Research Article

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Comparison of Thoracotomy and Sternotomy Repair in Neonatal Aortic Coarctation Surgery: A Single Center Experience

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Abstract

Objectives: This study aimed to compare the rates of mortality and development of recoarctation between the thoracotomy and sternotomy methods applied in the repair of aortic coarctation during the neonatal period in our clinic.

Materials and Methods: Thirty-four neonatal patients who underwent aortic coarctation repair at our clinic between June 2017 and January 2023 were included in this study. The demographic data, physical examination findings, and transthoracic echocardiographic and angiographic examination data of all patients were retrospectively obtained from our hospital database. The patients who underwent thoracotomy and sternotomy were divided into groups 1 and 2, respectively. Postoperative recovery and mortality were recorded and compared between the groups.

Results: Thirty-four patients were included in the study, nine (26%) in group 1 and 25 (74%) in group 2. The median age and body weight of the patients in group 1 and group 2 were 14 (interquartile range: 9-22) days, 9 (interquartile range: 4-19) days, p=0.256 and 3.5 (interquartile range: 3.15-3.6) kg, 3 (interquartile range: 2.8-3.25) kg, p=0.057, respectively. Significant differences were found in isthmus diameters, aortic arch, and isthmus Z-scores between the groups (all p<0.05). Significant recoarctation developed in three patients, two (22%) in group 1 and one (4%) in group 2. Early in-hospital

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mortality was observed in nine patients, four (44%) in group 1 and five (20%) in group 2. There was no significant difference in mortality or restenosis between the two groups, p=0.201.

Conclusion: In our study, when sternotomy and descending aorta-ascending aorta end-to-side anastomosis techniques were compared with the thoracotomy repair method in neonatal aortic coarctation repair, no difference was found in terms of mortality and development of recoarctation. We believe that coarctation repair with sternotomy has a similar mortality and recoarctation frequency as coarctation repair with thoracotomy.

Keywords: Aortic coarctation, congenital heart disease, neonatal cardiac surgery

Introduction

Coarctation of the aorta is observed in 4/10,000 live births, constituting 5-8% of all congenital heart diseases[1,2]. If left untreated, systemic hypertension, congestive heart failure, cerebral hemorrhage, infective endocarditis, and dissection may develop, causing death[3]. In addition to isolated aortic coarctation, this pathology may be accompanied by aortic arch or isthmus hypoplasia, or both. It can also be observed together with intracardiac defects such as ventricular septal defects and transposition of the great arteries. The primary surgical approach for isolated aortic coarctation is a left thoracotomy with resection of the coarctation segment and end-to-end anastomosis of the aorta. In the presence of concomitant arcus aorta or isthmus hypoplasia and intracardiac defects, complete correction can be performed in one step with the classical median sternotomy and cardiopulmonary bypass support[4]. In this study, we aimed to compare the rates of mortality and development of recoarctation between the thoracotomy and sternotomy methods applied in the repair of aortic coarctation during the neonatal period in our clinic.

Materials and Methods

This study included 34 neonates who underwent aortic coarctation repair between June 2017 and January 2023. The study design was approved by the appropriate Başkent University Institutional Review Board (project number: KA22/315). Data were collected retrospectively from the hospital has database. Detailed physical examinations, laboratory tests, and echocardiographic evaluations were performed on all patients. Additional cardiac anomalies, genetic anomalies, preoperative prostaglandin E1 use, and the need for mechanical respiratory support were also noted. In the pre-operative echocardiographic evaluation, the diameter of the ascending aorta at the level of the right pulmonary artery, the largest systolic diameters of the proximal and distal transverse aortic arches, and the largest systolic diameters of the aortic isthmus and descending aorta were measured in millimeters. The aortic arch and isthmus diameters were measured, and Z scores were calculated. Echocardiography is a reliable diagnostic tool for evaluating cardiac function. In our study, we primarily used echocardiography to obtain measurements. In cases requiring more detailed information, computed tomography or magnetic resonance angiography can be used. However, these methods were not necessary for the patient in our study.

