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Clinical Investigation

Midterm Outcomes of Pediatric Mitral Valvuloplasty for Moderate to Severe Mitral Valve Regurgitation and Associated Risk Factors for Postoperative Deterioration

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Abstract

Background: Mitral valvuloplasty is considered the best treatment for pediatric mitral valve regurgitation. The objective of this analysis was to identify risk factors for postoperative mitral valve regurgitation progression and evaluate valvuloplasty effectiveness.

Methods: This retrospective, single-center study investigated the clinical efficacy of mitral valvuloplasty and identified factors that affect prognosis. Pediatric patients with moderate or severe mitral valve regurgitation who had undergone mitral valvuloplasty between September 2016 and August 2023 were included. Kaplan-Meier survival analysis was used to assess freedom from both mitral valve deterioration and cardiovascular death. Univariate and multivariate Cox regression analyses were performed to identify potential risk factors.

Results: The study comprised 137 pediatric patients (mean age, 37.5 months [range, 2.4-167.6 months]) who had moderate (64/137 [46.7%]) or severe (73.137 [53.3%]) mitral valve regurgitation. At midterm follow-up (median, 55.3 months), mitral valve regurgitation had statistically significantly decreased compared with preoperative levels ($P < .001$, Wilcoxon signed-rank test); freedom from cardiovascular death was 97.5%, and freedom from worsening mitral valve regurgitation was 89.4%. Cox regression analysis identified body weight ($P = .02$), left ventricular end-diastolic diameter ($P = .005$), and left ventricular ejection fraction ($P = .01$) at 1 month and cardiopulmonary bypass time ($P = .007$) as independent risk factors for deterioration. Patients weighing 10 kg or more ($P = .04$) or with a ventricular septal defect 8 mm or larger ($P = .04$) had worse outcomes.

Conclusion: Mitral valvuloplasty resulted in low mortality and positive long-term results in pediatric patients with mitral valve regurgitation. Early aggressive therapy is recommended to avoid late postoperative mitral valve deterioration.

Keywords: Mitral regurgitation; pediatrics

Introduction

Congenital mitral valve regurgitation is rare, occurring in about 0.49% of the population,[1,2] and the prevalence of secondary mitral valve regurgitation is even lower. In 1976, Carpentier introduced a classification system for mitral valve regurgitation. Type I is marked by normal leaflet motion and includes conditions such as annular dilatation, leaflet cleft defects, and partial leaflet hypoplasia. Type II is characterized by mitral valve insufficiency resulting from chordae tendineae or chordae redundancy, and type III, which involves limited leaflet motion, often leads to mitral valve stenosis.[3] Mitral valve regurgitation brought on by isolated mitral valve lesions,

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which is rare in pediatric patients, is usually linked to other congenital intracardiac anomalies, including patent foramen ovale, atrial septal defect (ASD), and ventricular septal defect (VSD).[4]

Treating mitral valve regurgitation in pediatric patients is difficult because of the disorder's complicated etiology and common association with major complications. The small area for surgical exposure and the delicate, thin character of the heart valves make surgical treatment in children especially challenging.[5] Moreover, because children grow quickly, prosthetic valves are usually inappropriate, and repeat valve replacements are often needed over time.[6] Currently, mitral valvuloplasty is the most common surgical intervention for pediatric patients with mitral valve regurgitation, especially in cases involving congenital anomalies.[7] Recent studies have shown favorable results from surgical repair of congenital mitral valve lesions, with improved long-term survival rates and a lower demand for reoperation.[8,9] This retrospective, single-center study was designed to evaluate the clinical efficacy of mitral valvuloplasty in treating mitral valve regurgitation in pediatric patients and to identify the factors that affect prognosis.

Key Points

- Mitral valvuloplasty is effective in addressing mitral valve regurgitation in pediatric patients.
- Patient weight, CPB duration, postoperative LV size, and LVEF substantially affect prognosis.
- The presence of a larger VSD correlates with poorer prognosis.

