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Research Article

UNVEILING PREOPERATIVE CLINICAL PROFILES IN PEDIATRIC AORTIC COARCTATION: INSIGHTS INTO SURGICAL INTERVENTIONS AND INSTITUTIONAL ANESTHESIA PRACTICES

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ABSTRACT

Objective: The study seeks to provide valuable insights into the outcomes of anesthesia and surgical practices employed in our institution, addressing the challenges posed by preoperative conditions such as heart failure, inotropic support requirements, and mechanical ventilation needs, particularly in the delicate population of newborns.

Materials and Methods: Our investigation conducted a retrospective analysis encompassing all patients who underwent surgery for aortic coarctation at the Pediatric Cardiac Surgery Clinic of the 350-bed Dr. Behçet Uz Child Disease and Pediatric Surgery Training and Research Hospital between 2012 and 2021.

Results: The study encompassed a cohort of 97 patients spanning from newborns to adolescents, with 61 males and 36 females, revealing a 19.5% incidence of genetic anomalies. Intraoperatively, 4.1% of patients required vasodilators, and 13.4% had a triple inotropic requirement. Postoperatively, monitoring distribution included 59 patients in the cardiac surgery intensive care unit, 36 in the neonatal intensive care unit, and 2 in the pediatric intensive care unit. Early extubation within the first 24 hours was achieved in 57.7% of patients.

Conclusion: This research contributes critical insights aimed at refining treatment strategies and enhancing overall outcomes, with particular attention to addressing challenges related to delayed extubation and postoperative vasodilator requirements.

Keywords: Aortic coarctation, surgery, anesthesia, postoperative complications, risk factors.

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INTRODUCTION

The prevalence of congenital heart disease has demonstrated a marked increase over the past three decades, particularly in developed countries, while maintaining relative stability globally. Noteworthy rises have been particularly prominent in Western European nations such as Germany, Austria, and France (1). Serving as a cultural and geographic bridge between Western and Eastern regions, Turkey experiences an annual incidence of approximately 11,000 to 17,000 newborns with congenital heart disease, necessitating intervention or surgery in 5,000 to 6,000 cases due to critical congenital heart disease (2). Among these conditions, aortic coarctation ranks among the twelve most prevalent critical congenital heart diseases, boasting a prevalence of 5.8 per 10,000 live births and emerging as the most prevalent within this group (3,4).

In the pediatric population, aortic coarctation manifests as a cardiac anomaly characterized by a congenital obstruction in the aortic lumen, potentially accompanied by aortic arch lesions. Clinical presentations range from heart failure and cardiovascular collapse to organ failure, acidosis, shock, and, in severe cases, even death, contingent on the degree of left-sided heart obstruction (5). Aortic coarctation may manifest in isolation or concomitantly with genetic anomalies, cardiac anomalies, respiratory system anomalies, abdominal wall anomalies, and brain anomalies (6). Intracardiac defects associated with aortic coarctation encompass ventricular septal defect (VSD), atrial septal defect (ASD), atrioventricular septal defect (AVSD), left ventricular out-flow tract obstruction, left ventricular hypoplasia, aortic arch hypoplasia, patent ductus arteriosus (PDA), the double outlet of the right ventricle (DORV), and total anomalous pulmonary venous connection (TAPVC) (7-9). Approximately 20-30% of pediatric patients with coarctation exhibit a bicuspid aortic valve (8-10).

The urgency of surgical treatment for aortic coarctation hinges on the preoperative clinical situation, presenting challenges such as preoperative heart failure, the requirement for inotropic support, and the need for mechanical ventilation, particularly in newborns. This study aims to offer a comprehensive understanding of the preoperative clinical characteristics associated with pediatric aortic coarctation cases subjected to surgical intervention. Additionally, the study seeks to provide valuable insights into the outcomes of anesthesia and surgical practices employed in our institution, addressing the challenges posed by preoperative

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conditions such as heart failure, inotropic support requirements, and mechanical ventilation needs, particularly in the delicate population of newborns.

