RESEARCH PAPER

APPLICATION OF THE ROSS PROCEDURE IN PEDIATRIC CONGENITAL AORTIC VALVE PATHOLOGY

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ABSTRACT
This study analyzes early clinical outcomes of the Ross procedure in children with congenital aortic valve defects. Fourteen patients underwent full aortic root replacement. Hemodynamic parameters and postoperative complications were evaluated. Results showed that the procedure is both safe and effective, with no regurgitation and a significant reduction in valve pressure gradient. The biomaterials used were practical in local settings, and the surgical technique aligned with international standards.

Keywords: Ross procedure, congenital aortic valve, pediatric cardiac surgery, autograft, hemodynamics
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Introduction

Congenital aortic valve pathologies in children, including aortic stenosis and aortic insufficiency, are considered serious conditions that increase the load on the left side of the heart and lead to hemodynamic disturbances. Over time, these pathologies can result in cardiac hypertrophy, reduced left ventricular function, cardiac rhythm disturbances, and even sudden cardiac arrest. Therefore, early detection and effective surgical treatment of these conditions in children are of critical importance.

Traditional surgical solutions for aortic valve pathologies, such as the implantation of mechanical or bioprosthetic valves, face certain limitations in children. Mechanical valves require lifelong anticoagulant therapy, which increases the risk of bleeding and reduces the quality of life in children. Additionally, as children are in a growth phase, mechanical prostheses pose challenges related to anatomical size mismatch. Bioprosthetic valves, while not requiring antithrombotic therapy, have a limited lifespan and increase the likelihood of reoperation due to tissue fibrosis or calcification [(Brown et al., 2021); (da Costa et al., 2020)].

The literature review indicates that the Ross procedure has emerged as a clinically effective and long-term stable solution for treating congenital aortic valve pathology in children. Starnes and co-authors, based on 20 years of experience, demonstrated the procedure's stability and high survival rates [1]. Brown and colleagues noted that the Ross autograft maintained full functionality over a 10-year period in children [2]. A study by Fricke and colleagues highlighted the low likelihood of reoperation and the long-term stability of the autograft [3]. da Costa and others compared the Ross procedure to mechanical valves, proving it to be a significantly more advantageous solution for children [4]. Harries and co-authors emphasized the growth potential of the autograft as a technical advantage [5].

Systematic analyses by Dib and colleagues have statistically substantiated the safety and efficacy of the Ross procedure in children and infants [6]. Michel and Hagl have reviewed the technical aspects of the procedure and its clinical potential based on German experience [7]. Authors such as Loshusan and Galzerano have described successful applications of the Ross procedure in complex and previously operated cases [8][9]. Echocardiographic monitoring, imaging techniques, and future research directions for the Ross procedure have been highlighted by Galzerano and colleagues [9]. Varrica and co-authors have demonstrated the impact of pulmonary graft diameter and surgical timing on the outcomes of the Ross procedure [10].

El-Hamamsy and colleagues have indicated that the Ross procedure can also be applied in adolescents and young adults, emphasizing the need to reassess contraindications [11]. The work of Bakhshaliyev and colleagues is particularly relevant in evaluating the mid-term outcomes of the Ross procedure in developing countries [12]. Conci and co-authors have proposed methods to enhance the stability of the Ross procedure using personalized root support [13]. Barandier has described the broad clinical potential of the Ross procedure through its application in autoimmune diseases [14].

The 2024 European Society of Cardiology guidelines recognize the Ross procedure as a clinical solution for aortic valve diseases [15]. Piccinelli and colleagues have evaluated the effectiveness of disseminating this knowledge through e-learning platforms [16]. Galzerano and co-authors have described new technologies, innovative approaches, and their clinical efficacy in the Ross procedure [17]. Analyses of the need for reoperations in other pediatric fields, such as studies on hydrocephalus by Wendling-Keim and colleagues, provide insights into common challenges in clinical practice [18]. Michel and Hagl have presented a scientific approach to evaluating the precise role of the Ross procedure in general pediatrics [19]. A comparative meta-analysis of the Ross procedure and mechanical valves by Galzerano and colleagues thoroughly highlights the advantages of the Ross method [20].Although the clinical efficacy and

safety of the Ross procedure have been proven in many centers today, its application remains limited in many developing countries. Reasons for this include the need for advanced surgical expertise and the lack of sufficient experience.

