follow-up data could have squeaked the results, but loss to follow-up is not significant between the groups.

For the three subgroups of patients, there is significant difference in annulus diameter with Group A having smaller annulus diameter compared to peers. Group C is having comparatively similar annulus diameter compared to peers, and still the results of BAV are comparable in both the groups.

4.3. Follow-up (Table 5)

The follow-up period ranged from 0 days to 14 years (median 3 years). Total patients lost to follow-up were $n = 34$ (20.6%); in Group A $n = 4$ (12.9%), Group B $n = 9$ (20.9%), and Group C $n = 21$ (35%), with no statistical difference between the three groups. All had a complete clinical and echocardiographic evaluation in our outpatient clinic. The last end point was especially rigorous and included all the significant residual findings or need for surgery or death. Indeed, studies that compared valvuloplasty with surgical valvotomy have had almost identical results for these methods.⁸ In such a situation, the lower treatment costs and higher patient comfort speak in favor of balloon valvuloplasty.

4.3.1. Limitations

The present study has been done on a large cohort of patient with the aim to look at the outcome of the patients in adults and adolescents, comparing them with the outcomes in the proven subsets of children; but we must realize that each subset of population has its own selective features and the adolescents are not grown-up children or miniaturized adults. Thus, the gradients that stand true for a small child may not be truly suitable for an active adult or adolescent population. The ventricular dysfunction was not graded in the present study and hence it would be interesting to look at the change in the ventricular function over time from a prospective cohort of patients. Less number of patients that required surgery although speaks volumes about the efficacy of BAV, but the statistical difference between the three groups could be influenced and non representative being too small a number

undergoing surgery. Technically, we expected more patients in Group C as compared to Group B or A for surgery. Our study had a large population of bicuspid aortic valves and thus the outcomes were skewed toward the same. Also, the incidence of bicuspid aortic valve was similar in the 3 groups of patient; this nullified the effect of the valve morphology on each selective subgroup. But we are not in a position to compare the outcome of valve morphology on long-term outcome and that was not a part of the study too.

5. Conclusion

There being no statistical difference in the long-term outcome in the adults and adolescents as compared to the children, who are considered more suitable for BAV, the BAV remains an obvious treatment of choice with good long-term outcome as demonstrated by this study.

Conflicts of interest

The authors have none to declare.

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