MATERIALS AND METHODS

Our investigation conducted a retrospective analysis encompassing all patients who underwent surgery for aortic coarctation at the Pediatric Cardiac Surgery Clinic of the 350-bed Dr. Behçet Uz Child Disease and Pediatric Surgery Training and Research Hospital between 2012 and 2021. The approval was obtained from the ethics committee of the Dr. Behçet Uz Child Disease and Pediatric Surgery Training and Research Hospital on 19/11/2020 with protocol number 2020/16-08. Informed consent was secured from the parents of all patients.

Data collection

Patient information, including age, gender, weight, height, body surface area (BSA), blood type, American Society of Anesthesiologists (ASA) score, RACHS (Risk adjustment for congenital heart surgery) score, genetic anomalies, accompanying cardiac defects, history of non-cardiac surgery, history of cardiopulmonary resuscitation (CPR), preoperative investigations (echocardiography findings, trans-fontanel ultrasonography findings, laboratory results), and preoperative clinical findings (heart failure, inotropic requirements, mechanical ventilation requirements, renal insufficiency), was extracted from medical records and hospital automation system records.

Intraoperative data were systematically collected, encompassing the type of operation, surgical technique, additional cardiac surgeries performed, intraoperative complications, anesthesia duration, intraoperative inotropic requirements, and postoperative lactate levels.

Postoperative data recorded included vasodilator infusion, complications, duration of mechanical ventilation, intensive care, hospital stay, VVR score, need for additional surgeries and anesthesia, and mortality.

Anesthesia management

Upon admission to the operating room, patients received intravenous midazolam at a dose of 0.05 mg/kg. Subsequently, warming procedures were initiated, and monitoring was conducted, encompassing electrocardiogram (ECG), non-invasive blood pressure, peripheral oxygen saturation, Bispectral Index (Medtronic, Minne-apolis, MN, USA), and Near-infrared Spectroscopy (INVOS; Medtronic, Minneapolis, Minnesota, USA).

Anesthesia induction involved midazolam (0.1 mg/kg), ketamine (2 mg/kg), fentanyl (1 mcg/kg), and low-dose sevoflurane inhalation, followed by intravenous rocuronium (1 mg/kg) administration and endotracheal intubation. Tidal volume was maintained at 8-10 ml/kg with end-tidal carbon dioxide (etCO2) monitoring. Positive end-expiratory pressure (PEEP) was applied as 5cmH2O in all patients. If the airway pressure was not high after intubation, the volume-controlled mode was preferred; if it was high, the pressure-controlled mode was preferred. Respiratory rate was adjusted according to the patient's age and metabolic status to maintain arterial carbon dioxide (PaCO2) levels of 35-45 mmHg. The lowest effective FiO2 level was used to keep oxygen saturation within the range of 92-98.

The left arm was not used because the subclavian artery was usually clamped or tied, and arterial monitoring was performed from the right radial artery. Acid-base balance was regularly monitored through blood gas analysis and ventilator settings were adjusted according to these values when necessary. Prostaglandin E1 infusion, which was started to allow postductal flow in infants, was continued. Central venous catheterization was executed via the left internal jugular vein, initiating intravenous fluid resuscitation at a rate of 10 ml/kg. The fluid infusion was adjusted based on central venous pressure monitoring.

Proximal and distal blood pressure differences were monitored during aortic clamping. When the aorta is cross-clamped, proximal aortic pressure increases while distal aortic pressure decreases. No attempt was made to reduce this pressure to normal values using a vasodilator, as this would lead to inadequate perfusion of the spinal cord. However, uncontrolled hypertension was not allowed. Since vasodilation and temporary hypotension may occur when the aortic clamp is removed, inotropic support was available to prevent

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hemodynamic fluctuation. Inotrope infusion selection and dose adjustment were made according to the patient's clinical condition and weight.

