



# Our Anesthesia Experience in Catheterization and Angiography Procedures in the Cardiac Catheterization Laboratory in Pediatric Patients with Congenital Heart Disease: Single Center 360 Cases

## Konjenital Kalp Hastalığı Olan Pediyatrik Olgularda Kardiyak Kateterizasyon Laboratuvarında Kateterizasyon ve Anjiyografi İşlemlerinde Anestezi Deneyimlerimiz: Tek Merkez 360 Olgu

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### Abstract

**Objective:** Pediatric cardiac catheterization and angiography are two of the methods used in the diagnosis and treatment of patients with congenital heart disease. Anesthesia approaches in these patients are special and come with many anesthetic challenges. In this framework, the objective of this study is to evaluate our anesthesia experience and complications in catheterization procedures performed in the pediatric angiography laboratory.

**Method:** This study was conducted with patients who underwent diagnostic or interventional catheterization in the pediatric angiography laboratory, between August 1<sup>st</sup>, 2020, and December 31<sup>st</sup>, 2021. Demographic and clinical characteristics of these patients, including their cardiac diagnosis, gender, weight, procedural characteristics, and anesthesia management principles employed during the procedure and complications, were evaluated.

**Results:** A total of 390 procedures were applied to 360 patients during the period covered by the study. The median age and weight of these patients were three months [interquartile range (IQR) 20 days-7 years] and 7 kg (IQR 3.4-24), respectively. Of these patients, 51% were male, and 49% were female. Of the 390 procedures, 134 were performed diagnostically, and 256 were performed invasively. The median duration of the procedure was 35 minutes (IQR 25-60). The catheterization procedure was performed under general anesthesia in 33% of the cases. A total of 52 (13.3%) complications were observed during the procedures. During

### Öz

**Amaç:** Pediyatrik kardiyak kateterizasyon ve anjiyografi konjenital kalp hastalıklı olgularda tanı ve tedavi amacıyla kullanılan yöntemlerden ikisidir. Bu olgularda anestezi yönetimi özeldir ve pek çok anestezi zorluklarıyla birlikte. Bu çalışmada, konjenital kalp hastalığı tanısı almış pediyatrik olgularda kateterizasyon işlemlerinde anestezi yönetim deneyimlerimizin ve komplikasyonların değerlendirilmesi amaçlandı.

**Yöntem:** Çalışma 1 Ağustos 2020-31 Aralık 2021 tarihleri arasında pediyatrik anjiyografi laboratuvarımızda tanısız veya girişimsel amaçlı kateterizasyon işlemi yapılan olgular üzerinde gerçekleştirildi. Olguların kardiyak tanısı, cinsiyet, ağırlık, işlem özellikleri, işlem sırasındaki anestezi yönetim ilkeleri ve gerçekleşen komplikasyonları incelendi.

**Bulgular:** Çalışma döneminde 360 olguya 390 işlem uygulandı. Olguların medyan yaşı 3 ay [çeyrekler arası aralık (ÇAA) 20 gün -7 yıl] ve medyan ağırlığı 7 kg (ÇAA 3.4-24) idi. Olguların %51'i erkek ve %49'u kızdı. Üç yüz doksan prosedürün 134'ü tanısız olarak ve 256'sı invaziv olarak gerçekleştirildi. Medyan işlem süresi 35 dakika (ÇAA 25-60) idi. Kateter işlemleri olguların %33'ünde genel anestezi altında gerçekleştirildi. İşlemler sırasında toplam 52 (%13,3) komplikasyon gözlemlendi. Anestezi yönetimi sırasında 17 olguda hipotansiyon, 10 olguda desatürasyon, 7 olguda ritim bozukluğu gelişti. İşlem sırasında iki hastada ekstrakorporeal membran oksijenasyonu desteğine ihtiyaç duyuldu. Dört hasta acilen ameliyat edildi. İşlem nedeniyle hiçbir hasta kaybedilmedi.



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**Cite this article as:** Özcanoğlu HD, Gümüş Özcan F. Our Anesthesia Experience in Catheterization and Angiography Procedures in the Cardiac Catheterization Laboratory in Pediatric Patients with Congenital Heart Disease: Single Center 360 Cases. Bagcilar Med Bull 2022;7(2):150-157

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Bagcilar Medical Bulletin published by Galenos Publishing House.