Abbreviations

ASD, atrial septal defect
CPB, cardiopulmonary bypass
LV, left ventricular
LVEF, left ventricular ejection fraction
VSD, ventricular septal defect

Patients and Methods

This retrospective study included 137 pediatric patients who had undergone mitral valvuloplasty at Capital Medical University Affiliated Anzhen Hospital between September 2016 and August 2023 and who had moderate or severe mitral valve regurgitation, as assessed by echocardiography, regardless of the presence or absence of clinically significant symptoms at the time of enrollment. Patients were excluded if they were older than 14 years of age or had mitral valve redo-valvuloplasty, ischemic mitral valve regurgitation, complete or partial endocardial cushion defects, a single ventricle with a common atrioventricular valve, or cardiomyopathy. Clinical and diagnostic data were collected at 3 time points: preoperatively, 1 month postoperatively, and at midterm follow-up (median follow-up, 55.3 months [range, 6.3-89.6 months]). Mitral valve regurgitation was quantified in terms of the ratio of the regurgitant jet area to the left atrium area (regurgitant fraction) and graded as none, mild (≤0.2), moderate (>0.2 to <0.6), or severe (≥0.6). Local ethics committee approval was obtained retroactively, so patients did not sign informed consent forms (Beijing Anzhen Hospital Ethics Committee, institutional review board No. 2024127X).

Mitral Valvuloplasty Technique

Most operations (91/137 [66.4%]) were performed via a median sternotomy, whereas a small right axillary incision approach was used in 46 (33.6%) patients. Standard aortic and superior and inferior vena cava cannulation were used to establish cardiopulmonary bypass (CPB). Patients underwent normothermic CPB after complete heparinization. The mitral valve was reached through a right atriotomy, either via an ASD or atrial septal incision. Rather than reestablishing the normal anatomical structure of the valve, the main goal of the operation was to restore mitral valve function.[10] Because mitral valve regurgitation in these patients usually results from an enlarged valve annulus, the technique used most often was reduction of the mitral valve annulus.[11,12] In patients with prolapsed valve leaflets, artificial chordae designed from 6-0 Gore-Tex thread (Gore) were used to support the leaflets, or the leaflets were corrected by plication. For leaflet plication, the prolapse was corrected with 6-0 Prolene (Ethicon) sutures at the commissural points on both sides of the near-normal valve leaflet at the annular margin, where the leaflet is vertically plicated to the annulus and secured. Subsequently, interrupted sutures were placed sequentially along the valve annulus, and the prolapsed leaflet was repositioned into the left ventricular (LV) side. In some older patients, a valvuloplasty ring was fitted to improve mitral valve performance. Annuloplasty rings from 3 companies were used: one 26-mm Physio II annuloplasty ring from Edwards, two 28-mm annuloplasty rings from Sorin, and 4 annuloplasty rings from Medtronic (three 28 mm and one 29 mm). Any leaflet tears were repaired. Coexisting cardiac malformations were corrected concurrently during the operation. All patients who had a VSD underwent repair at the same time as mitral valvuloplasty at Capital Medical University Affiliated Anzhen Hospital to avoid leaving residual deformities and the possible subsequent effects of a VSD on cardiac function.

Statistical Analysis

All continuous variables are expressed as mean (SD) or median (range), and categorical variables are expressed as frequencies (percentages). For subgroup analyses, the *t* test was used to compare parametric variables, and the χ^2 test was used to compare nonparametric variables. The Kaplan-Meier method was used to estimate the rate of freedom from worsening mitral valve regurgitation, and the differences in the rates of freedom from worsening mitral valve regurgitation were compared using the log-rank method. In addition, to evaluate risk factors for worsening mitral valve regurgitation, a univariate Cox regression analysis was performed; subsequently, variables with $P<.05$ were included in the multivariate Cox regression analysis. $P<.05$ (2 sided) was considered statistically significant. All statistical analyses were performed using SPSS, version 21.0, software (IBM Corp).

Results

Preoperative Characteristics

Table I lists the preoperative characteristics of the 137 patients included in the study. The average patient age was 37.5 months (range, 2.4-167.6 months).