Scientific analyses and comprehensive data on the application of the Ross procedure for treating congenital aortic valve pathologies in children in Uzbekistan are insufficient. In this regard, this study presents the initial clinical outcomes of Ross procedures performed on children with congenital aortic valve pathology at the Medion Innovation Center for Reconstructive and Cardiovascular Surgery in Tashkent. Our aim is to evaluate the efficacy and safety of this procedure in local conditions and to inform the broader public about its potential in pediatric cardiac surgery.

Materials and methods

Study type and center details

This study is a single-center, prospective, clinical observational study conducted at the cardiovascular surgery department of the Medion Innovation Center for Reconstructive and Cardiovascular Surgery in Tashkent. The study covers the period from 2022 to early 2025. During this period, the Ross procedure was planned and performed for children with congenital aortic valve pathology.

Patient selection requirements

The study included 14 children aged 2.5 to 14 years who had indications for the Ross procedure. The inclusion criteria were as follows:

1. Congenital aortic valve pathology (aortic stenosis or aortic insufficiency);
2. Confirmation of the diagnosis through echocardiographic examinations;
3. Absence of contraindications for surgery;
4. Obtaining voluntary consent.
5. Exclusion criteria included technical unsuitability for the Ross procedure, clinical destabilization, or other severe cardiac pathologies.

Diagnostic methods

All patients underwent comprehensive clinical, laboratory, and instrumental examinations prior to surgery. Transthoracic echocardiography (TTE) was used as the primary confirmatory diagnostic method. Based on TTE, aortic stenosis was identified in 12 patients (85.7%), while total aortic insufficiency was detected in 2 patients (14.3%). The following parameters were evaluated via echocardiography:

1. Aortic valve structure: Bicuspid valve present in 10 patients (71.5%);
2. Left ventricular end-diastolic volume (LVEDV): Mean 51.57 ± 17.3 mL;
3. Aortic valve fibrous annulus: Size 15 ± 2.1 mm;
4. Aortic pressure gradient: 61 ± 29.1 mmHg.

Operation method

The Ross procedure, utilizing the total root replacement technique, was performed on all patients. The surgery was conducted through a standard aortotomy. The patient's own pulmonary valve was carefully harvested and transplanted to the aortic position.

Operation method

All patients underwent the Ross procedure using the total aortic root replacement technique. The operation was performed via the standard surgical approach — median sternotomy (opening the chest along the midline).

Cardiopulmonary bypass was established using the central cannulation method — through the aorta, superior vena cava (SVC), and inferior vena cava (IVC).

To protect the myocardium from ischemic injury during surgery, a Custodiol-based crystalloid cardioplegic solution was used. This method proved highly effective in minimizing the metabolic demands of cardiac tissues and ensuring complete myocardial protection during the procedure.

This method ensures hemodynamic stability during the operation and provides effective myocardial protection.Various grafts were implanted in the pulmonary position.

In 12 patients, a Pilon xenograft (CemCor) was implanted; in 2 patients, a synthetic EuRos-Mi graft (MedInzh) was used.

Cardiopulmonary bypass (CPB) was conducted according to the standard protocol. A cardioplegic solution was used for aortic occlusion and myocardial protection.

The following parameters were recorded during the procedure:

Cardiopulmonary bypass time: 144.3 ± 14.3 minutes
Aortic cross-clamp time: 105.8 ± 10 minutes
Intraoperative blood loss: 42.8 ± 9.5 ml

Post-operative control

After surgery, patients were monitored in the intensive care unit for an average of 32 ± 2 hours.

During this period, hemodynamics, blood pressure, oxygen saturation, and heart rhythm were continuously monitored.

All patients were discharged from the hospital in stable clinical condition.

According to follow-up echocardiography performed prior to discharge:

No regurgitation was observed in the autograft placed in the aortic position.

A reduction in pressure gradient was noted, reaching **7 ±** 1.6 mmHg**.**

Statistical Analysis

All parameters were analyzed using the SPSS software.

Mean values were presented as mean ± standard deviation (SD)**.**

Data were described using ratios, percentages, and intervals.

Results

During the study period, the Ross procedure was successfully performed on all 14 patients.

In every case, the total aortic root replacement technique was utilized. Among these patients, 12 (85.7%) had aortic stenosis, and 2 (14.3%) had total aortic insufficiency.

In two cases, the Ross procedure was performed as a reoperation following previous cardiac surgeries: one after ventricular septal defect repair, and the other after resection of a subaortic membrane that had caused subaortic stenosis.