## Abstract

the anesthesia management, hypotension was observed in 17 patients, desaturation in 10 patients, and rhythm disturbances in 7 patients. Two patients needed extracorporeal membrane oxygenation support during the procedure. Four patients had to be operated on urgently. No patient was lost due to the procedure.

**Conclusion:** Anesthesia management is characteristic during the catheterization procedure in pediatric cases with congenital heart disease. A case-specific anesthesia approach should be preferred, taking into account factors such as the type of cardiac pathology, hemodynamic characteristics, and type of procedure.

**Keywords:** Anesthesia, cardiac catheterization, child, complication

## Öz

**Sonuç:** Konjenital kalp hastalıklı pediyatrik olgularda kateterizasyon işlemleri anestezi yönetimi özellik gösterir. Kardiyak patolojinin türü, hemodinamik karakteristikler, prosedür şekli gibi faktörler göz önünde bulundurularak olguya özel anestezi yaklaşımı tercih edilmelidir.

**Anahtar kelimeler:** Anestezi, çocuk, kalp kateterizasyonu, komplikasyon

## Introduction

Congenital heart diseases refer to a group of heterogeneous diseases featuring various pathologies and subgroups and are among the primary causes of mortality and morbidity in pediatric cases. Timely and accurate diagnosis and appropriate treatment approaches are critical in order to increase the chance of survival in these cases (1,2).

Electrocardiography (ECG) and echocardiography (ECHO) are the most frequently used diagnostic methods in the evaluation of cardiac diseases in children. In cases where these methods do not produce satisfactory results, cardiac catheterization and angiography may be performed for diagnostic or interventional purposes (3). However, given that the heart's anatomy may be evaluated with high sensitivity and specificity also by other methods such as computed tomography (CT) and magnetic resonance imaging in pediatric cases, catheterization procedures are performed more frequently for interventional purposes than for diagnostic purposes. Interventional procedures include many different techniques such as the closure of defects, electrophysiological studies and ablation, balloon atrial septostomy, percutaneous pulmonary valve replacement, balloon valvuloplasty (aortic or pulmonary), and stent placement in the patent ductus arteriosus (3,4).

The goals of anesthetic management during pediatric cardiac catheterization include to provide adequate sedation, analgesia, immobility, and hemodynamic stability. Cardiac catheterization in children with congenital heart disease can be performed under general anesthesia or through the administration of sedoanalgesia with oxygen support. Many factors, such as the characteristics of pediatric patients and the variety of procedures to be performed, affect anesthesia management. Furthermore, the choice of various anesthetic agents according to the

nature of the procedure and the type of primary cardiac pathology creates additional difficulties (5).

The objective of this study is to evaluate our experience in anesthesia management and complications in catheterization procedures performed in the pediatric angiography laboratory context of pediatric patients diagnosed with congenital heart disease.

## Materials and Methods

### Population and Sample

The population of this retrospective study consisted of patients with congenital heart disease younger than 18 years of age who underwent cardiac catheterization and angiography in the pediatric angiography laboratory between August 1<sup>st</sup>, 2020 and December 31<sup>st</sup>, 2021. Prematurely born patients, patients older than eighteen years old, those who underwent angiography due to electrophysiological studies, those whose records could not be accessed, and those who were initially operated under extracorporeal membrane oxygenation (ECMO) were excluded from the study. The study protocol was approved by the Local Ethics Committee and carried out in accordance with the principles outlined in the Declaration of Helsinki (University of Health Sciences Turkey, Başakşehir Çam and Sakura City Hospital 2022.03.84).

The decision for cardiac catheterization and angiography was taken upon the evaluation of the results of detailed physical examination and cardiac examinations (ECG, teloradiography, ECHO) of each hospitalized patient by the pediatric cardiologist. All patients were evaluated preoperatively by a pediatric cardiac anesthetist. Patients' legal guardians were informed in detail about the advantages and disadvantages of the procedure and the complications that might be encountered. One unit

of erythrocyte suspension was prepared for use in cases deemed necessary.

