





Original Article

## Clinical outcomes of pulmonary valve replacement surgery in pediatrics: a single-center experience long-term study

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### Abstract

**Introduction:** Heart valve disease in pediatrics is an increasing global concern, especially in developing countries. This study aims to determine the clinical outcomes of pulmonary valve replacement (PVR) surgery in pediatrics.

**Methods:** The authors retrospectively identified all pediatrics undergoing PVR surgery at Imam Reza hospital (Mashhad, Iran) between 2000 and 2020. Their medical records were reviewed for demographic characteristics, clinical data (intra-operative and postoperative), and follow-up results. Echocardiography and electrocardiography were performed on all patients before the surgery and periodically after the surgery.

**Results:** Among 50 pediatrics undergoing surgical PVR, 38 (76%) were female and others were male (14%), with a mean age of  $10.39 \pm 5.31$  years. The leading cause of PVR was the Tetralogy of Fallot. There was a significant relationship between age at the time of surgery and the size of the pulmonary valve ( $P=0.02$ ). There were also statistically significant differences between QTc intervals before and after surgery ( $P=0.001$ ). Furthermore, there was a significant correlation between QTc intervals before and after surgery and the age of pediatrics at the time of surgery ( $P=0.01$ ,  $r=-0.6$ ). There was also a statistically significant relationship between the ICU stay ( $P=0.01$ ) and the weaning time of the mechanical ventilation ( $P=0.03$ ).

**Conclusion:** It is recommended that this procedure is postponed as much as possible to decrease postoperative life-threatening events in pediatrics. In addition, if this surgery is conducted with good surgical and nursing management, it can be safe with low complications among other cardiac valve procedures.

**Keywords:** Congenital Heart Disease, Pulmonary Valve Atresia, Pulmonary Valve Insufficiency, Pulmonary Valve Stenosis, Tetralogy of Fallot

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## Introduction

Despite the increasing life expectancy due to improvements in the diagnosis and treatment of cardiovascular disease, congenital heart defect repair is still a challenge due to its high morbidity and mortality rates(1-2).

Patients with congenital heart disease (CHD) are a fast-growing population, and valvular heart defects are the leading cause of many congenital lesions(3). Surgical innovation has provided new treatments that have improved survival in this population. Nevertheless, there are many challenges in treating patients with complicated anatomic and rare physiologic patterns(4).

Among valvular heart diseases, pulmonary valve (PV) defects have a high morbidity and mortality rate, especially when combined with other structural heart defects(5).

The major structural defects of the PV that need surgical intervention include congenital pulmonary stenosis (PS) and pulmonary regurgitation (PR) in CHD(6).

Congenital PS is the most frequent entity within CHD that may occur in 5 per 10,000 live births(7). While PS is mostly found as an isolated defect, valvular PS is often associated with other congenital life-threatening co-morbidities. Additionally, in some cases, this defect is combined with genetic syndromes(8-9). Despite the introduction of novel approaches to PS correction, such as balloon pulmonary valvuloplasty(10-11).

Since surgical valvoplasty is an alternative procedure, it is considered for pediatrics with the main pathologic patterns, such as hypoplastic pulmonary annuli or severe pulmonary regurgitation(12). On the other hand, a mild type of PR is relatively common in normal individuals; however, if it is combined with CHD, it needs special considerations(13).

Isolated congenital PR is rare and most often associated with congenital pulmonary valve atresia(14). For patients with PR, Pulmonary Valve Replacement (PVR) surgery is the most studied therapeutic and wise approach(15).

There is no evaluation of the clinical outcomes of surgical PVR in pediatrics in Iran. Therefore, the

present study aimed to determine this issue as the first attempt to investigate the clinical situation in pediatrics undergoing surgical PVR.

## Materials and Methods

After the study protocol was approved (Approval code: IR.MUMS.MEDICAL.REC.1397.234), a retrospective cohort study was conducted on all pediatrics undergoing PVR surgery between 2000 and 2020 in Imam Reza hospital (Mashhad, Iran). The inclusion criteria were being below 18 and requiring surgery of the congenital (structured) valvular defects. On the other hand, the exclusion criteria were as follows: 1) other cardiac operations and simultaneous repair of complex congenital heart defects, 2) the incidence of general complications, such as re-exploration, due to massive bleeding, as well as tamponade, and 3) all deaths less than six months after surgery.

