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PRIMARY REPAIR FOR CONGENITAL AORTIC VALVE DISEASES IN CHILDREN

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✓ ***Resume,***

The article presents an analysis of 163 patients with congenital aortic valve disease to assess whether aortic valve repair as a first strategy could yield benefit to postpone the need for the Ross procedure and AV replacement in children. The immediate and long-term postoperative results, in particular, intracardiac hemodynamics, systolic function of the left ventricle, freedom from recurrent moderate and greater aortic regurgitation, stenosis and reoperation were evaluated.

Key words: aortic valve, aortic regurgitation, aortic stenosis, aortic valve repair, neocuspidization of aortic valve.

ПЕРВИЧНАЯ ПЛАСТИКА ПРИ ВРОЖДЕННЫХ ПОРОКАХ АОРТАЛЬНОГО КЛАПАНА У ДЕТЕЙ

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✓ ***Резюме,***

В статье представлен анализ 163 пациентов с врожденным пороком аортального клапана, чтобы оценить, можно ли применить пластику аортального клапана в качестве первичной методики для отсрочки процедуры Росса и замены аортального клапана механическим протезом у детей. Оценивались непосредственные и отдаленные послеоперационные результаты, в частности, внутрисердечная гемодинамика, систолическая функция левого желудочка, свобода от реоперации и повторной более умеренной степени аортальной регургитации, стеноза.

Ключевые слова: аортальный клапан, аортальная регургитация, аортальный стеноз, пластика аортального клапана, неокспидизация аортального клапана.

БОЛАЛАРДА АОРТА КЛАПАНИ ТУҒМА НУҚСОНЛАРИ БИРЛАМЧИ ПЛАСТИКАСИ

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✓ ***Резюме,***

Мақолада аорта тавақаси туғма нуқсони билан хасталанган 163 беморларнинг таҳлиллари келтирилган. Илмий амалиётдан мақсад, аорта тавақаси бирламчи пластикаси Росс операциясини ва аорта тавақасини механик протез билан алмаштириш операцияларини кечиктиришга асос бўлиш ёки бўлмаслигини баҳолаш. Операциядан кейинги эрта ва узоқ натижалар жумладан, юрак ичи гемодинамикаси, чап қоринча систолик функцияси, такрор операция ва қайта аорта тавқаси етишмовчилиги ёки стенози кузатилиш даражаси ўрганилган.

Калит сўзлар: аорта тавақаси, аорта тавақ етишмовчилиги, аорта тавақ стенози, аорта тавақ пластикаси, аорта тавақ неокспидизацияси.

Introduction

Aortic valvulopathy represents 4% of all congenital heart defects with the development of aortic regurgitation (AR) as well as all forms of stenosis (AS) [1]. Currently, when choosing a surgical method for treating this pathology, there are the following options: reconstructive surgery or aortic valve replacement (AVR), each of these methods has its advantages and disadvantages. The advantage of mechanical prostheses is their longevity, but it is associated with a high lifetime risk of developing thromboembolic complications, bleeding, infectious endocarditis (IE), the need for re-replacement, "patient-prosthesis mismatch" [2]. The advantages of biological valves include a low risk of thromboembolic complications and the absence of the need for continuous use of anticoagulants. At the same time, all bioprostheses are prone to primary tissue degeneration, leading to impaired valve function and the need to replace it. At the same time, the intensity of degenerative processes of biological valves in children is significantly higher than in adults [3,4]. With Ross surgery, the advantages of pulmonary autograft are excellent hemodynamic parameters, the absence of thromboembolism, the need for anticoagulant therapy and a low risk of IE. However, issues related to valve-containing conduits used during Ross surgery to reconstruct the right ventricle outflow tract and a high percentage of dilatation of the neo-aortic root as the child grows, with the subsequent development of neo-aortic insufficiency, remain unresolved [5,6].

