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FULL LENGTH ARTICLE

Cardiac Catheterisation Interventions in Neonates and Infants Less Than Three Months

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Abstract

Introduction: **Pediatric cardiac catheterization interventions become an established way of care for selected patients with congenital heart diseases. Cardiac catheterization for neonates and small infants can be challenging. The indications for diagnostic cardiac catheterization have decreased with the advent of advanced non-invasive imaging modalities.**

Patients and method: **Between June 2012 and July 2017 patients less than three months who had cardiac catheterization in two centers were reviewed**

Results: **During the study period, 174 patients underwent interventional cardiac catheterization,83.3% of them had CHD with two-ventricle circulation and 29 patients (16.7%) had single ventricle pathophysiology. Procedures include diagnostic cath, BAS, balloon pulmonary and aortic valvuloplasty, coarctation angioplasty, and stenting procedures. The vascular access depends upon the type of procedure. All except one had general anesthesia. ICU admission was required on 106 patients (62%). Patients were divided according to the type of cardiac lesion (single versus biventricular pathology) as well as according to the type of intervention (stenting and non-stenting procedures). Comparing these groups revealed that: stent procedures and procedures for patients with single ventricle pathologies were performed at an earlier age, with more contrast, fluoro and procedure time than for non-stent procedures and procedures for patients with biventricular pathologies. Complications include transient arrhythmias in most patients, perforation of the RVOT in one and lower limb hypoperfusion in 12 patients. ICU complications include low cardiac output symptoms (LCOS) in 10 (7%), and sepsis in 8. No intra-procedure mortality. The overall survival was 94%. Ten patients died, with one early and 9 late mortality. 60% of the dead patients had PDA stenting. Reintervention varies according to the patient's diagnosis.**

Conclusion: **Cardiac catheterization intervention an important modality in the management of neonates and infants with critical CHD. Well planned procedures and team expertise are essential. Stenting procedures and procedures for patients with single ventricles carries higher morbidity and mortality.**

Keywords: Pediatric cardiac catheterisation, PDA stenting, Balloon pulmonary valvuloplasty, Balloon aortic valvuloplasty, Balloon coarctation angioplasty

1. Introduction

Pediatric cardiac catheterization interventions become an established way of care for selected patients with congenital heart diseases (CHD). Interventional procedures in small infants become more feasible with reduced morbidity and mortality. This is related to the current availability of a wide range of choices of catheters, wires, balloons, sheaths, and flexible, low-profile

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coronary stents as well as the improvements in pediatric anesthesia and ICU care. The current balloons and coronary stents can be delivered through a 4 to 5 Frech sheaths.[1]

The indications for diagnostic cardiac catheterization have decreased with the advent of advanced non-invasive imaging modalities (echocardiography, cardiac MRI, and cardiac CT). [2]

Catheter interventions performed in the neonatal period range from simple interventions like bedside atrial septestomy to stent implantation for PDA, arch and pulmonary arteries. Other interventions might include transcatheter balloon dilation of the pulmonary or aortic valves, balloon angioplasty, and occlusion of the PDA or collaterals. Furthermore, hybrid procedures; for closure of ventricular septal defects or during hybrid ductal stenting with bilateral pulmonary artery banding in HLHS; can also be performed.

Although neonatal catheter interventions are less invasive than surgical procedures, it is important to consider, and to be ready, that several complications can happen during or after the procedure. These procedures must be performed after a complete evaluation by the whole team including the anesthetist and intensivist, and a stand-by ICU bed should be ready. [3]

Cardiac catheterizations are not free from complications. In addition to the exposure to ionized radiation and the risk of general anesthesia, other possible complications might include: the risk of hypothermia (especially in small infants), arrhythmias (temporary instability or even permanent, as in heart block), vascular injury/perforations and/or tears, cardiac perforation, cardiac valve injury, blood loss that require transfusion, allergic reactions to contrast, drugs, or anesthetics, renal insufficiency caused by contrast material, diffuse central nervous system injury, stroke, and even death [2].

Balloon atrial septestomy is an established intervention for patients with ineffective mixing in the setting of parallel circulation or atretic atrioventricular valve with restrictive interatrial communication[4].

Balloon aortic and pulmonary valvuloplasty and balloon coarctation angioplasty are established procedures for the management of patients with stenosed pulmonary or aortic valves and patients with re-coarctation of the aorta after coarctation repair [2].

Stenting of the ductus arteriosus as a mean to establish a reliable source of pulmonary blood flow for palliation of cyanotic CHD is an attractive procedure because it can avoid the complications of cardiac surgery [Blalock-Taussig (BT) Shunt] such as chylothorax, phrenic, or recurrent laryngeal nerve injury or pulmonary artery distortion [5].

