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Research Article

Surgical Treatment of Aortic Coarctation: Comparative Analysis of Different Methods and Their Effectiveness Depending on Patient Age

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Abstract

The aim of this study was to evaluate the effectiveness and safety of various surgical methods for the treatment of coarctation of the aorta (CoA) considering the age characteristics of patients. The retrospective cohort study included 120 patients, divided into four age groups and subjected to one of four types of operations: resection with end-to-end anastomosis (EEA), aortoplasty with a prosthetic patch (APP), extended end-to-end anastomosis (EEEA), or installation of an intermediate prosthetic graft (IPG). The results showed that infants and young children achieved the best outcomes with the use of extended anastomosis, while APP demonstrated universality and effectiveness for all age groups. The frequency of reinterventions remained high in patients with hypoplastic aortic arch and severe coarctation. The findings of this study underscore the importance of an individualized approach to choosing the surgical method for treating CoA, especially for high-risk patients.

Key Words: congenital heart defects; coarctation of aorta; resection with end-to-end anastomosis; aortoplasty with a prosthetic patch; extended end-to-end anastomosis

Introduction

Coarctation of the aorta (CoA) is a severe congenital anomaly of the cardiovascular system, characterized by a narrowing of the aorta, which disrupts blood circulation and can lead to serious complications, including hypertension and heart failure. Despite significant advancements in medicine, the diagnosis and treatment of CoA remain pressing issues in modern cardiac surgery. Various surgical techniques, including resection with end-to-end anastomosis, aortoplasty with a prosthetic patch, and the use of grafts, are widely employed for the correction of this pathology. However, the choice of the optimal treatment method remains a subject of debate, particularly concerning the patient's age and the severity of the anomaly.

This study presents a retrospective analysis of data from patients who underwent surgical treatment for CoA using different techniques. The primary objective of the study is to assess the efficacy and safety of various surgical approaches, considering patient age and associated factors such as operative duration, aortic cross-clamp time, and the frequency of reinterventions. The data analysis aims to identify the advantages and limitations of each method, which may serve as a foundation for further refinement of surgical strategies for CoA treatment.

Materials And Methods

A retrospective cohort study was conducted, involving a retrospective analysis of medical records. Since clinical audits do not entail deviations from standard clinical management, neither patient consent nor formal ethical review/approval was required. Therefore, this study was registered as a clinical audit, and all data were de-identified. However, all patients had provided informed consent for medical examinations and surgical procedures.

A total of 120 patients were categorized into four age groups: Group 1 included patients under 1 year of age (46 patients); Group 2 consisted of patients aged 1 to 3 years (15 patients); Group 3 comprised patients aged 3 to 10 years (25 patients); and Group 4 included patients older than 10 years (34 patients).

These patients underwent one of four different types of surgical procedures, and accordingly, they were further classified into four groups based on the type of surgery:

•Group I: Resection with end-to-end anastomosis (EEA) – 27 patients

•Group II: Aortoplasty with a prosthetic patch (PPA) – 52 patients

•Group III: Resection with extended end-to-end anastomosis (EEEA) – 35 patients

•Group IV: Prosthetic interpositional graft (PIG) – 6 patients

This classification allowed for a comparative assessment of different surgical techniques concerning patient age and treatment outcomes.

Age groups:	**Operation groups:**				
	Group I (EEA)	Group II (PPA)	Group III (EEEA)	Group IV (PIG)	**Total by age groups**
Group 1 (<1 year)	12	5	29	0	**46**
Group 2 (1-3 years)	5	4	6	0	**15**
Group 3 (3-10 years)	7	16	0	2	**25**
Group 4 (>10 years)	3	27	0	4	**34**
Total by operation groups	**27**	**52**	**35**	**6**	**P<0.001**

Table 1: Distribution of Patients by Age and Surgical Group

The baseline patient characteristics for each surgical group are presented in the table below:

Information	**Operation groups:**				
	Group I (EEA) (27 patients)	Group II (PPA) (52 patients)	Group III (EEEA) (35 patients)	Group IV (PIG) (6 patients)	**P-value**
Mean age (months)	41.9 ±50.3	162 ±140	5.69 ±5.97	171 ±67	**<.001*** **
Gender (males)	17 (62.9%)	40 (76.9%)	23 (65.7%)	5 (83.3%)	**.450**
Height (m)	0.878 ±0.297	1.34 ±0.364	0.665 ±0.101	1.44 ±0.275	**<.001*** **
Weight (kg)	12.3 ±9.83	38.4 ±25.3	6.01 ±1.94	38.3 ±20.7	**<.001*** **
BMI	14.2 ±3.34	18.3 ±5.48	13.3 ±1.04	17.3 ±3.90	**<.001*** **

Table 2: Patient Information by Surgical Grouphe template is used to format your paper and style the text.