To prevent acidosis due to increased lactic acid and PaCO2, especially before removing the aortic clamp, mild hyperventilation was performed by increasing the respiratory rate. Post-repair, clamps were removed, hemostasis was achieved. Pressurized ventilation was applied to eliminate atelectasis that occurred before the thorax was closed. Closure procedures were applied with attention to lung expansion, and postoperative pain was managed with pethidine and paracetamol. If the patient's hemodynamics were stable, blood gases were normal, and temperature was appropriate, he was extubated under operating room conditions. Patients were closely monitored in the intensive care unit for the initial 24 hours post-surgery.

Statistical analysis

Statistical analyses were conducted using SPSS 27.0 (IBM SPSS Corp.; Armonk, NY, USA). Descriptive statistics were presented in tabular form, representing continuous variables as mean ± standard deviation or median, minimum, and maximum, based on distribution. Categorical variables were summarized as numbers and percentages. The normal distribution characteristics of variables were analyzed with Kolmogorov-Smirnov and Shapiro-Wilk tests.

RESULTS

The study encompassed a cohort of 97 patients spanning from newborns to adolescents, with 61 males and 36 females, revealing a 19.5% incidence of genetic anomalies. Isolated aortic coarctation was identified in 26 patients, while additional cardiac anomalies were observed in others (Table 1). Notably, balloon angioplasty had been previously performed in 14.4% of patients, and 4.1% underwent non-cardiac surgery during the preoperative period. The preoperative assessment indicated an ASA V score in 3.1% of patients. During this period, 27 patients required inotropic support for heart failure, 22 patients needed mechanical ventilation, four experienced kidney failure due to perfusion impairment, and six presented with cerebral pathology (Table 1).

The predominant surgical approach was left thoracotomy, and various surgical techniques were applied to patients, as detailed in Table 3 and Figure 1(a). Difficult intubation emerged as the most common anesthesia complication in patients with genetic anomalies. Intraoperatively, 4.1% of patients required vasodilators, and 13.4% had a triple inotropic requirement (Table 2).

Table 1. Demographic and Preoperative data

Demographic data		**Preoperative data**	
	n (%)		n (%)
Age			
Newborn	41 (42.3 %)	RACHS score, mean	8.15 (6-16)
Infant	37 (38.1 %)	ASA score	
Toddler	8 (8.2 %)	III	72 (74.2 %)
Preschool	2 (2.1 %)	IV	22 (22.7 %)
School	41 (42.3 %)	V	3 (3.1 %)
Adolescent	37 (38.1 %)	Preoperative non-cardiac surgery	4 (4.1 %)
		Tracheoesophageal fistula	2 (2.1 %)
Gender		Hirschsprung	1 (1 %)
Male	61 (62.9 %)	İntestinal perforation	1 (1 %)
Female	36 (37.1 %)	History of Preoperative CPR	2 (2.1 %)
Weight, mean (min-max)	3.8 (1.8-63)	History of preoperative COVID-19	1 (1 %)
Height, mean (min-max)	52 (43-170)	Arrhythmia	
BSA, mean (min-max)	0.34 (0.15-1.72)	Long QT syndrome	1 (1 %)
Genetic abnormality	19 (19.5 %)	Pulmonary hypertension	22 (22.6 %)
Hypoplastic aortic arch	47 (48.4 %)	Valve anomaly	
Other cardiac defects		Mitral regurgitation	2 (2.1 %)
VSD	28 (28.8 %)	Tricuspid regurgitation	10 (10.3 %)
ASD	19 (19.5 %)	Aortic stenosis	3 (3.1 %)
Pulmonary stenosis	6 (6.2 %)	Left ventricular concentric hypertrophy	11 (11.3 %)
AVSD	3 (3.1 %)	Pericardial effusion	2 (2.1 %)
Heterotaxy syndrome	3 (3.1 %)	Preoperative mechanical ventilation	22 (22.6 %)
DORV	2 (2.1 %)	Preoperative heart failure	31 (31.9 %)
Shone complex	2(2.1%)	Preoperative need for medication	
Tetralogy of Fallot	1 (1%)	Positive Inotropes	27 (27.8 %)
TAPVC	1 (1 %)	Milrinone	7 (7.2 %)
Bicuspid aortic valve	22 (22.6 %)	Prostaglandin E1	14 (14.4 %)
Coarctation type		Preoperative renal failure	4 (4.1 %)
Discrete	76 (78.4 %)	Preoperative trans fontanel ultrasonogra-phy	
Tubular	21 (21.6 %)	Normal	62 (91.1 %)
Localization of coarctation		Germinal matrix hemorrhage	5 (7.4 %)
Juxtaductal	89 (91.7 %)	Hydrocephaly	1 (1.5 %)
Preductal	8 (8.3 %)		
Preoperative peak gradient, mean (min-max)	45 (30-100)		
History of balloon angioplasty intervention	14 (14.4 %)		