Operative Outcomes

The specific valvuloplasty methods used are presented in Table II. Annuloplasty was performed in 130 (94.9%) patients, with most (109/137 [79.6%]) undergoing junctional annuloplasty—that is, suturing at the junction of the anterior and posterior mitral valve leaflets to reduce the size of the annulus, such as the modified Kay-Wooler and Reed methods. Of the 61 (44.5%) patients with mitral valve prolapse, 51 (83.6%) underwent annuloplasty to treat mitral valve regurgitation arising from mitral valve prolapse. Leaflet cleft suturing was performed in 36 (26.3%) patients with concomitant leaflet clefts. Eleven patients (8.0%) underwent leaflet plication, with concurrent use of other techniques, including annuloplasty (10 patients), leaflet suturing (2 patients), and annuloplasty ring implantation (1 patient). In addition, 6 patients (4.4%) underwent artificial chordae implantation, with 3 patients also undergoing annuloplasty and 3 patients undergoing annuloplasty ring implantation. One patient was treated for mitral valve regurgitation with a valvuloplasty ring alone. If patients had other preoperatively or intraoperatively diagnosed cardiac malformations, these were also corrected: 68 cases of VSD repair, 8 cases of tricuspid valve regurgitation repair, 7 cases of patent ductus arteriosus ligation, 6 cases of ASD repair, 2 cases of patent foramen ovale closure, 4 cases of aortic valve repair (2 for stenosis, 2 for insufficiency), 2 cases of coarctation of the aorta correction, 1 case of partial anomalous pulmonary venous connection repair, 1 case of Ebstein anomaly correction, 1 case of cor triatrium repair, and 1 case of aortopulmonary fenestration repair.

The mean (SD) aortic cross-clamp time was 70.61 (30.78) minutes, and the mean (SD) CPB time for all patients undergoing mitral valvuloplasty was 100.82 (38.02) minutes. The mean (SD) total time on mechanical ventilation was 46.39 (34.95) hours. The mean (SD) length of stay in the postoperative care unit was 105.21 (69.61) hours.

Clinical and Echocardiographic Results

The median follow-up period was 55.3 months (range, 6.3-89.6 months; IQR, 26.3-74.2). The 30-day postoperative death-free rate was 99.3%. Two patients died of cardiac failure brought on by recurrence of mitral valve regurgitation (postoperative months 13 and 25, respectively), and 1 patient died of respiratory failure in the hospital on postoperative day 23. For the patients who survived until follow-up, the midterm actuarial cardiac-free death rate was 97.5%. Moreover, mitral valve regurgitation had improved greatly at midterm follow-up ($P<.001$), with 99.2% of patients remaining in New York Heart Association class II or below. At follow-up, 4 patients had severe mitral valve regurgitation, and 14 had moderate mitral valve regurgitation. Of the 137 patients in this study, 4 required mitral valve reoperation for regurgitation, resulting in a 97.1% freedom from reintervention rate. The midterm actuarial freedom from worsening mitral valve regurgitation was 89.4%.

Echocardiographic follow-up data are shown in Table III. Left ventricular end-diastolic diameter ($P<.001$) and left atrial diameter ($P<.001$) were statistically significantly lower at 1 month postoperatively compared with

TABLE I. Preoperative Characteristics (N = 137)

Characteristic	Value
Age, mean (SD), mo	37.5 (43.5)
Sex, No. (%)	
Female	88 (64.2)
Male	49 (35.8)
Height, mean (SD), cm	89.1 (29.1)
Weight, mean (SD), kg	13.7 (11.7)
Mitral valve regurgitation degree, No. (%)	
Moderate	64 (46.7)
Severe	73 (53.3)
Mitral valve abnormality, No. (%)	
Abnormalities of the tendon cords	7 (5.1)
Abnormalities of the papillary muscles	4 (2.9)
Abnormalities of the valve leaflets	78 (56.9)
Abnormalities of the annulus	48 (35.1)
Previous cardiac surgery, No. (%)	13 (9.5)
Combined with other cardiac malformations, No. (%)	
None	36 (26.3)
Ventricular septal defect	68 (49.6)
Tricuspid regurgitation	8 (5.8)
Patent ductus arteriosus	7 (5.1)
Atrial septal defect	6 (4.4)
Patent foramen ovale	2 (1.5)
Aortic stenosis	2 (1.5)
Aortic regurgitation	2 (1.5)
Coarctation of the aorta	2 (1.5)
Partial anomalous pulmonary venous connection	1 (0.7)
Ebstein anomaly	1 (0.7)
Cor triatrium	1 (0.7)
Aortopulmonary fenestration	1 (0.7)

preoperative measurements. Mean (SD) LV ejection fraction (LVEF) was lower at 1 month postoperatively (62.0% [7.8%]) than before surgery (67.7% [7.3%]) ($P = .001$). In addition, a time trend analysis based on a mixed-effects models showed continued reductions in LV and left atrial dimensions during midterm follow-up (negative β values, $P < .05$); LVEF returned to preoperative levels, and the time effect β value was not statistically significant ($P = .16$) (Table IV). A Kaplan-Meier analysis comparing the survival of patients with moderate and severe mitral valve regurgitation found no statistically significant difference in the proportion of patients free from worsening mitral valve regurgitation between the 2 groups ($P = .42$) (Fig. 1).