An alternative to AVR is reconstructive surgery, the advantage of which is the preservation of the native anatomy and physiology of aortic valve (AV), which

saves the possibility of its growth in proportion to the somatic growth of the child, as well as the absence of thromboembolism, hemorrhagic complications associated with anticoagulant therapy. Native AV has a natural resistance to infection, which reduces the risk of IE [7]. Despite the unresolved basic issues regarding the durability of the satisfactory functioning of repaired AV, certain technical difficulties in their implementation and careful selection of patients and the choice of the appropriate surgical technique, over the past decade AV repair has firmly taken the primary position in the armamentarium to surgical treat AV disease in children [8].

Objectives

To assess the immediate and long term results of AV repair in the paediatric patients, and whether this repair as a first strategy could provide some benefit in the long term, such as obviating the need for the Ross procedure and AV replacement in children.

Material and methods

163 patients extracted from Ukrainian Children's Cardiac Center patient database were analyzed, in which various methods of primary reconstructive surgery on AV were used. The whole patients experienced primary congenital AV pathology. The conotruncal heart disease were ruled out from the study. The median age at surgery was 9,7±12,7 years. All patients by age were divided into 4 groups. 1 group was 63 (38,7%) patients aged 1 m - 1 year; 2 group consisted of 43 (26,4%) patients aged 1 - 10 years old; 3 group was 34 (20,8%) 10 - 18 years old patients; 4 group included 23 (14,1%) patients >18 years old. The mean BSA was 0,94±0,66 kg/m2. There was a male preponderance (130/33). Most of the children were symptomatic at surgery (70% in NYHA class II or III). Indication for AV repair was AS in 80 (49,1%) patients, AR in 38 (23,3%) patients, AS and AR only in 45 patients. Congenital AV disease without concomitant congenital heart defects was detected in 112 children (68,7%). Patient characteristics for previous interventions and the presence of concomitant pathology are summarized in the table below (Table 1).

Table 1.

Characteristics of patients in previous interventions and the presence of concomitant pathology (n=163)

Variables	*n* (%)
Preop interventions	
Aortic coarctation repair	12 (7,4)
Prior balloon valvuloplasty <6/>6 мес	28/3 (19)
Concomitant pathologies	
Aortic root or ascending aorta aneurysm / dissection, type A	20/1 (12,9)
VSD (Pezzi-Laubri syndrome)/sub Ao	4/3 (4,3)
Endocardial fibroelastosis	6 (3,7)
Aorta recoarctation	2 (1,2)
Infectious endocarditis	1 (0,6)
Severe mitral valve regurgitation	4 (2,4)
Severe mitral valve stenosis	1 (0,6)
Severe tricuspid valve regurgitation	1 (0,6)
Severe pulmonary stenosis	2 (1,2)
Cor triatrum	1 (0,6)

The average duration of cardiopulmonary bypass was 98,4±54,7 minutes, the aortic cross-clamp time was 63,4±44,5 minutes.

To select the type of reconstructive surgery in patients with isolated AR, we used the well-known functional G. El Khoury classification [9], according to which three types of morphological and functional disorders of AV were distinguished. Commissurotomy was used in combination with the decalcification in isolated AV stenosis. Complex reconstructive operations were used in patients with combined AV disease. It should be noted that tricuspidization of AV was performed in 61 (47,0%) patients out of 130 patients with bicuspid aortic valve (BAV): restoration of valve anatomy close to native - creation of tricuspid AV. Types of tricuspidization surgery are as follows: isolated commissurotomy, commissurotomy with cusp extension using glutaraldehyde-treated autopericardial tissue and cusp replacement with glutaraldehyde-treated autopericardial tissue. It is noteworthy that in two cases, AV repair was conducted in patients with moderate regurgitation, which is due to the presence of a concomitant subaortic defect (Pezzi-Laubri syndrome).

Characteristics of patients for the implementation of various surgical techniques are shown in the table below (Table 2).

End point of was a composite freedom from reoperation and AS (>60 mmHg) or AR > grade 2 to better evaluate the LV and AV hemodynamic performance [10].