The patients were divided into two groups according to the surgical method applied: group 1 underwent thoracotomy and group 2 underwent sternotomy. Resection and end-to-end anastomosis and extended end-to-end anastomosis and subclavian flap aortoplasty were performed in patients in group 1. In group 2 patients, the descending aorta-ascending aorta end-to-side anastomosis technique was applied. Postoperative echocardiographic evaluations were performed on all patients. Recoarctation was defined as a gradient measurement of >20 mmHg in the presence of a diastolic-extending flow pattern in the descending aorta on continuous wave Doppler. Patients

in whom balloon angioplasty failed underwent a surgical correction.

Operative Technique

In patients treated with thoracotomy under general anesthesia, a left posterolateral thoracotomy was performed, and the thorax entered through the fourth intercostal space. The distal aortic arch descending aorta, left carotid artery, and left subclavian artery were dissected and removed from the surrounding tissue. The ductus arteriosus was then divided. Before placing the cross-clamps, 100 IU/kg heparin was administered. Resection and end-to-end anastomosis, resection, and extended end-to-end anastomosis or subclavian flap aortoplasty techniques were applied depending on the surgeon's preference and anatomical variations. In cases approached with sternotomy, median sternotomy was performed using cautery under general anesthesia. The thymus was removed, and cardiopulmonary bypass was initiated after aortobicaval cannulation. The ductus arteriosus was then divided. The ascending, arch, and descending aortas were dissected along with their branches and freed from the surrounding tissues. Cardioplegic arrests were also observed. In the presence of deep hypothermic circulatory arrest or antegrade selective cerebral perfusion, the isthmus was ligated from the distal left subclavian artery and transected. The distal aorta was the left stump. The descending aorta was cut from the distal part of the coarctation tissue and prepared for anastomosis, and an end-to-side anastomosis was made to the aortotomy extending from the distal ascending aorta to the proximal aortic arch (Figures 1 and 2). Whole-body perfusion was initiated after the de-airing procedure. Intracardiac repair was performed after the arch repair.

Statistical Analysis

Statistical analyses were performed using IBM SPSS statistical software (version 25.0; IBM Corp. 25.0, Armonk, NY, USA). Continuous variables were not normally distributed; therefore, the Mann-Whitney U test was used to compare variables between independent groups. The Fisher's exact test was used to compare dichotomous variables. Statistical significance was set at p-value <0.05. Continuous variables were expressed as medians

