

# Short-Term Outcomes of Two Surgical Techniques for the Treatment of Coarctation of the Aorta in Infants: Subclavian Flap Repair and Resection with Extended End-to-End Anastomosis Technique

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# Abstract

Background: The aims of the study were to analyze the importance of two different surgical procedures, and to determine outcomes for neonates with coarctation of the aorta in two newly established centers. Methods: Outcomes of two different surgical repairs for coarctation of the aorta in 43 infants were evaluated retrospectively. The study was designed as a nonrandomized, cross-sectional study. The subclavian flap repair was applied to 22 patients (51%) and resection with extended end-to-end anastomosis technique to 21 patients (49%). After all operative survivors were followed up with a mean follow-up of  $1.8 \pm 0.8$  years, data analyzed with t-test and the p value < 0.05 were considered statistically significant. Results: The overall mortality rate was 4.6%. Forty mmHg gradients were determined in a patient from Resection Group postoperatively in the fifteenth month. After the balloon angioplasty, the gradient decreased to 25 mmHg. The presence of ventricular septal defect (p = 0.094) was the only significant predictor of adverse short-term outcome among the associated cardiac defects analyzed. The first-year survival rate was 100% in both groups in isolated coarctation (p = 0.965), however; such rate was found as 100% and 93.25%

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in Waldhausen Group and Resection Group, respectively in complex coarctation (p = 0.294). Conclusions: Both the subclavian flap repair and resection with extended end-to-end anastomosis for coarctation of the aorta in infants provide excellent short-term outcomes with lower recurrence rates requiring surgery or angioplasty.

# **Keywords**

**Congenital Heart Disease, Coarctation of Aorta, Infant** 

# 1. Background

Left heart outflow obstruction due to aortic coarctation can impose abnormal pressure load on the left ventricle, inducing hypertrophy, with diastolic and systolic dysfunction. Abnormalities in left ventricular inflow trigger the increase in pulmonary venous pressure that predisposes to pulmonary edema in patients with coarctation of the aorta. Hence, the aortic coarctation ought to be treated in children during the infancy period [1]. Surgical procedures such as; resection with end-to-end anastomosis, patch aortoplasty, left subclavian flap angioplasty, bypass graft repair were reported in the surgical treatment of aortic coarctation. Although the superiorities of each method have shown in different case series; there is no unanimity about which process the best is. According to the literature, the most used technique is resection with extended end-to-end anastomosis procedure, but there is no exact data that this procedure is superior to others [2]. Cobanoglu *et al.* [3] compared the results of the end-to-end repair group with the results of the subclavian flap angioplasty group and found no difference between the groups. They said that, concomitant diagnosis of ventricular septal defect significantly increased the mortality rate of coarctation repair by approximately two times. Aims of our study were to evaluate the results of two surgical procedures, and to find out the specific predictors of short-term result, after repair of aortic coarctation in infants and prematurely born infants.

#### 2. Methods

#### 2.1. Patients

Two of hospital's ethics committee approved the present retrospective, non-randomized, cross sectional study. Forty-three patients below the age of 1 year with the diagnosis of coarctation of the aorta who underwent surgical repair Department of Pediatric Cardiac Surgery, Behçet Uz Children's Hospital, Izmir, Turkey and Department of Cardiovascular Surgery, Izmir University School of Medicine, Izmir, Turkey between May 1st 2010 and June 30th 2014 were included. The study was designed as a nonrandomized, cross-sectional case-control study. Non-probability sampling method was used.

All patients underwent echocardiography assessment postoperatively; however, diagnostic cardiac catheterization was performed if any signs of examination finding and/or of the coarctation, when the recurrence was suspected. Presence of blood pressure gradient over than 20 mmHg was considered as an indication for reintervention [3]. Cranial ultrasonography was performed to each patient in the pre and postoperative period to determine any intracranial hemorrhage.

**Inclusion criteria** were as follows: a) Diagnosis of coarctation of the aorta in infant period; b) Surgical repair at Department of Pediatric Cardiac Surgery, Behçet Uz Children's Hospital, Izmir, Turkey and Department of Cardiovascular Surgery, Izmir University School of Medicine, Izmir, Turkey; c) As specified in the scientific literature, we also defined "isolated coarctation" as the presence of coarctation of the aorta without any concomitant intracardiac lesions except bicuspid aortic valve, however, "complex coarctation" referred to the combination of coarctation of the aorta with any other intracardiac lesions [4] [5]; d) Two surgeons from two centers operated all the patients.