As shown in Table 1, the distribution of surgical procedures across different age groups is not uniform, as evidenced by a statistically significant p-value <0.001 based on the chi-square test. Table 2 further illustrates a statistically significant difference in the mean age between surgical groups. This indicates that specific surgical techniques were selectively performed in different age categories, necessitating a detailed

Discussion

Statistical analysis was conducted using SPSS Statistics 22.0, assessing homogeneity via Levene's test and normality of distribution using QQ plots. The mean and standard deviation (SD) were used to summarize symmetrically distributed numerical variables.

The chi-square test was applied for categorical (nominal and ordinal) variables. Paired t-tests or Wilcoxon signed-rank tests were used for paired variables, while independent t-tests or Mann-Whitney U tests were applied for independent variables, depending on normality and homogeneity. Pearson's correlation coefficient was used for correlation analysis.

A significance level of $P < 0.05$ was considered statistically significant throughout the study.

Results

As illustrated in the figure below, patients in Group 1, who underwent end-to-end anastomosis, were predominantly young children, with a limited number of procedures performed on patients up to a maximum age of 16 years. In contrast, patch aortoplasty was performed across a wide range of age groups, from infancy to 50 years.

Extended end-to-end anastomosis was primarily performed in younger patients, including neonates, whereas interpositional graft procedures were predominantly conducted in patients aged 12 to 20 years.

These observations suggest that patch aortoplasty is a versatile technique applicable to patients of all ages. Conversely, end-to-end anastomosis, particularly the extended end-to-end anastomosis, is primarily suitable for young children. Performing these surgical techniques in adult patients may present certain challenges.

Perioperative variables such as operative duration, aortic cross-clamp time, intensive care unit (ICU) stay, and total hospital stay are critical clinical factors. The data for each surgical group are presented in the table below:

Information	**Operation groups:**				
	Group I (EEA) (27 patients)	Group II (PPA) (52 patients)	Group III (EEEA) (35 patients)	Group IV (PIG) (6 patients)	**P-value**
Operation time (min)	119 ±33.1	145 ±44.4	155 ±16.9	224 ±68.7	**<.001*** **
Ao cross-clamp time (min)	29.4 ±7.09	23.9 ±12.0	28 ±5.48	40.8 ±11.7	**.016***
ICU stay (days)	2.59 ±5.15	1.50 ±2.37	1.37 ±0.8	2.0 ± 1.55	**.531**
Hospital stay (days)	7.04 ±4.38	8.54 ±4.34	8.31 ±2.13	8.83 ±1.72	**.436**

Table 3: Intraoperative Patient Data by Surgical Group

These findings indicate that operative time and aortic cross-clamp time vary significantly across different surgical techniques.

Specifically, end-to-end anastomosis (EEA, Group I) had the shortest operative duration compared to other procedures, whereas patch aortoplasty (PPA, Group II) required the least aortic cross-clamp time. The length of ICU and hospital stay did not show statistically significant differences between the surgical groups.

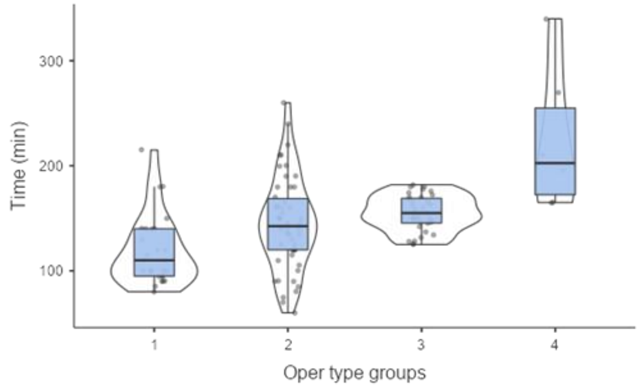

Figure 2: Mean Operative Time by Surgical Group

Discussion

In contemporary literature, patients undergoing extended end-to-end anastomosis (EEEA) are generally younger. For instance, Wright et al. (University of Michigan, USA) reported that among 83 patients, the median age was 21 days, ranging from 2 to 365 days [1]. Similarly, Kaushal et al. (Chicago, USA) provided data on 201 patients who underwent EEEA between 1991 and 2007, with a median age of 23 days, all being younger than 2 years [2].

The high mobility requirement of the aorta during surgery—since the descending aorta needs to be mobilized and anastomosed under the aortic arch—makes EEEA more feasible in younger patients and presents technical challenges in older individuals. Even when performed in older patients, there is an increased risk of postoperative complications due to high aortic wall tension, including rupture, bleeding, and recoarctation.

For end-to-end anastomosis (EEA), while this method does not require the same level of aortic mobility as EEEA, it still presents challenges. Some authors have reported its feasibility in older patients. For example, Abjigitova et al. (Netherlands) stated that EEA is a viable and effective approach in older patients, presenting data on 90 adults (mean age: 24 years, range: 20–36 years) who underwent CoA repair between 1961 and 2008, with 49 patients (57%) undergoing EEA [3]. Similarly, Egbe et al. (Mayo Clinic, USA) reported data on 204 patients (mean age 35 ± 12 years), of whom 51% underwent EEA [4]. Both studies concluded that EEA is an effective method across all age groups.