* BSA: body surface area , #VSD: ventricular septal defect , † ASD: atrial septal defect , ‡ AVSD: atrioventricular septal defect , § DORV: the double outlet of the right ventricle, ** TAPVC: total anomalous pulmonary venous connection. * RACHS: Risk adjustment for congenital heart surgery, #ASA: American Society of Anesthesiologists, † CPR: cardiopulmonary resuscitation

Postoperatively, monitoring distribution included 59 patients in the cardiac surgery intensive care unit, 36 in the neonatal intensive care unit, and 2 in the pediatric intensive care unit. Early extubation within the first 24 hours was achieved in 57.7% of patients (Figure 1 b).

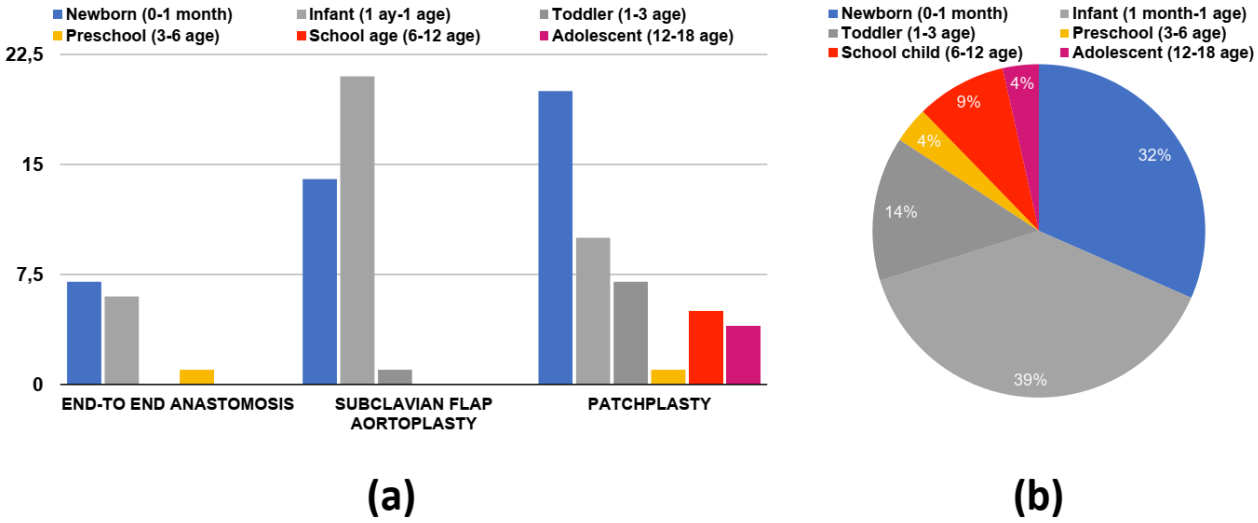

Figure 1. (a) Distribution of operation types according to pediatric age, (b) Distribution of extubations performed in the first 24 hours postoperatively

The prevalent cardiac-related complication in the postoperative period was identified as low cardiac output syndrome (LCOS). Five patients required non-cardiac surgical interventions during this period, necessitating general anesthesia. The overall mortality rate stood at 9.3%, with an early mortality rate of 5.2% attributed to cardiac reasons and the remaining 4.1% linked to prolonged hospitalization leading to sepsis in the neonatal and pediatric intensive care units (Table 2).