**Exclusion criteria** were as follows: a) Patients with interrupted or hypoplastic aortic arch; b) Long segment coarctation was excluded from this cohort.

Data about type of coarctation of the aorta, age, sex, associated anomalies (**Table 1**), initial and postoperative peak systolic gradient, technique of surgery, presence of recurrent disease, complications including hemorrhage,

Cardiac Anomalies			
Isolated Coarctation	Waldhausen Group	<b>Resection Group</b>	p Value
N = 36	17	19	NS
Patent Ductus Arteriosus	17	19	NS
<b>Complex Coarctation</b>	Waldhausen Group	Resection Group p Val	
$\mathbf{N} = 7$	n = 5	n = 2	NS
Ventricular Septal Defect	4	2	0.009
Aortic (or Subaortic) Stenosis	2	-	NS
Patent Ductus Arteriosus	5	2	NS
Associated Noncardiac Anomalies	Waldhausen Group	<b>Resection Group</b>	p Value
Renal Anomalies	1	-	Ns
Genitourinary Anomalies	-	1	NS
Craniofacial Defects	1	-	NS
Gastrointestinal Defect	1	-	NS
Genetic Anomalies	-	1	NS

Table 1. Cardiac or non-cardiac anomalies of the isolated or complex coarctation of the aorta cases.

left arm function chylothorax, spinal cord injury, as well as the follow-up time, mortality, the intervention and its success were analyzed (Table 2 and Table 3). Recurrence was defined as the presence of a peak systolic gradient of 20 mmHg or more at the repaired side of the aorta.

#### 2.2. Surgical Technique

A signed consent form was obtained from both parents of each patient before they operated. The surgical technique was based on surgeon preference. The operations performed under standard general anesthesia techniques, and hypothermia did not used in any patient.

All procedures performed through a left thoracotomy. The lung retracted anteriorly. Division of the ductus or ligamentum with preservation of the recurrent laryngeal nerve can facilitate the surgical exposure. Collaterals and other branches from the aorta preserved if feasible. Pulmonary artery banding performed in patients with large ventricular septal defect with pulmonary over circulation in both groups.

**Surgical procedure for Waldhausen Group**: Subclavian artery was tied and divided distally at the thoracic outlet. An incision through the coarctation segment was carried onto the subclavian artery and distally, well beyond the coarctation zone onto the descending thoracic aorta. It was made sure that the flap tissue symmetrically positioned across the coarctation segment. Posterior aortic ridge resected. The subclavian artery patch is sewn on with running 7 - 0 polypropylene (Prodek®, UK) sutures [5].

**Surgical procedure for Resection Group**: Control of the proximal aorta was accomplished tangentially below the left carotid artery; the left subclavian artery was controlled either with the same clamp or separately. The entire area from the left subclavian artery to an area of normal proximal descending aorta resected. The proximal aorta was spatulated along the lesser curve of the arch to a point immediately below the origin of the left carotid artery. The distal aorta was appropriately beveled and anastomosed to the underside of the arch with 7 - 0 polypropylene (Prodek®, UK) sutures avoiding tension at the suture line [6] [7].

# 2.3. Follow-Up

Postoperative follow-up visits were scheduled in the cardiology and cardiovascular surgery clinics at the sixth weeks, third months, sixth months, and first year, as dictated by their clinical condition. Blood pressure was measured at upper and lower extremities. Peripheral pulses were also examined. The pressure gradients were derived from the descending aorta by transthoracic echocardiography. If there was a resistance in the diastolic phase of blood pressure, we had a suspicion about recoarctation in the anastomosis region, and we applied cardiac catheterization. The presence of a gradient greater than 20 mm Hg was considered as an indication for intervention. One patient from **Resection Group** has lost the follow-up.

Variables	<b>Overall values</b>	Waldhausen group	Resection group	p valu
Any complication, n/N (%)				
Acidosis, n/N (%)	2/43 (4.65%)	2/22 (9.09%)	-	-
Cardiac arrest, n/N (%)	2/43 (4.65%)	2/22 (9.09%)	-	-
Chylotorax, n/N (%)	1/43 (2.32%)	-	1/21 (4.76%)	-
Pleural effusion requiring drainage, n/N (%)	1/43 (2.32%)	1/22 (4.54%)	-	-
Recurrent laryngeal nerve damage, n/N (%)	1/43 (2.32%)	-	1/21 (4.76%)	-
Spinal cord injury, n/N (%)	0/43 (0%)	-	-	-
Mechanical ventilator support, n/N (%)	34/43 (79%)	12/22 (54.5%)	20/21 (95.2%)	NS
Unplanned cardiac reoperation, n/N (%)	1/43 (2.32%)	1/22 (4.54%)	-	-
Postoperative infection, n/N (%)	5/43 (11.6%)	2/22 (9.09%)	3/21 (14.2%)	NS