The mean age of the patients was 7.40 ± 3.45 years (range: 2.5 – 14 years). Of the total, 12 patients (85.7%) were male**.** According to echocardiographic findings**,** a bicuspid aortic valve was identified in 10 patients (71.5%)**.** The mean left ventricular end-diastolic volume was 51.57 ± 17.3 ml**,** indicating the impact of the pathology on cardiac function. The aortic valve annulus diameter averaged 15 ± 2.1 mm, and the pressure gradient was 61 ± 29.1 mmHg**.**

Figure 1. Pressure Gradient

From a surgical standpoint, grafts ranging from 15 mm to 23 mm in diameter were implanted in the pulmonary position.

In 12 patients, a Pilon (CemCor) xenograft was used, while in 2 patients, a EuRos-Mi (MedInzh) synthetic graft was implanted.

The mean cardiopulmonary bypass time was 144.3 ± 14.3 minutes, and the aortic cross-clamp time was 105.8 ± 10 minutes**.**

Intraoperative blood loss averaged 42.8 ± 9.5 ml**,** reflecting the high level of technical control and procedural safety achieved during the Ross procedure.

Table 1. Demographic and Preoperative Characteristics of the Patients

Index	Value
Number of patients	14
Average age (years)	7,40 ± 3,45
Number of men (%)	12 (85,7%)
Bicuspid Aortic Valve (%)	10 (71,5%)
Left ventricular diastolic volume (KDO LJ, ml)	51,57 ± 17,3
Aortic ring diameter (mm)	15 ± 2,1
Mean Pressure Gradient Across the Aortic Valve (mmHg)	61 ± 29,1

After surgery, patients were monitored in the intensive care unit for an average of 32 ± 2 hours.The mean total hospital stay was 8 ± 2 days**.** All patients were discharged from the hospital in satisfactory hemodynamic condition and without complications.

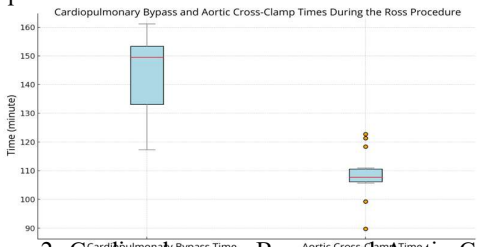

Figure 2. Cardiopulmonary Bypass and Aortic Cross-Clamp Times

According to postoperative echocardiographic findings, no regurgitation was observed in the autograft positioned in the aortic site, and the pressure gradient significantly decreased to 7 ± 1.6 mmHg.

This indicates the high effectiveness of the Ross procedure and confirms the stable restoration of valve function.

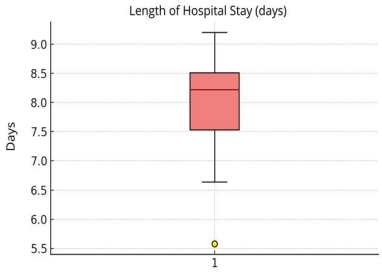

Figure 3. Duration of Hospital Stay in Patients

Additionally, no clinical differences were observed based on the types of homografts and grafts used in the Ross procedure.

In both the 12 patients who received a Pilon (CemCor) xenograft and the 2 patients who received a EuRos-Mi synthetic graft, the hemodynamic function of the pulmonary position prosthesis was fully preserved, with no signs of regurgitation or stenosis.

This demonstrates the potential effectiveness of using locally available and custom-made materials in the Ross procedure.

Other key clinical indicators — such as cardiopulmonary bypass time (CPB), aortic cross-clamp time, and postoperative echocardiographic dynamics — were found to be highly consistent with recently published international data. This reflects the high technical quality of Ross procedures performed at our center.

The newly created boxplot diagrams clearly illustrate the distribution of key indicators during the Ross procedure and the rehabilitation phase. In particular, the cardiopulmonary bypass time**,** aortic cross-clamp time**,** pressure gradient, and length of hospital stay showed consistent values with only minimal individual variation, which confirms that the procedure was performed in accordance with high clinical standards.