Table 2. Intraoperative and Postoperative data

Intraoperative data		**Postoperative data**		
	n (%)		**n (%)**	**Mean (min-max)**
Operation type		Vasodilators infusion	7 (7.2 %)	
Thoracotomy	95(97.9 %)	VIS score		13.7 (0-143,7)
Sternotomy	2 (2.1 %)	VVR score		21.0 (0-186.5)
Surgical technique		Extubation time		
End-to-end anastomosis	15(15.4 %)	0-24 hours	56 (57.7 %)	
Subclavian flap aortoplasty	35(36.1 %)	25-48 hours	9 (9.2 %)	
Patchplasty	47(48.4 %)	49-72 hours	4 (4.1 %)	
Simultaneous cardiac surgery		73-96 hours	8 (8.2 %)	
Pulmonary artery banding	15(15.4 %)	> 97 hours	20 (20.6	
Modified Blalock-Taussig shunt	1 (1 %)	ICU stay (days)		18.9 (1-111)
Thromboendarterectomy	1 (1 %)	Neonatal ICU		38.2 (1-111)
Complications		Cardiovascular surgery ICU		5.8 (1-18)
Difficult intubation	4 (4.1 %)	Pediatric ICU		57.5 (20-95)
Bradycardia	2 (2.1 %)	Postoperative complications		
Intraoperative need for vasodilators	4 (4.1 %)	Re-intubation	3 (3.1 %)	
Intraoperative need for inotropes		Bradyarrhythmia	3 (3.1 %)	
One	35(36.1 %)	LCOS	5 (5.2 %)	
Two	25(25.7 %)	Seizure	2 (2.1 %)	
Three	13(13.4 %)	Sepsis	4 (4.1 %)	
	Mean (min-max)	Postoperative need for surgery or anesthesia		
Lactate value at the end of the operation (mmol/l)	2 (0.8-6.4)	Re-coarctation	4 (4.1 %)	
Anesthesia time (minute)	217.8 (80-400)	VSD and pulmonary artery debanding	5 (5.2 %)	
		Pulmonary venous return anomaly	1 (1 %)	
		Supravalvular aort stenosis	1 (1 %)	
		Vena cava superior candida vegetation	1 (1 %)	
		Subdural hematoma draining	1 (1 %)	
		Bronchoscopy	2 (2.1 %)	
		Tracheostomy	2 (2.1 %)	
		Mortality	9 (9.3 %)	
		Early (LCOS)	5 (5.2 %)	
		Late (Sepsis)	4 (4.1 %)	

* VIS: vasoactive inotropic score, #VVR: Vasoactive-Ventilation-Renal, † ICU: intensive care unit ‡ LCOS: low cardiac output syndrome, § VSD: ventricular septal defect

DISCUSSION

This study delves into the surgical management of pediatric patients undergoing aortic coarctation surgery, with an emphasis on anatomical classification and clinical implications. Anatomically, aortic coarctation is predominantly classified based on the location of the obstructed area in the ductus arteriosus, with juxta ductal stenosis being the most common, alongside the preductal and postductal stenosis (5).

Clinical manifestations of aortic coarctation, often asymptomatic in the neonatal period before ductus arteriosus closure, can progress to respiratory failure and various symptoms, including left ventricular hypertrophy, cardiomegaly, heart failure, and pulmonary edema if diagnosed late (5). Our study identified

heart failure in 31.9% of patients, with 27.8% requiring inotropic infusion, aligning with literature reporting preoperative heart failure rates ranging from 11.2% to 32% (11-12).