#### Variables **Overall values** Waldhausen group **Resection group** p value 43 22 21 n NS In-hospital mortality, n/N (%) 2 (4.65%) 2(9.09%)0.007 Length of stay in ICU, d; mean SD (median) $18.58 \pm 15.18$ $16.18 \pm 14.2$ $21.0 \pm 16.04$ 0.294

ICU: intensive care unit.

#### 2.4. Statistical Analysis

Results were presented as mean  $\pm 1$  standard deviation and percentage (%). Intergroup variables were compared using the paired and unpaired t-test (SPSS for Windows 7.0 release). A p value less than 0.05 were considered statistically significant. We analyzed age, gender, body weight, and the type of surgical procedure, cross clamp time, associated lesions and preoperative pressure gradient at the coarctation segment as possible predictors of mortality in a multivariate analysis. Logistic regression analysis was performed to examine the association between **Resection** and **Waldhausen group**.

# 3. Results

#### 3.1. Characteristics of the Study Groups

Subclavian flap repair (Waldhausen procedure), (Waldhausen Group) was applied to 22 patients (51%) and resection with extended end-to-end anastomosis procedure (Resection Group) to 21 patients (49%).

Of the total 43 patients, 65.1% were male (15 Female/28 Male). Sixteen patients in **Waldhausen Group** and 12 patients in **Resection Group** were male. The number of patients with term birth was 32 (74.4%). There were 11 (25.6%) premature patients. Seventeen patients (39.5%) were neonates. Mean age at the time of operation was  $53.95 \pm 64.37$  days (range, 2 to 269 days). Mean weight was  $4023.25 \pm 1607.06$  grams (range, 2100 to 7500 grams). Eleven (25.5%) patients were intubated preoperatively. Mean gestation age was  $34.86 \pm 4.14$  months (range, 26 to 40). The positive inotropic drug infusions were given 21(48.8%) patients preoperatively.

Isolated coarctation was diagnosed in only 36 cases (74.4%), of whom 17 were in **Waldhausen Group** and 19 were in **Resection Group**. The remaining 7 (25.6%) patients had one or more associated congenital heart defects. All patients had patent ductus arteriosus. Five of them were in **Waldhausen Group** and two of them were in **Resection Group**. The three most commonly associated lesions were patent ductus arteriosus (100%), ventricular septal defect (20.9%) and aortic stenosis or bicuspid aorta (4.65%) that was shown in **Table 1**. Nine (20.9%) patients were taking prostaglandin E1 infusion. Five patients in **Waldhausen Group** and four patients in **Resection Group** were prostaglandin E1-dependent (p = 0.888). Preoperative use of prostaglandin E1 was not found to be a predictor of survival.

The preoperative peak aortic coarctation level gradients ranged from 50 to 99 mmHg with a mean gradient of  $79.20 \pm 12.16$  mmHg. The gradients were measured as  $79.0 \pm 12.9$  mmHg (range 50 to 99 mmHg) for Waldhausen Group and  $79.42 \pm 11.65$  (60 to 99 mmHg) for Resection Group (p = 0.909).

The mean aortic cross-clamp time for the two groups was  $15.9 \pm 4.3$  minutes. There was no significant difference in the mean aortic cross clamp time between the two groups  $(13.95 \pm 3.6 \text{ versus } 18.09 \pm 4.07, \text{ respectively})$  (p = 0.07). Increasing in the aortic cross-clamp time for every one minute was found to be a significant factor on postoperative survival (p = 0.001).

#### 3.2. Postoperative Outcomes, Morbidity and Mortality

Mean intubation time was  $11.50 \pm 10.37$  (range, 0 to 36 days),  $11.72 \pm 9.68$  (range, 0 to 32 days) for **Waldhausen Group** and  $11.28 \pm 10.22$  (range, 0 to 36 days) for **Resection Group** (p = 0.885). Mean intensive care unit time after the operation was  $18.58 \pm 15.18$  (range, 1 to 63 days) in all patients, and was  $16.18 \pm 14.2$  (range, 1 to 60 days) in **Waldhausen Group**, and  $21.0 \pm 16.04$  (range 2 to 63 days) in **Resection Group** respectively (p = 0.294). Only three patients in **Resection Group** required pulmonary banding in the same operation.