### **Anesthetic Approach and Procedural Characteristics**

All procedures were carried out in the pediatric angiography laboratory, under sterile conditions, using the Philips Biplane Azurion 7 B12/12 (Philips Medical Systems International B.V., Best, Netherlands) image-guided therapy system. The procedure was performed with appropriate positioning under sterile conditions and general anesthesia (laryngeal mask or intubation) or sedoanalgesia and with sheaths and catheters of appropriate size for the planned procedure. The percutaneous technique was used for the intervention. Right heart catheterization was performed via the femoral vein, and left heart catheterization was performed via the femoral artery. Sometimes other axillary carotids, umbilical artery, or vein routes were preferred according to the technique used to perform the procedure. In all cases except the cases under two months old, punctures were performed with the support of ultrasonography.

All patients were monitored with ECG, peripheral oxygen saturation, arterial blood pressure, temperature, and urine analysis during the procedure. In addition, near-infrared spectroscopy monitoring of regional cerebral oxygenation was performed in all newborn cases. Advanced life support devices (ECMO), and necessary vasoactive inotropic medications, infusion pumps were on standby in the operating room. All patients were premedicated using diphenhydramine and dexamethasone after establishing vascular access in order to prevent possible allergic reactions due to the contrast agent. Oxygen was provided via mask as 2-4 liters/minute. All patients were actively heated to prevent hypothermia. General anesthesia was administered to patients who were to undergo interventional procedures such as pulmonary valve replacement, patent ductus arteriosus (PDA) stent, atrial septal defect (ASD), and ventricular septal defect (VSD) closure. General anesthesia was induced with hypnotic agents combination, usually composed of 0.1 mg/kg midazolam, 1-2 mg/kg ketamine, 0.5-3 mg/kg propofol and neuromuscular blocking agent esmeron 0.6 mg/kg. Sevoflurane 1-2% was used for anesthesia maintenance. Sedoanalgesia was preferred in diagnostic cases where general anesthesia was not required. Sedoanalgesia was induced either by bolus injection or infusion of 0.1 mg/kg midazolam, 1-2 mg/kg ketamine and 0.5-3 mg/kg propofol or 0.05 mcg/kg/min remifentanyl combination. Targeted sedation level for the procedures was considered

according to the Ramsay sedation score (RSS) 4 (6); 1-Patient is anxious, agitated, or restless. 2. Patient is cooperative, oriented, and calm. 3. Patient is responsive to verbal command only. 4. Patient exhibiting brisk response to light glabellar tap or to an auditory stimulus. 5. Patient exhibiting a sluggish response to light glabellar tap or to an auditory stimulus. 6. No response to any of these stimulation). Airway security was provided by orotracheal intubation or laryngeal mask if targeted sedation level was not satisfactory.

### **Definitions**

A data form was created and then filled out for each patient using their data available in the hospital data system, including age, gender, weight, diagnosis, type of procedure performed, American Society of Anesthesiology risk score (ASA), Catheterization Risks in Pediatrics (CRISP) score (7), procedural data, anesthetic approaches, agents used, and anesthetic complications observed during the procedure.

Life-threatening complications such as death, permanent rhythm problems, bleeding requiring blood transfusion, desaturation or respiratory arrest, presence of hypotension requiring the use of inotropes, cardiac perforation, stent embolization, complications requiring rushing into surgery were categorized as major complications, and complications requiring switching to ECMO support and non-life-threatening complications such as transient rhythm disturbance, hypotension not requiring the use of inotropes, laryngospasm, and allergic reactions were categorized as minor complications. Any death that occurred within the first 24 hours after the completion of cardiac catheterization and angiography was deemed procedurerelated death.

Desaturation was defined as having more than a 10% decrease compared to the baseline SpO<sub>2</sub> (peripheral capillary oxygen saturation) value, whereas hypotension was defined as having more than a 20% decrease compared to the baseline blood pressure. The arrhythmias were categorized as asystole, sinus bradycardia, conduction abnormalities (complete atrioventricular block), supraventricular arrhythmias (supraventricular tachycardia, atrial fibrillation, atrial flutter, or focal atrial tachycardia), and ventricular tachycardia, or ventricular fibrillation (8,9).