All data were collected from the pediatrics cardiac surgery portal and included demographic variables, the findings of clinical and para-clinical examinations (echocardiographic findings) before and after the cardiac surgery, as well as the intra-operative findings. Moreover, the electrocardiographic study was conducted after the PVR surgery. The incidence of intraoperative and early postoperative complications was evaluated for all cases, which included valve-related events (paravalvular leakage, endocarditis, and thrombosis), the mal-function of the simultaneously replaced valve, and arrhythmia.

Continuous variables were reported as mean±SD. In analytical statistics, the normality of quantitative variables was firstly assessed using the Kolmogorov-Smirnov test. The student T-test and Mann-Whitney U test were used to assess and compare the two groups in terms of parametric and non-parametric variables, respectively. Additionally, an analysis of variance (ANOVA) test was run to evaluate more than two quantitative feature variables.

The extracted features from the electrocardiogram were compared before and after the measurement using the Wilcoxon signed-rank test. A significance level of  $P < 0.05$  was considered. All statistical analyses were performed using the SPSS

software (version 22.0, SPSS Inc., Chicago, IL, USA).

## Results

Among 50 pediatrics undergoing surgical PVR, 38 (76%) were female and others were male (14%), with a mean age of  $10.39 \pm 5.31$  years, ranging from 18 months to 17 years. Among these patients, 48 patients only had PVR surgery but two of them experienced PVR surgery combined with aortic valve replacement; therefore, these two were excluded from the study. Fortunately, there was no death among all patients after six months of follow-up. The mean percentile weight of the pediatrics based on their age was  $27.95 \pm 24.58$  kg at birth time and  $36.73 \pm 30.65$  kg at the time of surgery.

All valves used in these pediatrics were biological and most of them (80.68%) were manufactured by St. Jude® medical cardiac valves (Minnesota, USA).

After evaluating the collected data, two patients had a redo PVR surgery nine years after their primary surgery. The mean size of the PVs in these patients was in group sizes of 15-19 mm and 20-25 mm. The mean size of the PVs used in all patients was  $23.80 \pm 2.64$ .

There was no significant relationship between the mean age of the patients and the need for reintervention in the follow-up period ( $P=0.09$ ).

Furthermore, the age of the pediatrics was not significantly related to the aortic cross-clamp time ( $P=0.53$ ) and cardiopulmonary bypass time ( $P=0.63$ ). There were also no statistically significant differences among aortic cross-clamp time ( $P=0.51$ ), cardiopulmonary bypass time ( $P=0.59$ ), and the

gender of the patients. Nevertheless, the Pearson correlation test revealed that the time of the aortic cross-clamp and the cardiopulmonary bypass increased with an increase of age ( $r=0.7$ ).

On the other hand, there was a significant relationship between the age at the time of surgery and the PV size ( $P=0.02$ ). The linear regression analysis revealed that concurrent with the increase of age, the size of the valve increased by 0.13 mm in size.

The transpulmonary pressure gradient was measured after surgery, and the data were categorized into three levels: mild form (0-29 mmHg), moderate form (30-59 mmHg), and severe form (more than 60 mmHg).

Among 28 patients with the last transpulmonary pressure gradient in pulmonary stenosis, 15 were in the mild, 11 in the moderate, and 2 in the severe form. On the other hand, among 4 pediatrics with the last transpulmonary pressure gradient in pulmonary insufficiency, 1 was in the mild and 3 were in the moderate form. The mean pressure gradient was  $33.33 \pm 18.32$  mmHg in the pulmonary stenosis group and  $20.75 \pm 6.39$  in the pulmonary insufficiency group.

The most common cardiac anomalies in patients were the Tetralogy of Fallot in 32 (66.6%), isolated pulmonary stenosis in 7 (14.5%), pulmonary atresia in 5 (10.4%), PV insufficiency-stenosis in 2 (4.1%), and truncus arteriosus in 2 (4.1%) patients.

The frequency of the postoperative complications showed that one patient had post-surgery excessive hemorrhage (2%), and one had a complete atrioventricular block (2%). The postoperative complications are illustrated in (Table 1).