Table 2. Intraoperative and Early Postoperative Outcomes

Index	Value
Cardiopulmonary Bypass (CPB) Time (minutes)	144,3 ± 14,3
Aortic Cross-Clamp Time (minutes)	105,8 ± 10
Intraoperative Blood Loss (ml)	42,8 ± 9,5
Duration of Stay in the Intensive Care Unit (hours)	32 ± 2
Length of Hospital Stay (days)	8 ± 2
Pre-Discharge Pressure Gradient (mmHg)	7 ± 1,6
Regurgitation in the Aortic Position	No
In-Hospital Mortality	No

Most importantly, no in-hospital mortality was recorded in this series. Furthermore, no additional surgical interventions or severe cardiac complications were observed during the early postoperative period.

Discussion

The results of this study further confirm the effectiveness of the Ross procedure in treating congenital aortic valve pathologies in children. All 14 patients included in the study underwent successful surgery, with no early complications or in-hospital mortality recorded in any case. These findings demonstrate that the Ross procedure is a safe and effective surgical option in pediatric cardiac surgery.

The pre-discharge echocardiographic evaluation confirmed the restoration of valve function, as evidenced by a reduction in pressure gradient across the aortic position to 7 ± 1.6 mmHg and the absence of regurgitation.

These results are consistent with previous major studies, including those by Starnes et al. (2020) and Brown et al. (2021), which also reported excellent hemodynamic outcomes of the Ross procedure in pediatric patients.

The main advantages of the Ross procedure — including the autograft's compatibility with physiological hemodynamics, its ability to accommodate somatic growth, and the lack of need for anticoagulant therapy — were confirmed in our clinical practice as well.

Notably, in two cases, the Ross procedure was performed following previous cardiac surgeries, demonstrating its feasibility even in reoperations and complex cardiac pathologies.

The outcomes associated with the use of both homografts and synthetic grafts were also favorable, as all grafts implanted in the pulmonary position maintained full functional capacity.

In particular, the Pilon (CemCor) xenograft and the EuRos-Mi (MedInzh) synthetic graft proved suitable for use under local clinical conditions. This finding is especially significant when compared to the reoperation rates reported by Fricke et al. (2020) — no such need for reintervention was observed in our study.

In such procedures, precise technical preparation, high-level anesthetic management, and meticulous surgical technique play a decisive role. In particular, the balanced management of aortic cross-clamp and cardiopulmonary bypass times proved to be a key factor in the successful execution of the Ross procedure.

Our mean values (CPB – 144.3 ± 14.3 minutes, cross-clamp – 105.8 ± 10 minutes) are consistent with those reported in the international literature.

At the same time, this study has certain limitations: the number of patients is relatively small, the follow-up period is short, and long-term functional outcomes were not assessed.

Future studies should aim to include a larger patient cohort and conduct long-term follow-up evaluations to better understand the durability and efficacy of the procedure.

Conclusions

Based on the results of this study, the following conclusions can be drawn:

The Ross procedure is an effective and safe surgical method for children with congenital aortic valve pathology.

By restoring near-physiological valve function, it ensures stable hemodynamic outcomes.

A significant decrease in pressure gradient and the absence of regurgitation after surgery indicate a clear clinical improvement in valve function.

The lack of mortality and severe complications during hospitalization confirms that the Ross procedure can be safely performed in pediatric cardiac surgery.

The use of homografts and synthetic grafts demonstrated clear clinical effectiveness, highlighting the potential for utilizing modern biomaterials under local conditions.

Based on these findings, the Ross procedure is recommended as an optimal surgical solution for children with congenital aortic valve pathologies, particularly when integrated into clinical strategy alongside long-term follow-up.

Contributed by the authors

Conceptualization – Y.S.S. and A.R.K.;Methodology – A.R.K.;Surgical procedures – Sh.Sh.A. and A.R.K.;Data analysis – N.A.Z.;Echocardiography – A.A.B.;Anesthesiology and intensive care – Y.M.L.;Writing – original draft – N.A.Z.;Editing – Y.S.S.;Visualization – N.A.Z.;Supervision – Y.S.S.

All authors have read and agreed to the published version of the manuscript.

Compliance with ethics

The study was conducted in accordance with the Declaration of Helsinki and approved by the Local Ethics Committee of the Medion Innovation Clinic (Protocol No. 2022-ROSS, approval date: January 20, 2022).

Informed consent

Written informed consent was obtained from the parents of all patients for participation in the study and for publication of the results.

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Data Use Statement

All data presented in the article are included in full within the manuscript. Additional information is available upon request.

Gratitude

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No conflict of interest

The authors declare no conflict of interest related to this study.

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