Statistical analysis

Quantitative variables were described by the following statistics: continuous data are presented as mean ± standard deviation. Qualitative variables were described by absolute and relative frequencies (percent). Differences were considered statistically significant at $p < 0,05$. When evaluating the results obtained, the following methods of statistical analysis were used: $\chi 2$-Pearson criteria (analysis of contingency tables), paired t-student test. Freedom from an event was analysed using the Kaplan-Meier. The

Table 2.

Operative data (n=163)

Variables	*n* (%)
Repair procedure	
Leaflets	
Decalcification	79 (48,5)
Trusler technique	26 (16)
Free margin plication	22 (13,5)
Leaflet patch extension	15 (9,2)
Leaflet replacement	11 (6,7)
Neocuspidization	10 (6,1)
Leaflet perforation closure	6 (3,7)
Triangular resection	3 (1,8)
Raphe	
Raphe resection	41 (25,1)
Raphe shaving	28 (17,1)
Commissures	
Commissurotomy	83 (51)
Neocommissure creation	3 (1,8)
Subcommissural annuloplasty	9 (5,5)
Functional aortic annulus - valve sparing procedures	
Subannular ring annuloplasty	8 (5)
David operation	7 (4,3)
Supracoronary ascending aortic replacement	2 (1,2)
Yacoub operation	1 (0,6)
Florida sleeve technique	1 (0,6)
Concomitant procedures	
Subaortic stenosis resection	13 (7,9)
Ascending aorta reduction aortoplasty	8 (5)
Mitral valve repair	5 (3)
Ventricular septal defect repair by Yacoub/Patch closure	4/3 (4,3)
Pulmonary valvular stenosis repair	2 (1,2)
Aortic coarctation repair	2 (1,2)
Mitral valve replacement	1 (0,6)
Cor triatrum repair	1 (0,6)
Morrow operation	1 (0,6)

calculation was performed on a personal computer using the Microsoft Excel and SPSS 22.0 software package.

Results

Considering that BAV was predominant in 130 (79,75%) patients, the latter were classified according to Sievers classification [11] (Table 3).

Table 3.

Intraoperative assessment of BAV by Sievers (n=130)

Main category: number of raphes	0 raphe - Type 0	1 raphe - Type 1			2 raphes - Type 2		
Subcategory		L-R	R-N	N-L	L-R/R-N	L-R/L-N	L-N/R-N
N (%)	6(4,6)	60(46,1)	26(20)	4(3)	28(21,5)	4 (3)	2 (1,5)

L: left coronary cusp; R: right coronary cusp; N: noncoronary cusp.

The first type with the subcategory L-R turned out to be the most frequent in 46,1% of all BAV. Moreover, the "monocusp" anatomy (the second type) was in 34 (26,1%) cases. The most frequent subcategory of the second type was L-R/R-N in 28 out of 34 patients.

On top of that according to the classification of G. El Khoury, the mechanisms of AR (isolated and predominant mixed form) in 62 patients were determined using transthoracic echocardiography (TTE). The most common morphological and functional mechanisms of AR were enlargement of ventriculoarterial junction (VAJ) (I c), AV cusp prolapse (II) and cusp restriction or retraction of AV (III). Based on the calculation of isolated and combined mechanisms of the development of AR, 158 AV pathologies were detected in 62 patients, where 51,3% accounted for mechanism I, II - 24,7%, and III - 24,0% (Figure 1).