Risk Factors for Worsening Mitral Valve Regurgitation

Worsening mitral valve regurgitation was defined as moderate or severe mitral valve regurgitation, reoperation necessitated by recurrence of mitral valve regurgitation, and cardiac death attributable to recurrence of mitral valve regurgitation at follow-up.

TABLE II. Mitral Valvuloplasty Techniques Used in the Study Patients

Technique	No. (%)
Annuloplasty	130 (94.9)
Leaflet cleft suturing	36 (26.3)
Annuloplasty ring implantation	7 (5.1)
Artificial chordae implantation	6 (4.4)
Leaflet plication	11 (8.0)

TABLE III. Echocardiographic Data

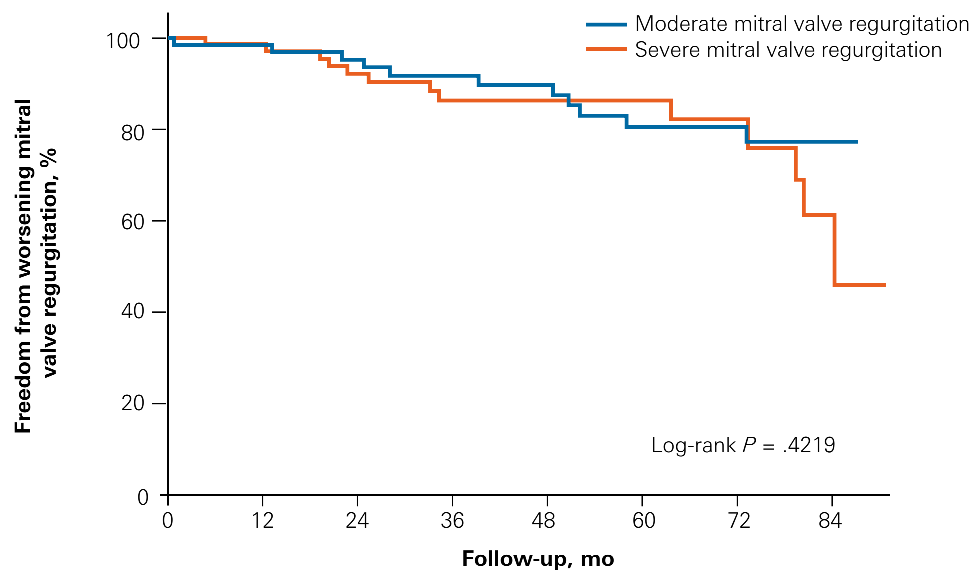
Data point	Preoperative	1-mo postoperative	*P* value[a]	Midterm follow-up
LV end-diastolic diameter, mean (SD), mm	40.3 (8.3)	31.6 (7.4)	<.001	36.1 (8.7)
Left atrial diameter, mean (SD), mm	30.2 (12.1)	23.6 (11.0)	<.001	25.4 (10.9)
LV ejection fraction, mean (SD), %	67.7 (7.3)	62.0 (7.8)	<.001	67.7 (5.6)
Ventricular septal defect, mean (SD), mm	8.8 (3.9)			
Atrial septal defect, mean (SD), mm	11.7 (11.8)			
Patent foramen ovale, mean (SD), mm	2.3 (0.7)			
No mitral valve regurgitation, No.		8		9
Mild mitral valve regurgitation, No.		118		104
Moderate mitral valve regurgitation, No.	64	10		13
Severe mitral valve regurgitation, No.	73	1		11

LV, left ventricular.
[a] $P < .05$ was considered statistically significant.

TABLE IV. Longitudinal Changes in Echocardiographic Parameters: Time Trend Analysis Based on Mixed-Effects Model

Parameter	Preoperative, mean (SD)	Midterm follow-up, mean (SD)	Time effect β	*P* value
LV end-diastolic diameter, mm	40.3 (8.3)	36.1 (8.7)	–.12	<.001
Left atrial diameter, mm	30.2 (12.1)	25.4 (10.9)	–.09	.002
LV ejection fraction, %	67.7 (7.3)	67.7 (5.6)	.05	.16

LV, left ventricular.