Mortality in the early postoperative period (before one month) was present in two patients who had large ventricular septal defect in **Resection Group** secondary to acidosis and low cardiac output syndrome; however, late mortality was not seen in any of the participants. In the postoperative period, none of the patients had signs of ischemia at left arm and subclavian steal syndrome. Overall, the discharge mortality was 4.65%. However, the discharge mortality for low-weight premature infants was 18% compared with 0 % for full-term infants with the body weight of over than 2500 grams and up to 4000 grams at the time of repair (p = 0.002). The postoperative mean aortic gradient was found as  $6.32 \pm 6.85$  (range 0 to 40 mmHg) in **Waldhausen Group** and 7.66  $\pm$  8.63 (range 0 to 40 mmHg) in **Resection Group** (p = 0.203). The complications in the postoperative period were shown in **Table 2**. According to multivariate Cox analysis, body weight and mechanical ventilator support were found to have an effect on the gradient %95 CI of the OR: (1.6, 7.02). The cardiac catheterization was applied to one patient in **Waldhausen Group** after we determined a peak gradient of 55 mmHg in the control echocardiography at the third month of postoperative follow-up; no restenosis was seen in this patient. Balloon dilatation was applied to a patient in **Resection Group** in the 15 month when aortic gradients were defined 40 mmHg.

The first year survival ratio in cases with isolated coarctation was 100% in both groups (p = 0.965), however, it was found as 100%, and 95.35% among cases with complex coarctation in **Waldhausen Group** and **Resection Group**, respectively (p = 0.294). The difference was not statistically significant. Sepsis was the major cause of mortality.

Postoperative chylothorax was seen in only one patient in whom 1200 cc lymphatic fluid was collected in the pleural space. Intravenous and nasogastric feeding fluid that contains rich of medium chain triglycerides was applied. Intravenous infusion of Sandostatin was given at the dose of 1 mcg/kg/day. The drainage tube pulled at the postoperative twelfth day with no repetition of chylothorax.

The presence of large ventricular septal defect (p = 0.009) was the only significant predictor of adverse short-term outcome among the associated cardiac defects analyzed (Table 1).

Incidence of recurrent laryngeal nerve injury ranged from 0 % in Waldhausen Group to 2.32% in **Resection** Group (p = 0.668). The incidence of spinal cord injury is low 0% in this series.

Infection ratio in the postoperative period was 2/22 (9.09%) in Waldhausen Group and 3/21 (14.2%) in **Resection Group** (p = 0.745).

Cranial ultrasonography revealed no signs of intracranial hemorrhage in the pre and postoperative period. The patients in **Waldhausen Group** had no signs of ischemia at left arm and subclavian steal syndrome. All operative survivors were followed with a mean time of  $1.8 \pm 0.8$  years (range, 1 to 3 years).

The hypertension was not detected in any patient on follow-up period.

#### 4. Discussion

Conte *et al.* mentioned that resection and end-to-end anastomosis, either with or without extension, is by far the most commonly used technique for repair of isolated coarctation [8]. Using the technique of resection and extended end-to-end anastomosis, Kaushal *et al.* [7] reported a re-intervention rate of 4.0% in a series of 201 patients. The recurrence rates reported in different studies varied between 4% and 22% [9] [10]. In our study, the overall rate of recurrence was 2.32% in all groups. Surgical re-intervention did not observe in the present study.

Recoarctation frequency may increase in our patients in long-time, although the short-term results are hopeful.

Cobanoglu *et al.* [3] mentioned that, concomitant diagnosis of ventricular septal defect significantly increased the mortality rate of coarctation repair by approximately two times. However, they reported a very favorable prognosis with an overall low mortality rate in such critically ill patients. In our study, all of our patients also had patent ductus arteriosus. The second accompanying congenital defect was ventricular septal defect. The presence of ventricular septal defect (p = 0.094) was the only significant predictor of adverse short-term outcome among the associated cardiac defects analyzed.

Researchers stated that, in the group of patients with coarctation and ventricular septal defect, the management strategy for the ventricular septal defect did not seem to influence early outcome significantly. However, each of those patients had different anatomic and physiologic manifestations of ventricular septal defect, and the management strategies selected was influenced by those factors by institutional and/or individual surgeon preferences [11] [12].