### **Statistical Analysis**

The distribution of the research data was classified in the computer environment, and descriptive values were

obtained using the SPSS (Statistical Package for the Social Sciences for Windows) software package. Results were expressed as median [(interquartile range (IQR)] and percentage-percentile values.

## Results

Cardiac catheterization and angiography were performed in 360 patients (45 emergent cases), of whom 184 were male and 176 were female, during the period covered by the study. The median age and weight of these patients were three months (IQR 20 days-7 years) and 7 kg (IQR 3.4-24), respectively. According to ASA scoring, 12% of the patients were in ASA II, 36% in ASA III, and 52% in the ASA IV category. Two percent of the patients had a history of allergy.

The most common diagnoses were pulmonary artery atresia (PAA) (n=78), tetralogy of Fallot (TOF) (n=44), PDA (n=36), and hypoplastic left heart syndrome (HLHS) (n=34). Detailed information about patient diagnoses is given in Table 1. Of the 390 procedures evaluated within the scope

**Table 1. Diagnoses of the patients who underwent cardiac catheterization**

	n	%
Tetralogy of fallot	44	12.2
Complex pathologies	18	5
Atrial septal defect	28	7.7
Patent ductus arteriosus	36	10
Ventricular septal defect	10	2.7
Double outlet right ventricle	21	5.8
Pulmonary atresia	78	21.6
VSD-PA	36	10
Tricuspid atresia-PA	4	1.1
IVS-PA	6	1.6
With complex pathologies	32	8.8
HLHS	34	9.4
TAPVR	8	2.2
Pulmonary stenosis	25	6.9
Tetralogy of fallot-absence of pulmonary valve	3	0.8
Coarctation of aorta	12	3.3
Interrupted aortic arch	8	2.2
Aortic stenosis	3	0.8
Shone-aortic stenosis	4	1.1
TGA or taussig bing anomaly	16	4.4
<b>Total</b>	<b>360</b>	<b>100</b>

VSD-PA: Ventricular septal defect pulmonary atresia, IVS-PA: Pulmonary atresia with intact ventricular septum, HLHS: Hypoplastic left heart syndrome, TGA: Transposition of great arteries, TAPVR: Total anomalous pulmonary venous return

of this study, 256 (65.6%) were interventional, and 134 (34.3%) were diagnostic procedures. The most common interventional procedures were PDA stent placement and PDA closure. Evaluation of the pulmonary artery and its branches due to TOF was the most common reason for performing the diagnostic cardiac catheterization procedures. The list of diagnostic and interventional procedures performed is given in detail in Table 2.

## Anesthesia Methods

Cardiac catheterization was performed under general anesthesia in 33% of cases (n=119). Orotracheal intubation and LMA were preferred for airway in 12% and 21% of cases, respectively. Sedoanalgesia was used in 67% of cases (n=241). The most common drug combination for sedoanalgesia was midazolam and remifentanyl. Anesthetic methods and agents are shown in Table 3.

Twenty-seven cases had a genetic syndrome. Six cases experienced difficult intubation even they were intubated without complication. Invasive arterial monitorization was performed in 32 cases (9%). In 51 cases (14%), the CRISP score category was >3.

**Table 2. List of the procedures performed on the cases**

Procedure	n	%
Diagnostic	134	34.3
Interventional	256	65.6
ASD closure	28	7.1
PDA closure + MAPCA closure	1	0.2
PDA closure	35	8.9
VSD closure	3	0.6
PDA stenting	66	16.9
Balloon atrial septostomy	16	4.1
Balloon atrial septoplasty and PDA stenting	8	2
Pulmonary balloon valvuloplasty	24	6.1
Aortic balloon valvuloplasty	3	0.7
Aortic arch stenting	1	0.2
Balloon coarctation angioplasty	10	2.5
Stenting of coarctation of the aorta	4	1
Pulmonary balloon angioplasty + PDA stenting	1	0.2
Percutaneous pulmonary valve implantation	9	2.3
RVOT stenting in infants	11	2.8
Sequestering artery/MAPCA closure	7	1.8
Other procedures	29	7.4
<b>TOTAL</b>	<b>390</b>	<b>100</b>