Ductal stenting may provide acceptable short-term palliation in cyanotic newborns that have another source of pulmonary blood flow, such as patients with critical pulmonary stenosis or pulmonary atresia with intact ventricular septum after pulmonary valve perforation and balloon dilatation. Careful follow-up is mandatory, because of early and unpredictable restenosis of the PDA stent putting the patient at risk of severe cyanosis and death. The improved outcomes described in more recent reports are due in part to the availability of flexible, low-profile stents designed for coronary artery use that can be delivered safely through a 4 to 5 French sheath [6, 7].

We are presenting a two-center experience in cardiac catheterization interventions in neonates and infants less than three months. This is considered a challenging age group for the interventionist because of the weight as well as the type of lesions requiring intervention.

Abbreviations

AVSD	Atrioventricular Septal Defect
BA	Balloon Angioplasty
BAS	Balloon Atrial Septestomy
BTS	Blalock-Taussig Shunt
CHD	Congenital Heart Defects
CoA	Coarctation Of The Aorta
CT	Computed Tomography
DCM	Dilated Cardiomyopathy
HLHS	Hypoplastic Left Heart Syndrome
ICU	Intensive Care Unit
LCO	Low Cardiac Output
LPA	Left Pulmonary Artery
LVOT	Left Ventricular Outflow Tract
Medina C.C	Madinah Cardiac Center
MRI	Magnetic Resonance Imaging
PDA	Patent Ductus Arteriosus
PS	Pulmonary Stenosis
PSCC-Q	Prince Sultan Cardiac Center Qassim
RAA	Right Aortic Arch
RCC	Right Common Carotid Artery
RVOT	Right Ventricular Outflow Tract
TAPVR	Total Anomalous Pulmonary Venous Return
VSD	Ventricular Septal Defect

2. Patients and Method

During the period from June 2012 to July 2017, all infants less than three months who had cardiac catheterization in two cardiac centers (center A “PSCC-Q” and center B “Madinah C.C.”) were included. The study was approved by the research

Table 1. Procedures performed with the patient's diagnosis. Total Number of patients was 174, with 11 patients required more than one procedure.

Procedure Performed	Diagnosis	No (%)
Balloon pulmonary valvuloplasty 61 (35.1%)	Critical Pulmonary Valve Stenosis	14 (8%)
	Severe Pulmonary Valve Stenosis	41 (23.6%)
PDA stenting 42 (24.1%)	Ebstein Anomaly of the Tricuspid Valve with Pulmonary Atresia	1(0.6%)
	Isolated LPA from left PDA, small VSD	1 (0.6%)
	Mitral atresia, PA, TGA, Hypoplastic LV	2 (1.1%)
	PA Intact Ventricular septum	9 (5.2%)
	PA, VSD, PDA	23 (13.2%)
	Tricuspid Atresia, PA, PDA	8 (4.6%)
	Dextro, LTGA, VSD, Hypoplastic RV, PA, RAA, PDA from RCC	1(0.6%)
	DILV, PA, PDA	1(0.6%)
	DILV, PS	3 (1.7%)
Atrial Septestomy 25 (14.3%)	Mitral atresia, PA, TGA, Hypoplastic LV	3 (1.7%)
	PA Intact Ventricular septum	1(0.6%)
	Tricuspid Atresia, PFO, Unrestricted PBF	2(1.1%)
	D-TGA, IVS	13 (7.5%)
	D-TGA, Small VSD	8(4.6%)
Balloon aortic valvuloplasty 12 (9.8%)	Critical Aortic valve Stenosis	7 (4.0%)
	Severe Aortic valve Stenosis	5 (2.9%)
Diagnostic cath 7 (4%)	DORV, Severe PS	1(0.6%)
	PA, VSD, PDA	1(0.6%)
	SMALL FISTULA BETWEEN RCA AND RPA	1(0.6%)
	D-TGA, IVS	1(0.6%)
	DCM, PDA	1(0.6%)
	DILV, PS	1
Balloon CoA angioplasty 19 (10.9%)	Re CoA post CoA repair	18 (10.8%)
	Native CoA with depressed LV function	1 (0.6%)
BTS Stenting 1 (0.6%)	TA, PA, S/P BTS; BTS Proximal Stenosis	1
Hybrid VSD device closure and arch repair 1(0.6%)	IAA type B, VSD	1
LPA stenting 1 (0.6%)		1
LVOT Stenting 1 (0.6%)	D-TGA, Large VSD, Critical PS	1
RVOT stenting 2 (1.1%)	PA, VSD, PDA	1
Stenting of vertical vein 1 (0.6%)	Obstructed TAPVR	1
Pericardiocentesis 2 (1.1%)	Pericardial effusion	2 (1.1%)
Total 185 Procedures (100%) in 174 Patients		Total of 185 Procedures