**Table 1.** Postoperative complication in patients after pulmonary valve replacement

Postoperative complication	N (%)
Post-surgery excessive hemorrhage	1 (2)
Complete atrioventricular block	1 (2)
Permanent pulmonary stenosis	3 (6)
Pericardial effusion	4 (8)
Post-surgery fever	1 (2)

The electrocardiography after cardiac surgery showed that except for one of the pediatrics with a complete atrioventricular block, the common conduction abnormality in the others was long QTc intervals (32%). There were also statistically significant differences between QTc intervals before and after surgery ( $P=0.001$ ). Moreover, there was a significant correlation between QTc intervals before and after surgery and the pediatrics' age at the time of surgery ( $P=0.01$ ,  $r=-0.6$ ).

Pediatrics had no life-threatening dysrhythmias (ventricular tachycardia and ventricular fibrillation), and the mean QRS duration in all of them was  $138\pm 65$  msec before surgery, which decreased to  $124\pm 32$  after the PVR surgery. However, this reduction was not statistically different before and after surgery ( $P=0.08$ ).

There was a statistically significant relationship between the ICU stay ( $P=0.01$ ) and the weaning time of the mechanical ventilation ( $P=0.03$ ) with age. These findings show that with an increase in patients' age, the need for ICU stay and the weaning time dramatically decrease.

## Discussion

This study was conducted to determine the clinical outcomes of surgical PVR in pediatrics. Unfortunately, very few studies have been carried out on pediatrics with PVR.

The redo PVR in this study was reported in two cases, which showed the good management of pediatrics after surgery. Albeit, the findings cannot demonstrate the leading cause of re-operation after the first surgery due to the limited number of patients experiencing this conduction. However, other studies reported some factors that can cause redo PVR surgery (16-19).

In the present study, the need for a redo PVR was observed nine years after the primary surgery. However, other studies reported having above five cases needing re-operation corrective PV-related surgeries at least in the first five years of the follow-up (18, 20).

This study noted that pediatrics who needed redo PVR had smaller valves than others, which

was parallel with the findings of McKenzie et al. that showed a significant correlation between the use of smaller size valves and the risk of valve reintervention. On the other hand, the mean age of patients was  $10.39\pm 5.31$  years in this study, and there was no significant relationship between the age of patients and the need for a reintervention strategy. Nevertheless, other studies showed that the intervention in the primary stages could significantly increase the risk of reinterventions (20-21).

In the present study, the most prevalent cause of PVR was the Tetralogy of Fallot, which was in line with the findings of similar previous studies (20-22). In addition, Cesnjevar et al. revealed that the later planning of the PV intervention, due to the Tetralogy of Fallot, can decrease the chance of reintervention if the primary defects are successfully corrected. Meanwhile, the successful management of the Tetralogy of Fallot correction was reported in previous studies (2).

The ICU stay and the weaning time was dramatically higher in younger patients, compared to those in others. This result was similar to McKenzie et al. findings (20). On the other hand, there were no statistically significant differences between the age of the patients and the ICU stay, as well as weaning time, in other similar studies (21-22).

These differences in the results may be due to the diversity of age ranges in this study, compared to other studies. The differences in age ranges were remarkably lower in other studies and they approximately evaluated patients between 5 to 12 years old.

According to the present study findings, the transpulmonary pressure gradient in pulmonary stenosis after surgery was reported in the mild and moderate categories. Therefore, it is expected that this item increases many years after the surgical procedure. It is thus recommended that long-term follow-up studies consider this issue.

The unique finding of this study was the electrocardiographic analysis before and after surgery. These findings revealed statistically significant differences between QTc intervals before and after surgery. Furthermore, there was a significant correlation between this item and the

pediatrics' age at the time of surgery. Therefore, based on these findings, the incidence of life-threatening dysrhythmias with longer QTc intervals seems imminent in younger pediatrics after PVR. Additionally, it seems crucial to perform close electrocardiographic monitoring and implement protective strategies after PVR surgery in ICU and even after the patients' discharge from the hospital.

It is suggested that future studies consider the effect of other predisposing risk factors, such as consanguineous marriages, on long-term postoperative patients' characteristics(23).

## Conclusion

The findings of this study suggested that the PVR surgery in pediatrics was postponed as much as possible, and after the surgery, electrocardiographic studies included other critical care and intervention more than ever. Moreover, the surgical approach of PVR with a high quality of surgery, post-surgery care, and a long-term follow-up can be the safest procedure with a low complication rate.

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## Conflict of interest

The authors declare no Conflict of interest.

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