ASD: Atrial septal defect, RVOT: Right ventricular outflow tract, PDA: Patent ductus arteriosus, MAPCA: Major aortopulmonary collateral arteries, VSD: Ventricular septal defect

## Complications

A total of 45 (11.5%) complications were observed during the procedures. Of these complications, 29 (7.4%) were classified as major, and 23 (5.9%) were classified as minor complications. Two neonatal patients received ECMO support during the procedure. One of these patients was the patient whose PDA was closed during PDA stenting due to

**Table 3. Anesthesia management in catheterization procedures**

<b>Local anesthesia + sedation</b>	241 (67)
<b>General anesthesia</b>	119 (33)
Endotracheal intubation	43 (12)
Laryngeal mask airway	76 (21)
<b>Genetic syndrome</b>	27 (7)
<b>Difficult intubation</b>	6
<b>Sedo-analgesic medications</b>	
Midazolam-propofol	41 (17)
Midazolam-ketamine	52 (22)
Remifentanil-midazolam	107 (44)
Dexmedetomidine	18 (7)
Ketamine-propofol	23 (10)
<b>Invasive artery monitoring</b>	32 (9)
<b>CRISP score category &gt;3</b>	51 (14)
<b>Urgent procedure</b>	45 (13)
<b>Total fluid volume (mL)</b>	60 (40-90)
<b>Transfer to pediatric cardiac intensive care unite</b>	70 (19)

n (%) or median interquartile range

VSD-pulmonary atresia, and the other was the patient who was followed up with the diagnosis of HLHS and developed ventricular fibrillation and cardiac arrest during balloon atrial septostomy.

Four patients developed complications during the procedure, requiring them to be rushed into surgery. Two of these patients had hypoxic spells due to TOF, and the other two required an emergency shunt surgery due to PAA. During the anesthesia management, hypotension was observed in 17 patients, 9 of whom required the administration of inotropes, low saturation was observed in 10 patients, and rhythm disturbances were observed in 7 patients. No patient died during the procedure and within the first 24 hours after the procedure. The major and minor complications the patients developed during the procedure are summarized in Table 4.

## Discussion

In this study, we aimed to share our experiences and complications by evaluating our anesthesia management approaches in 360 pediatric patients with congenital heart disease where diagnostic and interventional cardiac catheterization procedures were performed. In this retrospective study, we observed that general anesthesia and sedoanalgesia approaches could be applied safely

**Table 4. Complications, treatments and clinical outcomes**

MAJOR	n	TREATMENT	OUTCOME
Stent embolization	8	The stent of 1 patient was snared and removed, then the procedure continued.	Discharged
		2 patients underwent emergency surgery.	Discharged
		The stents of 4 patients were fixed with a second stent or a balloon.	Discharged
		1 patient supported with ECMO	Discharged
Spell	2	Underwent emergency surgery.	Discharged
		Transferred to the ICU.	Discharged
Arrhythmia	2	1 patient received CPR.	Discharged
		1 patient supported with ECMO	25 <sup>th</sup> day exitus (HLHS)
Anemia due to excessive bleeding	2	ES transfused.	
Hypotension	9	Inotropic support was increased	
Desaturation	4	Endotracheal intubation and increased oxygen supply	
<b>MINOR</b>			
Hypotension	8		
Vascular complications	7	Heparin infusion was initiated.	
Desaturation	2	Corrected after stenting or balloon.	
Arrhythmia	5	Corrected by catheter manipulation.	
Allergy	1	Corrected with diphenhydramine and dexamethasone.	

CPR: Cardiopulmonary resuscitation, ECMO: Extracorporeal membrane oxygenator, HLHS: Hypoplastic left heart syndrome

in selected patients and procedures by using appropriate anesthetic agent combinations. It was determined that most cardiac catheterization and angiography procedures were performed for interventional purposes with acceptable complication rates. This study is one of the few studies conducted in Turkey, which has investigated the anesthesia management efficiency in the context of pediatric patients with congenital heart disease.