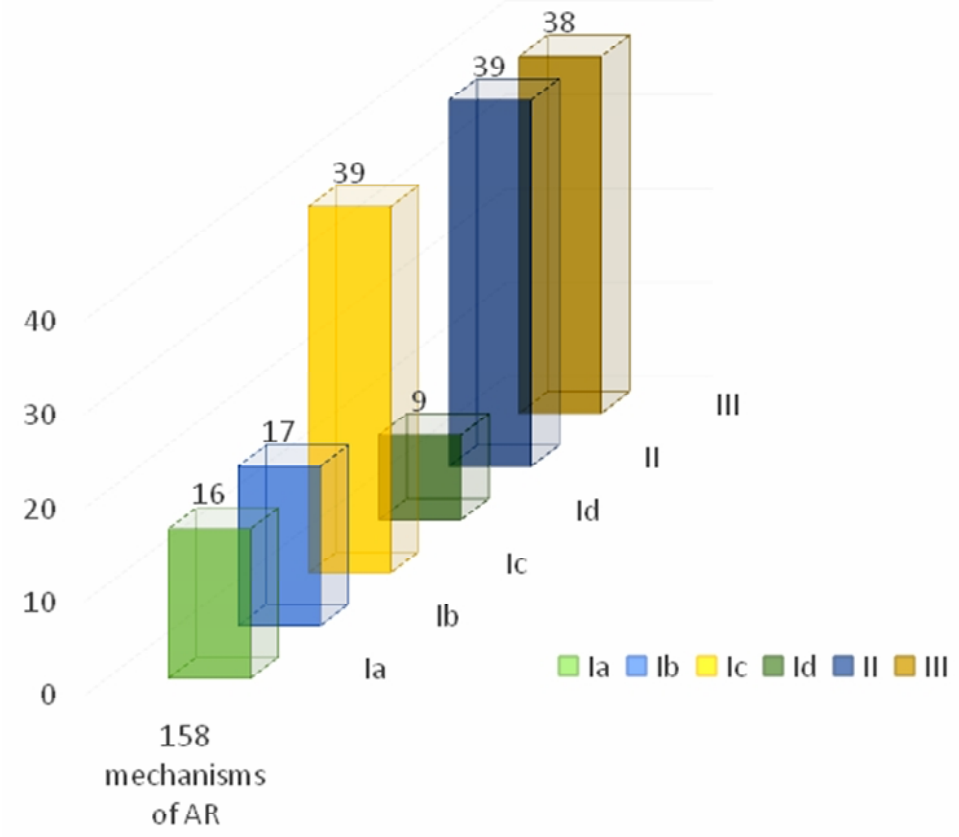

Figure 1. Functional classification for AR by El Khoury (n = 62).

The ejection fraction (EF) of the left ventricle (LV) averaged 68,2 ± 10,4%. The end-diastolic diameter z-score of the left ventricle (LVEDD) was normal (z <1,0) in 87 (53,4%) patients, while mild LV dilatation (z-score 1-2) was detected in 18 patients, moderate (z-score 2-2.5) in 14, severe (z-score > 2.5) in 44. LV remodeling (concentric/ eccentric hypertrophy, concentric remodeling) was detected in 130 (79,7%) patients.

Upon intraoperative checking, retraction of one or two AV cusps occurred in 18 (29,0%) patients with AR, whereas in patients with AS - in 19 cases (20,9%), among which retraction of the right cusp was determined in most cases, 10,9% and 11,3%, respectively (Table 4).

Table 4.

Intraoperative assessment of cusp retraction in patients with AR (n=62) and AS (n=101)

Variables	AR group	AS group
Right coronary cusp,	11 (10,9)	7 (11,3)
Left coronary cusp	3 (3,0)	1 (1,6)
Noncoronary cusp	2 (2,0)	3 (4,8)
Left coronary cusp+ Right coronary cusp	2 (1,8)	4 (6,4)
Right coronary cusp + Noncoronary cusp	1 (1,0)	3 (4,8)

The early postoperative results were satisfactory (competent AV or trivial AR) in 56,5% of children (n=92). 40,5% of patients (n=66) had mild AR. Residual AS of the first degree was observed in 19,0% of patients (n=31). Unsatisfactory early results were observed in 3,0% cases: moderate AR was recorded in 1,8% of children (n=3), severe AR was observed in one case (0,6%). Moderate AR in combination with moderate AS occurred in 0,6% of patients (n=1). Severe AS was not detected after surgery.

There were no mortalities at the hospital stage. The immediate postoperative period in all patients proceeded without complications.