Preoperative renal failure, observed in 12% of aortic coarctation cases in previous studies, adds to the complexity (11). Mechanical ventilation, especially in critically ill pediatric patients, may extend hospital stays after congenital heart surgery. Additionally, aortic arch hypoplasia is prevalent in 31% of infants, often accompanied by other intracardiac pathologies (13).

Pediatric anesthesia management for aortic coarctation necessitates meticulous monitoring, slow induction, and successful intubation. Airway abnormalities and difficult intubation risks are higher, particularly in patients with genetic syndromes and congenital heart disease, underscoring the importance of preoperative identification to prevent complications (14).

Blood pressure must be carefully managed during aortic coarctation surgery. Hemodynamic fluctuations can adversely affect organ perfusion. Therefore, invasive blood pressure monitoring will help evaluate the effectiveness and safety of the applied treatment. Inotropic support may be required to balance hemodynamic fluctuations that may occur during anesthesia induction and maintenance. In addition, sudden hemodynamic changes may occur during the clamping and unclamping of the aorta in the intraoperative period and the use of inotropes may be required (15,16). After the cross-clamp is removed, infants generally do not have hypertension, but older children experience paradoxical blood pressure elevations that need to be controlled aggressively. Uncontrolled hypertension may pose a risk of cerebral hemorrhage. Adequate pain control and early extubation may help prevent postoperative hypertension (16).

Each patient should be evaluated individually and ventilator parameters should be adjusted according to the specific needs of the patient. Appropriate tidal volume adjustment under general anesthesia helps prevent over ventilation and lung damage. The respiratory rate should be adjusted according to the patient's age and metabolic status to maintain target ($PaCO_2$) levels. Application of PEEP supports alveolar stability and reduces the risk of atelectasis. However, excessive PEEP application should be avoided because this may negatively affect cardiac output by reducing venous return. Since prolonged application of high FiO_2 levels can lead to oxygen toxicity, it is preferable to keep them as low as possible. Pressure-controlled ventilation

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modes may be preferred to avoid excessive airway pressures. This helps protect lung tissue and reduces the risk of barotrauma. The effect of positive pressure ventilation on hemodynamic parameters should be considered. Adjustments should be made to take into account the potential effects of ventilation settings on cardiac output and blood pressure, especially during aortic clamping. Atelectasis may occur due to long surgical procedures and inadequate ventilation. Pulmonary edema may develop due to fluid accumulation in the lungs as a result of deterioration of fluid balance and heart failure.

Acid-base balance should be monitored regularly by blood gas analysis and ventilator settings should be adjusted according to these values when necessary. In particular, PaCO2 and pH levels are important in evaluating the effectiveness of ventilation strategies. Ventilation and perfusion disorders can lead to acidosis or alkalosis. In particular, changes in calcium and potassium levels can affect cardiac and neuromuscular functions.

Postoperative complications encompass a spectrum, including persistent hypertension, low cardiac output syndrome (LCOS), chylothorax, recoarctation, renal failure, necrotizing enterocolitis (NEC), neurological complications, diaphragm paralysis, bronchial compression, and left recurrent laryngeal nerve injury (5,8,10,13). Our study identified a postoperative complication rate of 17.6%, including sepsis and reintubation, with a direct complication rate of 8.3%.

Infants operated for aortic coarctation face increased mortality risks associated with prematurity, low birth weight, genetic anomalies, mechanical ventilation, renal failure, sepsis, and necrotizing enterocolitis (6). Complex cardiac lesions further elevate hospital stay and mortality rates (11). Despite including patients with severe heart failure, our study had no intraoperative mortality, with an early mortality rate within the first 30 days at 5.1%.