Patients at risk, No.								
Moderate mitral valve regurgitation	64	63	58	47	40	32	26	7
Severe mitral valve regurgitation	73	63	54	39	29	23	14	4

Fig. 1 Kaplan-Meier analysis shows worsening postoperative mitral valve regurgitation among patients with moderate and severe mitral valve regurgitation.

P < .05 was considered statistically significant.

Worsening mitral valve regurgitation was seen in 23 patients at follow-up and included patients who had moderate or severe regurgitation at follow-up, patients who needed reoperation for recurrent mitral valve regurgitation, and patients who died of cardiac-related factors caused by recurrent mitral valve regurgitation. Because reoperation and death both indicate severe mitral valve regurgitation recurrence, they are summarized in the discussion of risk factors. Univariate Cox regression analysis identified patient age, weight, VSD size, preoperative LV end-diastolic diameter, postoperative LV end-diastolic diameter, postoperative LVEF, and time to CPB as risk factors contributing to mitral valve deterioration in the late postoperative period. A multifactorial Cox analysis found that weight, postoperative LV end-diastolic diameter, postoperative LVEF, and CPB time were independent risk factors for worsening mitral valve regurgitation during this period; sex, ASD size, and preoperative left atrial diameter were not associated with worsening mitral valve regurgitation (Table V). Multicollinearity among variables was assessed in terms of variance inflation factors, with all values less than 5 (eg, 2.8 for preoperative vs 1-month postoperative LV end-diastolic diameter), indicating that multicollinearity did not substantially affect the model results. To further validate the time effect, an interaction term between postoperative time and LVEF was introduced into the model, but its effect did not reach statistical significance ($P = .18$). Higher weight (≥10 kg) was a major risk factor for late postoperative worsening mitral valve regurgitation ($P = .04$). The midterm rate of freedom from worsening mitral valve regurgitation was 92.0% in patients who weighed less than 10 kg and 82.7% in patients who weighed 10 kg or more (Fig. 2A). Notably, 68 of the 137 patients (49.6%) had a concomitant VSD, even though VSD size was not found to be an independent risk factor for worsening mitral valve regurgitation. Patients with a smaller combined VSD (<8 mm) or without a VSD showed a notably higher rate of freedom from worsening mitral valve regurgitation in the late postoperative period than did patients with a larger combined VSD (≥8 mm) ($P = .04$). The midterm rate of freedom from worsening mitral valve regurgitation was 97.1% in patients with a smaller combined VSD (<8 mm) or no VSD and 74.4% in patients with a larger combined VSD (Fig. 2B).

Discussion

Studies have shown that mitral valvuloplasty has a lower mortality rate than mitral valve replacement in patients with mitral valve regurgitation.[13] Data indicate that the 12-month survival rates are not appreciably

TABLE V. Cox Proportional Risk Model for Late Postoperative Worsening Mitral Valve Regurgitation

	Single-factor Cox		Multifactor Cox	
Factor	**Hazard ratio (95% CI)**	***P* value**	**Hazard ratio (95% CI)**	***P* value[a]**
Preoperative				
Age	1.01 (1.00-1.02)	.02	0.80 (0.59-1.08)	.15
Sex	0.69 (0.27-1.77)	.44		
Weight	1.04 (1.01-1.07)	.008	1.49 (1.06-2.08)	.02
Atrial septal defect size	0.87 (0.52-1.46)	.60		
Ventricular septal defect size	1.13 (1.02-1.25)	.03	0.76 (0.55-1.05)	.10
Patent foramen ovale size	0.77 (0.21-2.78)	.69		
LV end-diastolic diameter	1.05 (1.01-1.10)	.01	1.56 (0.96-2.55)	.07
Left atrial diameter	1.07 (1.00-1.14)	.06		
Mitral valve annular inner diameter	1.06 (0.99-1.13)	.09		
Mitral valve regurgitation grading	2.39 (0.96-5.94)	.06		
LV ejection fraction	0.10 (0.00-23.93)	.41		
Perioperative				
Cardiopulmonary bypass time	1.01 (1.00-1.02)	.006	0.95 (0.91-0.99)	.007
Aortic cross-clamp time	1.01 (1.00-1.02)	.08		
Length of stay in the postoperative care unit	1.00 (1.00-1.01)	.26		
Mean total time on mechanical ventilation	1.01 (1.00-1.02)	.09		
1 mo postoperative	1.13 (1.02-1.25)	.03	0.76 (0.55-1.05)	.10
LV end-diastolic diameter	1.06 (1.02-1.11)	.004	1.74 (1.18-2.57)	.005
Left atrial diameter	1.13 (1.00-1.29)	.05		
Mitral valve regurgitation grading	0.79 (0.26-2.37)	.67		
LV ejection fraction	0.01 (0.00-0.91)	.05	0.00 (0.00-0.01)	.01
Postoperative hospitalization	1.01 (0.99-1.03)	.23		