Some authors have presented data on patch aortoplasty (PPA) in patients across various age groups [3,4,5], highlighting that interpositional graft (PIG) techniques were primarily used in older children and adults. Abjigitova et al. reported that PIG was mainly used for recoarctation repair [3].

Our findings were consistent with these results concerning age distribution: gender proportions remained similar across surgical groups, while differences in height and weight were attributable to age differences.

However, PPA required a longer operative time than EEA, despite a shorter aortic cross-clamp duration. This discrepancy arises because operative time correlated with patient age ($r = 0.330$, $p < 0.001$), whereas aortic cross-clamp time did not ($r = -0.024$, $p = 0.796$). These findings suggest that preparation and vascular dissection for CoA repair take longer in older patients, whereas the actual correction time remains similar across age groups. Thus, PPA had a longer operative duration than EEA.

When comparing EEA and EEEA, which had similar patient age distributions, EEA required less operative time than EEEA. This is due to the fact that EEEA involves dissecting and preparing the entire aortic arch and its branches, and the descending aorta must be further mobilized to facilitate anastomosis, which prolongs the procedure compared to EEA.

The rate of reintervention following CoA repair remains high, ranging from 12% to 42% [3,6]. The primary reason for reintervention continues to be recoarctation, which will be discussed in the next section. However, Abjigitova et al. reported that nearly 70% of reinterventions in their 40-year follow-up cohort were due to aortic-related procedures, including aortic valve repair, Bentall procedure, Ross procedure, and David procedure.

In our study, 9 patients (7.5%) required reintervention during the follow-up period. Among them, 3 patients underwent a Bentall procedure shortly after their primary CoA repair, while the remaining 6 patients required additional surgery for recoarctation correction.

Correlation analysis revealed an association between reintervention and preoperative aortic gradient ($r = 0.340$, $p < 0.001$) as well as the z-score of the aortic arch ($r = -0.238$, $p = 0.009$). These findings indicate that patients with more severe CoA and hypoplastic aortic arches are at higher risk for reintervention.

A Kaplan-Meier survival curve illustrates freedom from reintervention based on age group, surgical group, and aortic arch hypoplasia.

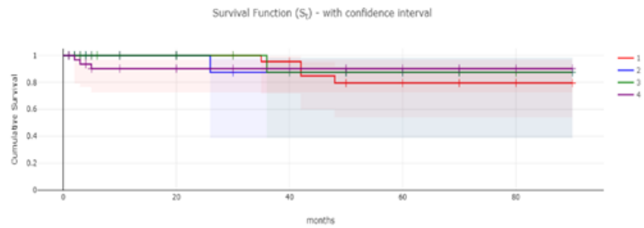

Figure 3: Freedom from Reintervention by Age Group

The Kaplan-Meier curve above demonstrates that early reintervention was observed in age group 4 (patients older than 10 years), but following this initial period, they remained relatively stable. In contrast, younger age groups exhibited a progressive increase in reintervention rates over time.

The lowest rate of freedom from reintervention was seen in Group 1 (patients younger than 1 year), where approximately 80% of patients eventually required a second intervention.

Figure 4: Freedom from Reintervention by Surgical Group

The Kaplan-Meier curve above illustrates that Group I (EEA) exhibited the lowest freedom from reintervention, with a reintervention rate approaching 30%. In contrast, Group II (PPA) and Group III (EEEA) demonstrated comparatively better long-term outcomes, with reintervention rates around 15%.

These findings suggest that EEA may carry a higher risk of recoarctation or other complications requiring further surgical intervention, whereas PPA and EEEA appear to be more durable over time.

Figure 5. Freedom from Reintervention in Patients with Aortic Arch Hypoplasia

Patients with aortic arch hypoplasia exhibited a significantly higher rate of reintervention compared to those without arch hypoplasia. The reintervention rate in these patients reached approximately 55%, indicating a substantial long-term risk.

Based on these findings, younger age, CoA repair using end-to-end anastomosis (EEA), and aortic arch hypoplasia are identified as major risk factors for reintervention. This underscores the need for careful surgical planning and patient selection to reduce the likelihood of future corrective procedures.

Conclusion

This study reaffirmed the importance of an individualized approach in selecting the optimal surgical technique for coarctation of the aorta (CoA), considering patient age and other key factors. The findings demonstrated that different surgical methods—end-to-end anastomosis (EEA), patch aortoplasty (PPA), and interpositional grafting (PIG)—each have distinct advantages and limitations. Specifically, infants and younger children exhibited better outcomes with extended end-to-end anastomosis (EEEA), whereas patch aortoplasty (PPA) proved to be a more versatile option, suitable for patients across all age groups.

Additionally, the study identified that patients with a hypoplastic aortic arch and more severe CoA are at a higher risk of requiring reintervention, emphasizing the need for thorough preoperative planning and vigilant postoperative monitoring. These findings can contribute to refining treatment strategies for CoA and reducing the incidence of reintervention, particularly in high-risk patient groups.

Further research is warranted to optimize surgical approaches and enhance long-term outcomes for patients of all age categories.

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