In Turkey, where approximately one-third of congenital heart diseases are critical and require early intervention, risk factors for prolonged postoperative hospital stay in pediatric patients undergoing isolated aortic coarctation surgery include prematurity, genetic abnormalities, congenital anomalies, non-cardiac surgeries, and a Vasoactive-Ventilation-Renal (VVR) score exceeding 25 for 12 hours postoperatively (2,6,17).

The VVR score emerges as a valuable predictor for outcomes in pediatric cardiac surgery, aiding in anticipating prolonged intensive care and hospital stay, ventilation duration, and mortality (18,19). Maller newborns and those receiving higher opioid amounts pose risks for delayed extubation, necessitating careful consideration in pediatric patients with aortic coarctation (20). In pediatric patients with extubation in the operating room after aortic coarctation, it has been noted that postoperative intensive care stay does not decrease, and there is a longer need for vasodilators due to high blood pressure (21). Repair of aortic coarctation surgery under cardiopulmonary bypass (CPB) in conjunction with other heart malformations highlights prolonged operation duration as an independent risk factor for perioperative brain injury in children under two years old (22).

CONCLUSION

In summary, this study contributes essential insights into the complexities of aortic coarctation surgery in the pediatric population, enhancing our understanding of the clinical landscape and offering valuable guidance for treatment strategies and outcomes improvement. The findings underscore the multifaceted nature of aortic coarctation, emphasizing the significance of risk factor identification for tailored postoperative care. The VVR score emerges as a robust predictor, facilitating outcome anticipation in pediatric cardiac surgery. Addressing challenges related to delayed extubation and post-extubation vasodilator needs is crucial for optimizing patient management. Anesthesia management plays a central role in preventing complications during and after surgery. Continuous monitoring of hemodynamic parameters, appropriate adjustment of ventilator parameters, appropriate fluid and drug management, pain control and keeping the patient's physiological condition stable reduce the risk of complications. Optimal management of these factors is essential in increasing surgical success and ensuring patient safety. In addition, it is important for the anesthesia team to work in coordination with the surgical team for early detection and intervention of possible problems.

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None

Authorship contributions

All authors contributed equally to the writing of this paper.

Data availibity statement

Data availibity statement here

Declaration of competing interest

All the authors declare no conflict of interest.

Ethics

The approval was obtained from the ethics committee of the Dr. Behçet Uz Child Disease and Pediatric Surgery Training and Research Hospital on 19/11/2020 with protocol number 2020/16-08.

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REFERENCES

1. Wu W, He J, Shao X. Incidence and mortality trend of congenital heart disease at the global, regional, and national level, 1990-2017. Medicine 2020; 99:23.

2. Dilli D, Varan B, Tasoglu, Oguz SS, Caylan N, Tezel B. Neonatal Critical Congenital Heart Diseases Screening Guide. Turkish Ministry of Health, General Directorate of Public Health, Ankara 2021, page 1-13.

3. Mai CT, Isenburg JL, Canfield MA, Meyer RE, Correa A, Alverson CJ et al. National population-based estimates for major birth defect, 2010-2014. Birth Defects Research 2019; 111(18):1420-35.

4. Stallings EB, Isenburg JL, Aggarwal D, Lupo PJ, Oster ME, Shephard H et al. Prevalence of critical congenital heart defects and selected co-occurring congenital anomalies, 2014-2018: A U.S. population-based study. Birth Defects Research 2022; 114(2):45-56.

5. Raza S, Aggarwal S, Jenkins P, Kharabish A, Anwer S, Cullington D et al. Coarctation of the aorta: Diagnosis and Management. Diagnostics 2023; 13:2189.

6. Schoenberg L, Prodhan P, Spray B, Akmyradov C, Zakaria D. Risk factors for increased post-operative length of stay in children with coarctation of aorta. Pediatric Cardiology 2021;42(7):1567-74.