As seen from the table. 5, both the peak and mean systolic pressure gradient (SPG) and the LVEDD z-score reduced in patients immediately after AV repair in comparison with the preoperative period (p=0,000). The degree of AR decreased: before surgery with a degree of ≥II - 63 patients (38,65%), after surgery - 5 (3,06%) children (p=0,000). There is a decrease in the total number of severe LV dilatation from 44 cases to 2 (p=0,000) and LV mass index indicated an improvement in LV systolic function (p=0,000).

The mean follow-up was 3,6±1,8 years. There was 1 early death due to LV systolic dysfunction at 9 months postoperatively.

Table 5.

Comparative characteristics of preoperative and early hemodynamic parameters

Parameters			Comparison group		p-value
			Before operation	After operation	
NYHA functional class		0	-	4	0,000
		1	49	124	
		2	85	34	
		3	29	1	
Gradient peak, (mmHg)			59,32±34,83	22,25±10,75	0,000
Gradient mean, (mmHg)			29,94±18,55	10,94±5,91	0,000
Regurgitation, degree		Mild	11	26	0,000
		Moderate	9	3	
		Severe	54	2	
EF, (%)			68,21±10,42	63,85±6,81	0,000
Fractional shortening, (%)			38,35±8,61	34,38±6,02	0,000
LVEDD z-score			1,84±2,93	0,21±2,12	0,000
LV dilatation, n (%)	Mild		18 (11,04)	5 (3,06)	0,484
	Moderate		14 (8,58)	3 (1,84)	0,133
	Severe		44 (27,0)	2 (1,22)	0,000
LV mass index, gr/m2			123,03±48,46	100,37±31,41	0,000

Table 6.

Comparative characteristics of preoperative and long-term hemodynamic parameters

Parameters			Comparison groups		p
			Before operation	After Operation	
Gradient peak (mmHg)			60,53±34,38	25,79±16,63	**0,000**
Gradient mean (mmHg)			30,37±18,38	13,11±9,41	**0,000**
Regurgitation, grade		1	11	64	**0,022**
		2	9	23	
		3	54	43	
Ejection fraction (%)			68,34±10,55	65,22±9,10	**0,000**
Fractional shortening (%)			38,28±7,87	35,68±6,87	**0,000**
			z-score		
Ventriculoarterial junction			1,61±2,18	1,44±1,55	0,278
Valsalva sinuses			1,23±2,52	0,91±1,48	0,075
Sinotubular junction			1,93±3,2	1,16±1,5	**0,006**
Ascending aorta			5,01±4,15	3,03±1,63	**0,000**
LVEDD z-score			1,84±2,93	0,93±2,13	**0,035**
LV dilatation, n (%)	Mild		18 (11,04)	25 (15,33)	0,467
	Moderate		14 (8,58)	7 (4,3)	0,514
	Severe		44 (27,0)	29 (17,8)	**0,000**
Indexed aortic root and left ventricle parameters					
Ventriculoarterial junction			17,71±11,53	16,67±4,45	0,234
Valsalva sinuses			22,94±14,75	20,74±7,98	**0,026**
Sinotubular junction			18,48±13,06	17,02±6,02	0,228
Ascending aorta			19,19±13,68	20,46±5,76	0,369
LVEDI (ml/m^2)			76,71±40,22	77,16±32,48	0,900
LVESI (ml/m^2)			25,84±23,07	28,03±18,69	0,315
LVSVI (ml/m^2)			51,03±23,06	50,53±20,23	0,815
LV mass index, gr/m^2			123,03±48,46	102,27±45,41	**0,000**
AV geometry					
Bicuspid, n (%)			130 (79,75)	102 (62,58)	**0,000**
Tricuspid, n (%)			33 (20,24)	61 (37,42)	**0,000**

Of particular interest is that preoperative z-scores of the VAJ, the Valsalva sinuses (SV), the sino-tubular junction (STJ), and the ascending aorta (AscAo) imply dilatation of the corresponding aortic root components and AscAo in children of all three groups. The mean diameter of VAJ, SV, STJ, AscAo in young adult patients of group IV were 28,9±7,2, 41,2±10,5, 39,0±10.9, 45,3±12,4 mm, respectively, which also represents dilatation of the aortic root and VA. It is noteworthy that sever VAJ dilatation (z>2,5) was observed in 12, 10, 17 patients of group II, III, and IV, respectively.