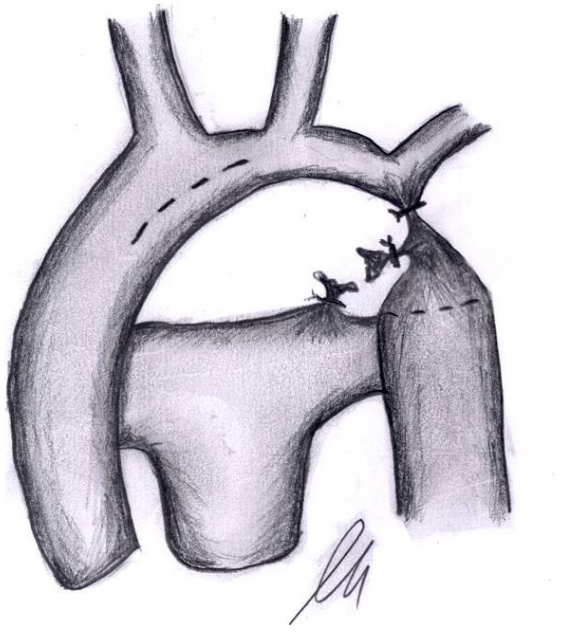

Figure 1. Ductus arteriosus division and anastomosis lines

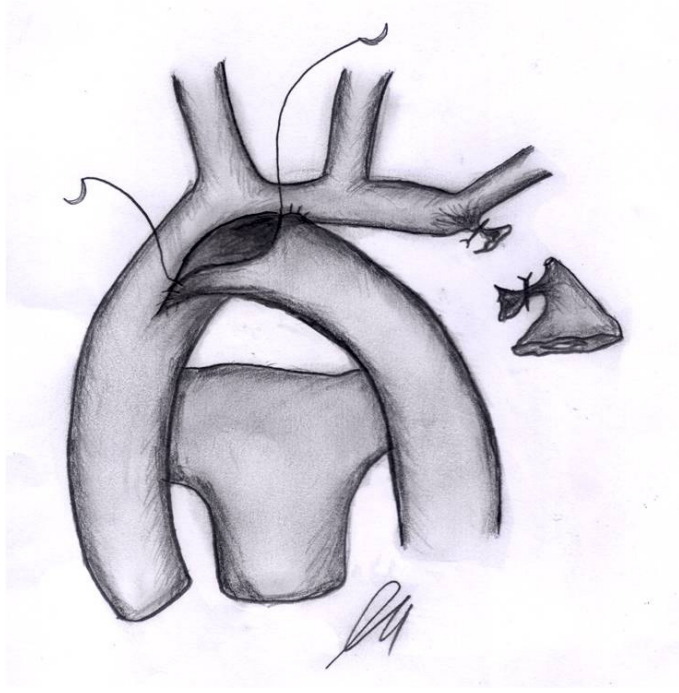

Figure 2. Descending aorta-ascending aorta end-to-side anastomosis

[interquartile range (IQR): 25th-75th], and categorical variables were expressed as numbers (percentages).

Results

The median age and body weight of 34 patients (18 male) included in the study were 12 (IQR: 4-20) days and 3.1 (IQR: 2.8-3.4) kg, respectively (Table 1). There were 9 (26%) patients in group 1 and 25 (74%) in group 2. In group 1, four patients underwent resection and end-to-end anastomosis, four underwent resection and extended end-to-end anastomosis, and one underwent subclavian flap aortoplasty. The descending aorta-ascending aorta end-to-side anastomosis technique was applied to all patients in group 2.

Biventricular cardiac physiology was observed in 30 patients (88%). A bicuspid aortic valve was detected in 10 (29%) patients: seven (78%) in group 1 and three (12%) in group 2. Simultaneous cardiac surgery was performed in 19 patients: two (22%) in group 1 and 17 (68%) in group 2. Genetic anomalies were detected in six (18%) patients: two in group 1 and four in group 2. Seventeen (50%) patients, 5 in group 1 and 12 in group 2, required preoperative mechanical ventilation. Seventeen (50%) patients, six (67%) in group 1 and 11 (44%) in group 2, received preoperative prostaglandin E1 infusion. The median preoperative aortic arch diameters of the patients in group 1 and group 2 were 3.5 (IQR: 3.1-4.4) mm and 3.3 (IQR: 3.6-3.9) mm, and isthmus diameters were 3.5