7. Wu Y, Li J, Wu C, Zhu J, He L, Feng C et al. Diagnosis and surgical repair for coarctation of the aorta with intracardiac defects: A single center experience based on 93 infants. Frontiers in Pediatrics 2020; 8:49.

8. Padalino MA, Bagatin C, Bordin G, Tua L, Francescato A, Pradegan N et al. Surgical repair of aortic coarctation in pediatric age: A single center two decades experience. Journal of Cardiac Surgery 2019; 1-10.

9. Fox EB, Latham GJ, Ross FJ, Joffe D. Perioperative and anesthetic management of coarctation of the aorta. Seminars in Cardiothoracic and Vascular Anesthesia 2019; 1-13.

10. Minotti C, Scioni M, Castaldi B, Guariento A, Biffanti R, Di Salvo G et al. Effectiveness of repair of aortic coarctation in neonates: A long-term experience. Pediatric Cardiology 2022; 43:17-26.

11. Heremans L, Henkens A, Beco G, Carbonez K, Moniotte S, Rubay JE et al. Results of coarctation repair by thoracotomy in pediatric patients: A single institution experience. World Journal of Pediatric and Congenital Heart Surgery 2021; 12(4):492-99.

12. McFarland CA, Truong DT, Pinto NM, Minich LL, Burch PT, Eckhauser AW. Implications of left ventricular dysfunction at presentation for infants with coarctation of the aorta. Pediatric Cardiology 2021; 42:72-7.

13. Brown JW, Rodefeld MD, Ruzmetov M. Transverse Aortic Arch Obstruction: When to Go from the Front. Semin Thorac Cardiovasc Surg Pediatr Card Surg Ann 2009; 12:66-9.

14. Foz C, Peyton J, Staffa SJ, Kovatsis P, Park, R, DiNardo JA et al. Airway abnormalities in patients with congenital heart disease: Incidence and associated factors. Journal of Cardiothoracic and Vascular Anesthesia 2021;35(1):139-44.

15. Mageed NA, Abd El Baser II, Taman HI. Anesthetic management of surgical repair of coarctation of aorta in neonates and infants. Anesthesia & Surgery 2020;1(5):1-5.

16. Hensley FA, Martin DE, Gravlee GP. A practical approach to cardiac anesthesia. In: Çiğdem Evren Denker editor. Chapter 14:Anesthetic management for patients with congenital heart disease: The pediatric population. Ankara: Güneş Tıp Kitabevleri, 2015: 389-451.

17. Kaipa S, Yabrodi M, Benneyworth BD, Ebenroth ES, Mastropietro CW. Analysis of factors associated with prolonged postoperative course after surgical repair of aortic coarctation. Cardiology in Young 2021; 31(2):191-98.

18. Alam S, Akunuri S, Jain A, Mazahir R, Hegde R. Vasoactive-ventilation-renal score in predicting outcome postcardiac surgery in children. International Journal of Critical Illness & Injury Science 2018; 8(3):143-48.

19. Abnay P, Sharma R, Bhan A, Raina M, Vadhera A, Akole R. Vasoactive-ventilation-renal score and outcomes in infants and children after cardiac surgery. Frontiers in Pediatrics 2023; 11:1086626. doi: 10.3389/fped.2023.1086626

20. Gil D, Aljiffry A, Dryer R, Rao N, Figueroa J, Downey L et al. Extubation delays and the associated prostaglandin and opiate dose following coarctation of the aorta repair. Progress in Pediatric Cardiology 2022; 67:101574.

21. Mohammed AK, Hassanien HM, Sobhy R. Coarctation of the aorta: to extubate early or to extubate late. Pediatric Anesthesia and Critical Care Journal 2016; 4(1):35-42.

22. Cheng M, Xu HZ, Zhang KJ, Peng XL, Pan ZX, Hu Y. Risk factors of perioperative brain injury in children under two years undergoing coarctation repair. Pediatric Neurology 2023; 141:109-17.