In comparison with the preoperative period, patients had a decrease in peak and mean SPG (p=0,000), indexed aortic root indices, and the total number of moderate and severe LV dilatation from 44 cases to 29 (p=0,000), LVEDD-z score (p=0,035) and LV mass index (p=0,000), STJ-z score (p=0,006), AscAo-z score (p=0,000) in the long-term postoperative period, which underscored an improvement in intracardiac hemodynamics and systolic function of the LV (p=0,000). Also, there was no statistically significant decrease in the VAJ z-score (p=0,278). There is a decrease in the severe AR from 54 patients to 43 in the long-term period after surgery (p<0,022).

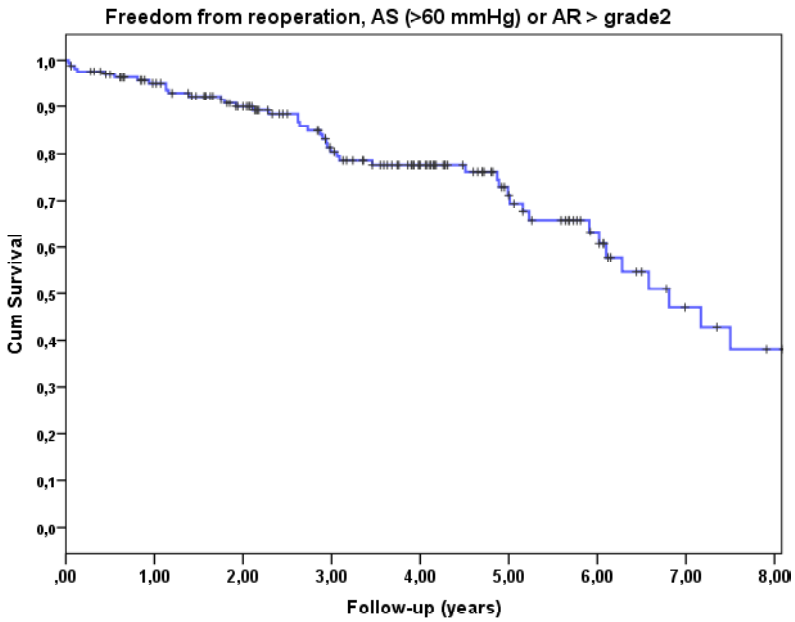

Figure 2. Freedom from reoperation, AS (>60 mmHg) or AR > grade 2 (n=163)