LV, left ventricular.
[a] $P < .05$ was considered statistically significant.

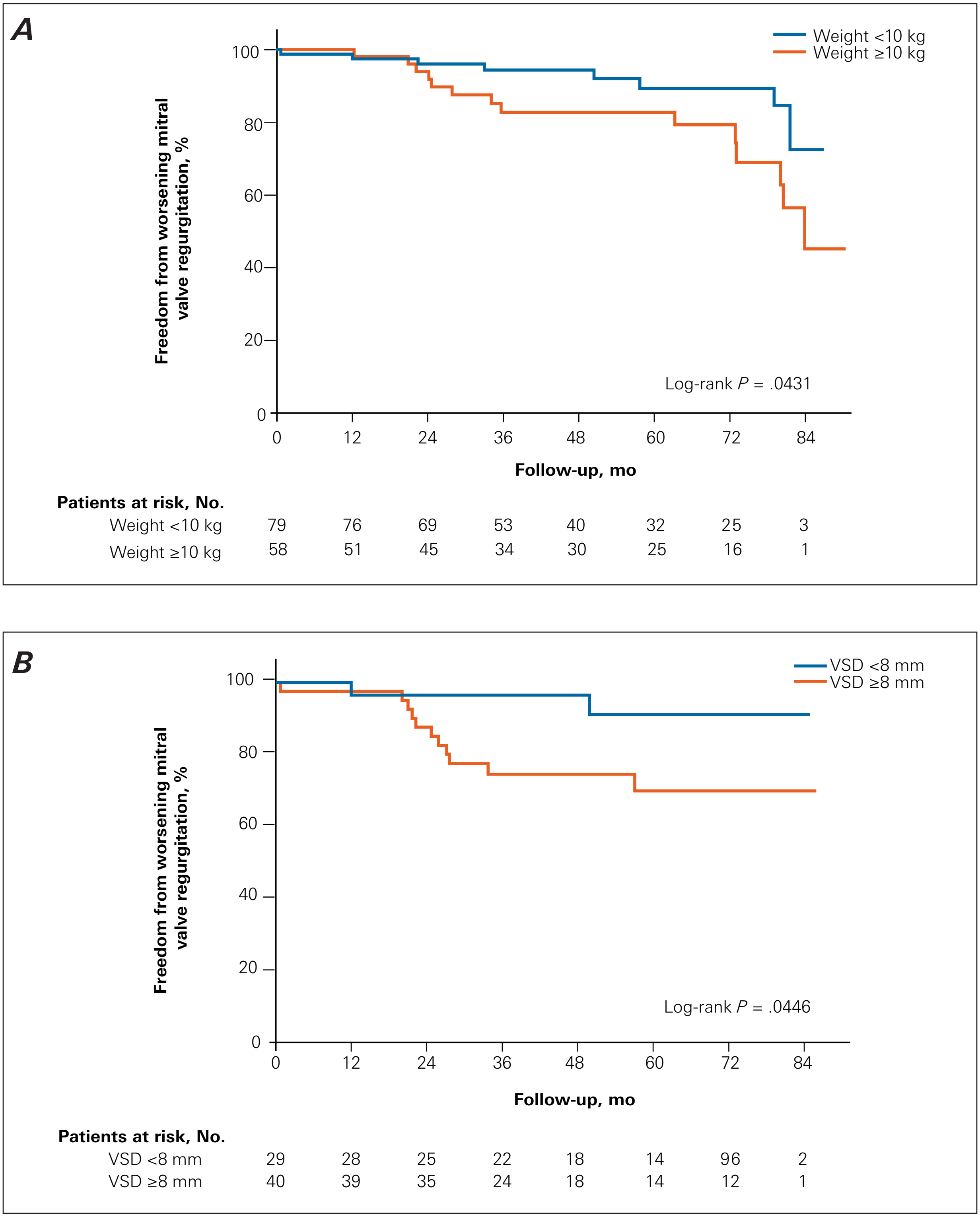


Fig. 2 Impact of risk factors on worsening postoperative mitral valve regurgitation. Kaplan-Meier curves depicting (**A**) the effect of body weight on freedom from worsening mitral valve regurgitation and (**B**) the effect of VSD size on freedom from worsening mitral valve regurgitation.
VSD, ventricular septal defect.
$P < .05$ was considered statistically significant.

different between patients undergoing valve repair and patients undergoing valve replacement for mitral valve regurgitation, however.[14] Given concerns about pediatric growth and development and the difficulties with postoperative anticoagulation adherence, mitral valvuloplasty remains the recommended surgical choice for pediatric patients with mitral valve regurgitation. In addition, mitral valvuloplasty produced a better prognosis than mitral valve replacement for surgical intervention in mitral valve regurgitation.[15] In pediatric patients who have mitral valve regurgitation that is not coupled with other complicated intracardiac malformations, the early mortality rate for mitral valvuloplasty is low, at approximately 2%.[16] The 10-year and 20-year survival rates are up to 98% and 94%, respectively, and the 10-year to 20-year reoperation-free intervention rate ranges from 80% to 90%.[17,18] The cumulative survival rates (mean [SD]) at 1 and 15 years after surgery are 92.3% (4.3%) and 70.3% (8.9%), respectively. The prognosis for pediatric patients with complex mitral valve malformations (eg, parachute-like or hammock-like mitral valves) or patients with additional cardiac malformations is usually poor, and multiple reconstructive operations or even mitral valve replacement is necessary over the patient's lifetime to help reduce the overall death rate.[17,19,20] The survival rate after mitral valvuloplasty in children younger than 5 years of age is satisfactory.[21] This study of mitral valvuloplasty in pediatric patients (mean [SD] age, 37.5 [43.5] months) supports these results. The in-hospital mortality rate was just 0.7%. The total mortality rate at follow-up was 2.2%, whereas the cumulative survival rate was 97.5%.