Several factors should be considered in the perioperative anesthetic management of the catheterization procedure in pediatric cases with congenital heart diseases. For this reason, patients' detailed history, cardiac pathology, genetic syndromes, allergy and bronchospasm history should be obtained. Also, cyanotic seizures should be questioned. Subsequently, anesthetic approach should be determined according to the physiological and anatomical characteristics of heart disease. In addition, it is necessary to have sufficient information about the pharmacodynamic and pharmacokinetic aspects of the medications used by the patients or to be used during the procedure (5).

Congenital heart diseases have increased risks during anesthesia. Myocardial ischemia and cardiac arrest can occur suddenly in patients with single ventricle physiology even after anesthesia induction and positive pressure ventilation. We have not experienced cardiac arrest after anesthesia induction and positive pressure ventilation.

Positive pressure ventilation under general anesthesia provides airway safety and control of PaCO<sub>2</sub>, but increased intrathoracic pressure may alter hemodynamic stability. Spontaneous ventilation mimics natural intrathoracic physiology and, consequently, may result in more stable hemodynamic data. However, oversedation can cause airway obstruction, hypoventilation and subsequent respiratory acidosis. These factors increase pulmonary vascular resistance and might alter shunt physiology and affect hemodynamic measurements. Although general anesthesia and sedation protocols were applied at different rates in the studies, there is a tendency toward sedoanalgesia. Tokel et al. (10) reported general anesthesia as low as 2% in their study. Similarly, in the studies of İyilikçi et al. (11), they applied sedoanalgesia in more than half of the cases. In comparison, in this study, the rate of general anesthesia was reported to be as high as 33%. Our study's high rate of general anesthesia, compared to other studies, is probably related to high intervention rates. The recent technological developments have allowed performing many diagnostic or interventional procedures on pediatric cases with a variety of heart diseases. In parallel, the percentage

of cardiac catheterization and angiography procedures performed due to interventional purposes has started to increase due to the developments in non-invasive imaging methods such as ECHO, CT, and magnetic resonance angiography. As a matter of fact, compared to the rates of interventional procedures reported by Tokel et al. (10) and Shim et al. (12), which are 30% and 50%, respectively, the rate of interventional procedures was found as 65.6% in this study.

Interventional procedures have significant advantages such as less invasiveness, shortened length of hospital stay, re-applicability, and provision of both palliation and cure (3,13). Among the procedures applied for therapeutic purposes in pediatric cases reported in the literature are balloon atrial septostomy, aortic coarctation balloon angioplasty, pulmonary and aortic valve valvuloplasty, stenting of the PDA, radiofrequency pulmonary valve perforation, right ventricular outflow tract velocity stent ASD closure, PDA closure and VSD closure (3,11-19). In comparison, in this study, interventional procedures were most commonly performed for stenting of the PDA. This finding can be attributed to the fact that the patients followed up in the cardiovascular surgery center, where this study was conducted, were predominantly those diagnosed with PAA or HLHS.

Different sedative and analgesic medications are preferred during catheterization. Ketamine, dexmedetomidine, propofol, midazolam, and fentanyl are the most commonly used agents. A case-based approach is recommended in the selection of medications. Senzaki et al. (20) have stated that dexmedetomidine is a better option in cardiac patients (especially infants) who have hypercyanotic seizures. Benzodiazepines may produce dose-related respiratory depression. This effect may be more pronounced in patients with congenital heart disease and when benzodiazepines are used in combination with opioids. Choice of medication should be made considering all these effects. Oklu et al. (21) compared propofol and ketamine infusion for cardiac catheterization. They reported no change with the use of ketamine, whereas a decrease in systemic vascular resistance resulted in increased right-to-left shunting with the use of propofol. Additionally, Akin et al. (22) stated that they could manage catheterization procedures with minimal side effects when they used ketamine and propofol in combination. Similar to the relevant studies available in the literature, the method of anesthesia management was decided based on a case-based approach in our study. Accordingly, midazolam-propofol, midazolam-

ketamine, remifentanil-midazolam, and dexmedetomidine and ketamine-propofol combinations were preferred considering the clinical and cardiac problems of the patient and the type of procedure to be performed.