Quaegebeur *et al.* [13] reported that neonates with other levels of left heart obstruction had significantly higher mortality both at one month and 24 months of follow-up. Survival was also influenced negatively by the need to extend the coarctation repair proximal to the left common carotid artery, regardless of the operative technique used. In this study, cases with coarctation of the aorta including the aortic arch were deliberately excluded.

The reason of using two different surgical procedures in our series that, Patch aortoplasty either with a prosthetic patch or a subclavian flap is used less frequently by authors, although prosthetic patch aortoplasty may be useful for older patients. Interposition grafts likely have limited, if any, role in neonatal surgery and might be used more commonly in older patients [14]. However, we observed that, chosen surgical method had no effect on the mortality.

Crawford and Sade [15] published spinal cord injury according to hyperthermia during surgery in patients who underwent repair of coarctation of the aorta; however no surgically induced spinal cord trauma was reported in their case series. The incidence of spinal cord injury was found as 0% in our study population since we also did not use hypothermia during surgical intervention. In our study, cross-clamp duration and hypotension implicate as stronger predictors of this problem.

As well as in patients with an aberrant right subclavian artery [16], Adams *et al.* [5] mentioned that the subclavian flap repair technique remained a good surgical modality for the surgical treatment of coarctation of the aorta in infants with a low rate of recoarctation requiring intervention when compared to other surgical procedures. There are different studies that compare the short-term and long-term results of subclavian flap procedure and resection with extended end-to-end anastomosis procedure [17]. In our study, the patients underwent subclavian flap repair did not have any signs of ischemia in left arm. Each of the two surgical techniques did not have any superiority to each other since both procedures achieved complete surgical success with the absence of postoperative residual gradient. Some centers have continued to use the subclavian flap as their choice of operation for repair of coarctation of the aorta in infants [3] [18].

In a 40-year review published by Dodge-Khatami *et al.*, simple end-to-end anastomosis and subclavian flap repair had the highest rate of recoarctation, when associated with hypoplastic aortic arch. The authors recommended resection with extended end-to-end anastomosis for repair of neonates and infants and expanded polyte-trafluoroethylene (Gore-Tex®, W. L. Gore & Associates, Inc, USA) patch aortoplasty for children over the age of 1 year [19]. In our study we could not proof the superiority of two techniques to each other because there was no significant difference in the operation techniques and their results in **Waldhausen Group** and **Resection Group**. No significant effect of operative procedure was determined on postoperative gradient; however long-term studies with large cohorts are needed to compare such surgical techniques better. The same difference between the mean aortic cross-clamp time, intubation time and length of intensive care unit stay formed an opinion that there isn't any significant impact of operative procedures on postoperative outcomes.

The reported mechanical ventilation times postoperatively and the hospital length of stay are very much longer than common current experience, so that, eleven patients were intubated preoperatively.

Postoperative chylothorax did not evaluated as a disadvantage of procedures because it is a complication coincided with each of two procedures [20] [21].

Postoperative infection ratio (11.6%) in two groups was thought that it is related with growth retardation in the preoperative period as well as socio-economic and cultural situation of the families. The increased disease ratio was thought to be associated with preoperative and postoperative intubation time in the premature and infant intensive care unit.

#### **5. Limitations of the Study**

The study of consecutive patients in two new established and different centers had some limitations. The small sample size is another limitation of the study. We could not supply the homogenization because of the nonrandomized groups and alternation of operative procedures. So, the data in our study must be evaluated as real-life data. Recoarctation and intervention ratios may increase in long-term follow-up in our cases.

# 6. Conclusion

Both the subclavian flap repair and resection with extended end-to-end anastomosis in the surgical treatment of coarctation of the aorta in infants provide excellent short-term outcomes with low rates of recoarctation requiring intervention. Early mortality was found to be associated with lower patient age as prematurity increased the mortality rate. The presence of large ventricular septal defect was the only significant predictor of adverse short-term outcome among the associated cardiac defects analyzed.

# **Competing Interests**

The authors declare that they have no competing interests.

# **Authors' Contributions**

MK, EH and ONS designed the study. MK, UK, PÖ and OD carried out studies searching and performed the eligibility assessments. GA, KA, MG, OD, and BA evaluated the qualities of the included studies and carried out data extracting. MK, PÖ, GA, BA and UK analyzed and interpreted the data. MK drafted the manuscript. MK, BA, GA made critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript.

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