Echocardiography usually indicates that the LVEF is high in patients with mitral valve regurgitation. In the early postoperative period after the reduction of regurgitation, however, a transient decrease in cardiac function is often seen. This phenomenon was noted in the current cohort, as well; mean (SD) LVEF was lower at 1 month postoperatively than preoperatively (62.0% [7.8%] vs 67.7% [7.3%], respectively; $P<.001$) but increased at follow-up (67.7% [5.6%]; $P=.001$). This finding implies that the heart's pumping capacity increases progressively with the resolution of mitral valve regurgitation, after a temporary drop in cardiac performance. The decrease in mitral valve regurgitation favorably affects left heart load and geometry, which helps restore mitral valve performance.[22,23] In this study, left atrial diameter and LV end-diastolic diameter were much lower 1 month after surgery than before surgery ($P<.001$), and these changes were maintained at mid-term follow-up. The quick drop in LV load after mitral valvuloplasty improves the structure and function of the left ventricle, which is beneficial for the development of the mitral valve in children and might slow progression of mitral valve regurgitation. This development helps some patients avoid the need for mitral valve replacement and enables the delay of necessary treatments.

The most effective mitral valvuloplasty strategy for young patients is still under debate. Because of concerns about the size of the prosthetic annulus and insufficient annular development in younger children, some investigators have recommended mitral valvuloplasty with a prosthetic annulus in children older than 2 years of age.[1] In contrast, other studies have suggested that normal annular growth and leaflet motion may be inhibited by scar tissue produced from the annulus itself and the sutures.[24] This experience supports the use of prosthetic valve rings in older patients.[25] In the current study, 7 patients underwent prosthetic valve ring implantation; the mean age was 106.8 months (range, 52.8-164.4 months), the mean LV end-diastolic diameter was 50.25 mm, and the mean mitral annular inner diameter was 32 mm. Using a prosthetic valve requires a sufficiently sized LV and mitral annulus to avoid postoperative restenosis.