Table 1. Data of the patients

	All patient (n=34)	Group 1 (n=9)	Group 2 (n=25)	p-value
Age (day)	12.5 (4-20.2)	14 (9-22)	9 (4-19)	0.256
Wieght (kg)	3.1 (2.8-3.4)	3.5 (3.1-3.6)	3 (2.8-3.2)	0.05
Gender (male/female)	18/16	4/5	14/11	0.703
Genetic syndrome, n (%)	6 (17.6)	2 (22.2)	4 (16)	0.644
Cardiac physiology (biventricular/ univentricular)	30/4	8/1	22/3	1
BAV, n (%)	10 (29.4)	7 (77.8)	3 (12)	0.001
PMV, n (%)	17 (50)	5 (55.6)	12 (48)	1
PGE1, n (%)	17 (50)	6 (66.7)	11 (44)	0.438
Aortic arch diameter (mm)	3.4 (3-4)	3.5 (3.1-4.4)	3.3 (2.6-3.9)	0.143
Aortic arch Z-score	-4.4 (-5.71/-3.28)	-3.18 (-3.47/-2.32)	-4.85 (-6.26/-4.19)	<0.001
Isthmus diameter (mm)	2.1 (1.7-3.5)	3.5 (3-3.5)	2 (1.5-2.5)	<0.001
Isthmus Z-score	-5.21 (-6.78/-2.81)	-2.84 (-3.54/-2.30)	-5.63 (-8.14/-4.46)	0.002
Pulmonary banding, n (%)	8 (23.5)	2 (22.2)	6 (24)	1
Simultaneous cardiac surgery, n (%)	19 (55.9)	2 (22.2)	17 (68)	0.025
CPB time (min)	-	-	86 (69-106)	-
X clamp time (min)	-	17 (12.5-31)	29 (22-66)	-
ASCP time, (n=15) (min)	-	-	20 (20-25)	-
DHCA time, (n=12) (min)	-	-	21 (16-29)	-
Peritoneal dialysis, n (%)	6 (17.6)	1 (11.1)	5 (20)	1
Chylothorax, n (%)	3 (8.8)	2 (22.2)	1 (4)	0.164
Tracheostomy, n (%)	2 (5.9)	1 (11.1)	1 (4)	0.465
Left main bronchus obstruction, n (%)	1 (3)	-	1 (4)	-
Recoarctation, n (%)	3 (8.8)	2 (22.2)	1 (4)	0.164
Exitus	9 (26.5)	4 (44.4)	5 (20)	0.201

ACCP: Antegrade selective cerebral perfusion, BAV: Bicuspid aortic valve, CPB: Cardiopulmonary bypass, DHCA: Deep hypothermic circulatory arrest, PGE1: Prostoglandin E1, PMV: Preoperative mechanical ventilation

(IQR: 3-3.9) mm and 2 (IQR: 1.5-2.5) mm respectively. The median aortic arch Z scores of the patients in group 1 and group 2 were -3.18 (IQR: -3.47/-2.32) and -4.85 (IQR: -6.26/-4.19), respectively. The median isthmus Z scores of the patients in group 1 and group 2 were -2.84 (IQR: -3.54/-2.30) and -5.63 (IQR: -8.14/-4.46), respectively. Preoperative isthmus diameter ($p<0.001$), arcus ($p<0.001$), and isthmus ($p=0.002$) Z scores were significantly lower in group 2 patients.

Peritoneal dialysis was needed in six (18%) patients, one (11%) in group 1, and five (20%) in group 2. Chylothorax developed in three (9%) patients: two (22%) in group 1 and one (4%) in group 2. Tracheostomy was performed in two (6%) patients due to chronic lung failure, one (11%) in group 1 and one (4%) in group 2. Left main bronchial compression occurred in one (3%) patient in group 2. Recoarctation developed in three (9%) patients, with development times of 5, 4 and 10 months, respectively. Two patients in group 1 who developed recoarctation were treated with balloon angioplasty, and one patient in group 2 was treated surgically. Nine (26.5%) hospital mortality were observed in four (44%) patients in group 1 and five (20%) patients in group 2. Five patients died due to low cardiac output, two died due to sepsis, one died due to chronic lung disease, and one died due to multiorgan failure. There was no significant difference in mortality between the two groups ($p=0.201$). The mean follow-up period was 34±21 months.

Discussion

Thoracotomy is the generally accepted approach for isolated aortic coarctation. However, in the presence of aortic arch or isthmus hypoplasia and intracardiac pathologies, repair is possible in a single sternotomy[5-8]. Different methods have been used to define aortic arch and isthmus hypoplasia. It can be concluded that the transverse aortic arch, distal aortic arch, and isthmus are <60%, 50%, and 40% of the ascending aortic diameter, respectively[9]. Similarly, if the hypoplastic aortic arch, the smallest aortic arch dimension, is less than the weight of the patient plus 1 (in mm) it can be considered hypoplasia[10]. In addition, values lower than -2 Z score can be defined as hypoplasia. We used all three methods depending on the patient's condition[11].