Hypovolemia might be present at the initiation of the catheterization, particularly in small infants and children, secondary to dehydration after prolonged periods of preoperative fasting. Hypovolemia is particularly important in newborns and patients with cyanosis or shunt-dependent lesions. In our study, considering these factors, necessary fluid infusion was done and hypovolemia was tried to be prevented (9).

Complication rates in pediatric cardiac catheterization and angiography depend on patients' diagnosis and procedure itself. Demographic and clinical characteristics such as age, weight, clinical condition at the time of the intervention, the type of underlying disease, whether the catheter procedure is diagnostic or interventional, anesthesia management, and the skill and experience of the cardiologist are factors in complication risks (11-13). Complications range from minor complications to complications requiring emergency open-heart surgery, complications leading to persistent severe sequelae, or even death. The catheterization-related complication rates in pediatric patients reported in the literature range from 2% to 40% (15). In a study, it was stated that the most common complication in the general population was vascular problems and that the vascular problems were even more pronounced in the neonatal age group (16). Kaya et al. (17) reported the complication rate as 5.8% in their series of 120 cases, whereas Bergensen et al. (18) reported complication rates between 7% and 25% in their prospective multicenter study. In comparison, in this study, the overall complication rate was determined as 13.3%. No patient died during or within the first 24 hours after the procedure.

Complications due to sedation and anesthesia or unexpected complications can be seen in catheterization procedures. Lin et al. (19) reported hypotension, which was seen in 0.68% of their cases, as the most critical complication of anesthesia management in their series. There are also studies in which hypotension has been described as a low-risk, self-correcting condition with no permanent consequences (19). Along these lines, Tokel et al. (10) reported anesthesia-related complications, which were seen in 6% of the 2.662 catheterization procedures evaluated within the scope of their study, as the most critical complication. They attributed this result to the very low rates of general anesthesia in their cases. In the series of

1535 cases by İyilikçi et al. (11), the rate of anesthesia-related complications, which primarily consisted of laryngospasm (n=3), desaturation (n=18), transition to general anesthesia (n=5), and hypotension (n=19), was reported as 2.9% (n=45). In comparison, the primary anesthesia-related complications in this study were hypotension and desaturation, which were observed in 4.3% and 2.5% of the cases, respectively. Apart from this, there was no major complication related to anesthesia.

### Study Limitations

The study's primary limitation is that it was carried out as a retrospective and single-center study and with a limited number of patients. Another limitation is that different methods have been adopted in the anesthesia management of patients due to the complexity of cardiac pathologies.

### Conclusion

Anesthesia management is an essential part of the catheterization procedure in pediatric patients with congenital heart disease. General anesthesia and sedoanalgesia can be safely applied using an appropriate combination of meticulously titrated anesthetics. A case-specific anesthesia approach should be preferred, considering the type of cardiac pathology, hemodynamic characteristics, and type of procedure. Ensuring ideal anesthesia management led by the cardiac anesthesiologist and adopting a multidisciplinary approach under adequate monitoring will help to reduce pediatric cases' catheterization-related morbidity and mortality rates.

### Ethics

**Ethics Committee Approval:** The study protocol was approved by the Local Ethics Committee and carried out in accordance with the principles outlined in the Declaration of Helsinki (University of Health Sciences Turkey, Başakşehir Çam and Sakura City Hospital 2022.03.84).

**Informed Consent:** All patients were evaluated preoperatively by a pediatric cardiac anesthetist. Patients' legal guardians were informed in detail about the advantages and disadvantages of the procedure and the complications that might be encountered.

**Peer-review:** Internally and externally peer-reviewed.

### Authorship Contributions

Concept: H.D.Ö., F.G.Ö., Design: H.D.Ö., F.G.Ö., Data Collection or Processing: H.D.Ö., Analysis or Interpretation: H.D.Ö., F.G.Ö., Drafting Manuscript: H.D.Ö., F.G.Ö., Critical

Revision of Manuscript: F.G.Ö., Final Approval and Accountability: H.D.Ö., F.G.Ö.

**Conflict of Interest:** No conflict of interest was declared by the authors.

**Financial Disclosure:** The authors declared that this study received no financial support.

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