Low body weight has been linked to mitral valve deterioration in children after mitral valvuloplasty,[26] but the data from this study suggest that patients who weigh more than 10 kg were more likely to have mitral valve degradation in the late postoperative period. This finding could be explained by the fact that heavier patients had a lesion presence of longer duration and tended to be older at the consultation. Patients in this study weighed 4.2 kg to 65.0 kg. Based on the Capital Medical University Affiliated Anzhen Hospital experience, surgical intervention is not advised for patients with very low body weight because their mitral valve tissues are often fragile, which complicates the operation and can reduce its effectiveness. Although the hospital has no minimum weight requirement for mitral valvuloplasty, this experience has shown that the procedure is more difficult to perform in children who weigh less than 5 kg, and these patients have a poorer long-term prognosis. In clinical practice, however, body weight is not the only factor to consider; patient symptoms, severity of mitral valve pathology, and other relevant factors should also be taken into account. Moreover, advanced age and higher body weight are risk factors for worsening mitral valve regurgitation after mitral valvuloplasty. Therefore, surgical intervention should be performed as early as appropriate.

Mitral valvuloplasty has been proposed as a practical, long-lasting operation in patients with mitral valve regurgitation and comorbid VSD because it offers the possibility of postoperative mitral valve development.[27] The results of this study support this recommendation. In this study, 68 patients (49.6%) with combined mitral valve regurgitation and VSD underwent mitral valvuloplasty, and the most common surgical technique was junctional annulotomy. At the most recent follow-up, 6 patients had moderate mitral valve regurgitation, and 2 patients had severe mitral valve regurgitation, meaning that 88.2% of patients were free from moderate or severe mitral valve regurgitation. This study also investigated how VSD size affected prognosis and found that patients with larger VSDs (≥8 mm) had a less favorable prognosis than patients with smaller VSDs or no VSD. The higher rate of intracardiac shunts linked with larger VSDs could cause this difference because they greatly increase LV preload and aggravate left heart enlargement. In turn, an enlarged left heart can aggravate mitral valve regurgitation and damage valvular tissue. Therefore, simultaneous correction of VSD during mitral valve regurgitation interventions is recommended.

This study has shown that mitral valvuloplasty substantially decreases mitral valve regurgitation in pediatric patients. Cox regression analysis identified CPB time, postoperative LV end-diastolic diameter and LVEF, and body weight as major determinants of long-term prognosis after mitral valvuloplasty; preoperative left atrial diameter, sex, and ASD size did not affect prognosis. Furthermore, no correlation was found between preoperative mitral valve prolapse and mitral valve degradation ($P = .73$); the smaller mitral annulus in children, the lower degree of valve calcification, and the better elasticity of the valve may help explain why annuloplasty improves mitral valve regurgitation caused by mitral valve prolapse. This finding implies that early surgical intervention may be helpful for pediatric patients who have mitral valve regurgitation secondary to mitral valve prolapse, even if the valve is in an ideal state.

Study Limitations

This study has several limitations. First, the sample size limits the capacity to fully investigate variations in the efficacy of several surgical techniques for the treatment of mitral valve regurgitation. Future prospective studies with larger cohorts are warranted to address this issue. Second, the median midterm follow-up period of almost 55.3 months is not sufficient to determine the long-term prognosis of mitral valvuloplasty in treating mitral valve regurgitation. Moreover, the results of this study come from a single center, which may affect the generalizability of the outcomes. This study did not address the correlation between repair type and long-term outcomes of mitral valve regurgitation recurrence, but more data are being collected to report on this issue in the future.

Conclusion

Mitral valvuloplasty can improve the outcome of mitral valve regurgitation in children, with a low mortality rate of 0.7% and favorable long-term outcomes. The risk of late mitral valve deterioration persists, however; independent risk factors for this deterioration are a weight of 10 kg or more, LV enlargement at 1 month postoperatively, reduced LVEF at 1 month postoperatively, and prolonged CPB time. In addition, a worse prognosis is seen in pediatric patients with mitral valve regurgitation and a larger VSD (≥8 mm). To prevent late postoperative mitral valve deterioration, Capital Medical University Affiliated Anzhen Hospital recommends early aggressive treatment at the appropriate time.

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