Aortic coarctation should be evaluated not only as a localized disease of the aorta but also as an anatomical and physiological developmental defect of the left ventricle[11]. In our study, ten patients had bicuspid aortic valves. In such cases, which can cause significant stenosis in the outflow tract, the diameter of the ascending aorta may remain below normal limits or enlarge due to post-stenotic dilatation. Therefore, comparing the diameters of the transverse arch, distal arch, and isthmus with those of the ascending aorta may lead to incorrect evaluations. Similarly, in severe coarctation with ductus-dependent systemic circulation, circulatory dynamics may be affected and edema may develop. In such cases, it may be impossible to determine the patient's actual weight, which may lead to an incorrect evaluation of the arcus according to the kilogram + 1 formula.

Limited surgical vision and small vessel diameters in newborns can cause difficulties in applying thoracotomy techniques. Tension and suboptimal sutures in the anastomosis may cause residual stenosis[12-14].

Ramachandran et al.[15] reported that preoperative transverse arch and isthmus diameters and Z scores were not related to postoperative residual stenosis in patients who underwent coarctation repair by thoracotomy and that residual stenosis was not observed even in hypoplastic isthmuses with a Z score below -2. They also stated that because cardiopulmonary bypass and deep hypothermia are not required, it provides a neurological advantage to the patient and the recovery period is shorter. Developments in cardiopulmonary bypass techniques have minimized these risks. Distal body perfusion may be insufficient during thoracotomy repair, particularly in patients with insufficient collateral circulation during the neonatal period. Moreover, it is possible to repair mild- tomoderate hypothermia accompanied by selective antegrade cerebral perfusion without deep hypothermic

circulatory arrest during sternotomy. Although there were no age restrictions in the authors' study, only neonatal patients were included. We also adopted the opinions of these authors for older patients with adequate collateral circulation, appropriate body weight and no excessive isthmus or arcus hypoplasia.

Although some studies have reported that the transverse aortic arch diameter does not cause recoarctation, leaving a hypoplastic segment during repair causes residual stenosis and postoperative hypertension[16-19]. Weismann et al.[18] determined that there was a significant correlation between the diameters of the transverse arch of the aorta and isthmus and Z scores before discharge and the development of recoarctation. Additionally, the presence of an untreated hypoplastic aortic arch may be responsible for the development of long-term recurrent aortic stenosis and hypertension[20]. The descending aorta-ascending aorta end-to-side anastomosis is a technique that allows physiological repair without residual stenosis with completely native tissues, provides an anastomosis with growth potential, can be performed with low mortality and morbidity, and allows simultaneous cardiac repairs[5].

Two of the patients who died had genetic anomalies and immunodeficiency, and four had concomitant pulmonary banding. Concomitant pulmonary banding during arch repair is a risk factor for mortality[9]. The rates of recurrent stenosis and mortality in our study were consistent with those reported in the literature[9,15,16,18].

Study Limitations

This was a retrospective study involving a single center. Therefore, a longer follow-up period is required. The small number of patients and inhomogeneity of additional cardiac anomalies complicate the evaluation.

Conclusion

In our study, we found that the mortality and recovery rates after sternotomy and coarctation repair were consistent with those reported in the literature. There was no significant difference between the two methods in terms of mortality and development of recoarctation. We believe that the sternotomy method, which is generally preferred when additional cardiac surgery is required, can also be used for isolated coarctation surgery during the neonatal period. Multicenter studies with larger patient series are required. We believe that our results will encourage further studies in this area and will support our findings. This study broadens our current knowledge of cardiology by comparing the methods of thoracotomy and sternotomy. Our findings would help inform clinicians and patients considering aortic coarctation surgery and facilitate the improvement of current practices and patient outcomes.

Ethics

Ethics Committee Approval: The study design was approved by the appropriate Başkent University Institutional Review Board (project number: KA22/315).

Informed Consent: This was a retrospective study.

Peer-review: Externally peer-reviewed.

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