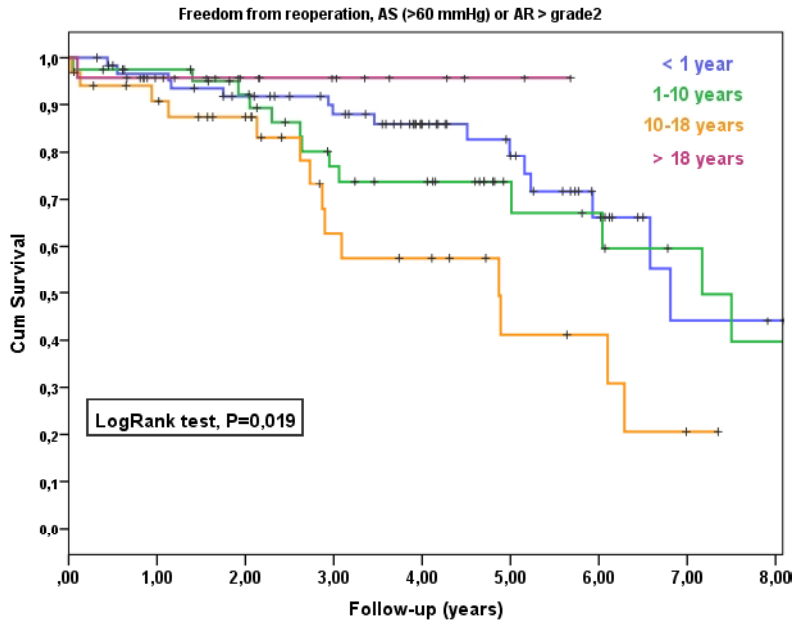

Figure 3. Freedom from reoperation, AS (>60 mmHg) or AR > grade 2 according to the age groups (n=163)

Freedom from reoperation, AS (>60 mmHg) or AR > grade 2 was 95%, 70% and 47% at 1, 5 and 7 years, respectively (Figure 2).

Because of the heterogeneous mechanisms of AR and AS development, an analysis of the treatment results was carried out depending on the initial characteristics of the congenital disease. It turned out that severe AR recurred in 12 patients (31,6%) in patients with isolated AR (n=38)

in the long-term postoperative period. The treatment results were worst in patients with a mixed predominant AR disease (n=24), as evidenced by the detection of severe AR in 45,83% (n=11) cases in the long-term period. AR and AS of the severe degree were recurrent in 19 and 1 patients (25,0%), respectively, in patients with isolated AS (n=80), while in patients with mixed predominant AS disease (n=21), indications for reoperation was 19,05% (n=4).

It should be noted that in 34 children under 18 years of age, VAJ dilation was revealed by z-score value, and of these, 18 (53,0%) children underwent reoperation (p=0,001). Of interest, there was no indication for reoperation in the 4th age group of patients (purple line) after valve sparing operations (Fig. 3).

The history of balloon valvulotomy (BV) in AS patients had a statistical insignificant impact on the frequency of reoperation, which was observed in 32,35% of patients with BV history compared to those 17,42% who did not have BV (p=0,15).

According to the study data, as shown in the figure 3, commissurotomy yielded satisfactory results as almost 70% freedom from reoperation and AS (>60 mmHg) or AR > grade 2 in children with isolated AS in the long-term follow-up period that mostly was done in the 1st age group (blue line).

Discussion

Based on the gained experience, it can be assumed that the reason for the unsatisfactory results are the peculiarities of the AV primary anatomy, lesions with a lack of tissue (such as BAV with restrictive raphe, unicuspid valve, post-balloon valvulotomy valve), and VAJ dilatation, which cannot be optimally adjusted in pediatric patients.

The obvious fact is that, in children, reconstructive surgery on AV demonstrated the poor results and required reoperation in 45,83% cases in the presence of mixed AV disease with a predominance of regurgitation. It can be assumed that the quality of the valves in patients with mixed AV disease is inferior to that of isolated AR, which makes it complex to perform reconstructive operation.

The excellent results in relation to freedom from reoperation and recurrent AR or AS in the IV group of patients explain the effectiveness of VAJ stabilization by means of valve-sparing operations, subannular ring plasty [12].

Basing on the data results, post- AV repair freedom from reoperation was 70 % at 7 years' follow-up, which can be considered as a primary method in the armamentarium to treat congenital aortic valvulopathy in the pediatric population.

Nevertheless, taking into account the results of leading cardiac surgery centers and our own experience, it becomes obvious that surgical treatment of congenital AV diseases in children has the still ongoing debate on the correct selection of patients, the optimal parameters of the cusps that can and should be preserved, the possibilities and the feasibility of annulostabilization in pediatric patients, the option of neocuspidization of AV and, the development of the optimal material to perform the augmentation and cusp replacement with severe dysmorphic AV [13,14].

Conclusion

Primary AV repair in the pediatric population is safe and provides excellent long-term results in terms of overall survival and valve-related operation to postpone the need for the AVR. BAV with severe restrictive raphe or cusp retraction, unicuspid valve, post-balloon valvulotomy valve, mixed predominant AR disease are predisposing factors to poor outcome of AV repair.

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