Abbreviations: AVSD = atrioventricular septal defect, BTS= Blalock–Thomas–Taussig shunt, CoA= Coarctation of the aorta, DCM = dilated cardiomyopathy, DILV = double inlet left ventricle, DORV = double outlet right ventricle, D-TGA = D-transposition of great arteries, LVOT = left ventricular outflow tract, L-TGA = L-transposition of great arteries, LPA = left pulmonary artery, PHT = pulmonary hypertension, PA= Pulmonary atresia, PDA= Patent Ductus Arteriosus, PS = pulmonary Stenosis, RAA = right aortic arch, RCC = right common carotid artery, RVOTO = right ventricular outflow tract obstruction, TAPVR = Total anomalous pulmonary venous return, VSD = ventricular septal defect.

committee in the two centers. Data were traced from the hospital databases as well as from the cath lab and outpatient records and reports.

The patient's characteristics, main diagnosis, cath lab variables, ICU and hospital course, as well as the midterm outcome, were reviewed. Follow up data were reviewed including any morbidity and/or mortality as well as the requirements for future unplanned reintervention. SPSS program was used for statistical analysis. Continuous variables were expressed as means ± standard deviations or medians with interquartile ranges as appropriate. Categorical variables are presented as percentages and frequencies. A comparison between the two centers was performed. Based on the diagnosis and the future destination of the CHD, patients from both centers were classified into two groups. Group one includes patients with CHD who are suitable for univentricular palliation. The second group (group two) includes patients with CHD with biventricular circulation. Comparison between the two groups was performed. Based on the type of intervention, patients were classified into those who had stenting and non-stenting procedures. Comparison between these two groups was also performed. The 2 sample t-test was used to compare numerical (continuous) variables and the chi-square test was used to compare categorical variables. A P value of less than 0.05 was considered statistically significant. Kaplan Meyer survival curve was created for the different intervention groups.

3. Results

During the study period (from June 2012 to July 2017); 185 cardiac catheterization procedures were performed in both centers for 174 patients [83 patients (48%) from center A (PSCC-Q), and 91patients (52%) from center B (Madinah C.C)]. The males to female ratio were 1.8:1 [111 (64%) were males]. Table 1 shows the patient's diagnosis which varies between simple lesions like pulmonary stenosis to complex lesions with single ventricle pathophysiology (Table 1).

According to the primary diagnosis, 145 patients (83.3%) have CHD with two ventricle circulation and 29 patients (16.7%) have CHD with a single ventricle ultimate future cardiac circulation. Four patients were syndromic (2 Down syndrome, one Noonan syndrome, and one Turner syndrome). Before cardiac catheterization 106 patients (62%) admitted to the NICU, 9 patients (5.2%) delivered prematurely, and 66 patients (38%) received prostaglandin infusion prior to intervention.

Table 1also shows the procedures performed for the patients [which range from simple diagnostic cardiac catheterization to balloon atrial septestomy, balloon pulmonary and aortic valvuloplasty, coarctation angioplasty, and stenting procedures (PDA, BTS, and RVOT stenting)] (Table 1).

The main age and weight at intervention were 43.3 days (SD ± 40.3 days) and 3.6 kg (+/−1.1 kg). Descriptive statistics for patients (age, weight at intervention) as well as the ICU and hospital data are presented in Table 2.

The vascular access depends upon the type of procedure. A 4 French introducer sheath was used in the femoral artery for procedures through the arterial side (balloon aortic valvuloplasty, balloon CoA angioplasty and retrograde PDA stents). A 5 to 7 French introducer sheath was inserted in the femoral vein for interventions on the right side (BAS, balloon pulmonary valvuloplasty and if feasible antegrade PDA stenting). All except 3 had a venous line (151 had introducer sheath and 20 had Vaygon canula). An arterial line was inserted on 88 patients (50.6%) (61 had a 4 Fr sheath and 27 had a Vaygon 20 cannula in the femoral artery). All except one had their procedure under general anesthesia. Extubation in the cath lab was feasible for 81 patients (46.6%). ICU admission was required on 106 patients (62%). Additional procedures were required on 8 patients (5%) (atrial septestomy and stenting of aorto-pulmonary collaterals).

Procedures complications include transient arrhythmias, especially in patients with single ventricle pathologies, small perforation of the RVOT by the coronary guidewire in a neonate with critical pulmonary stenosis (he did not require any intervention and the procedure was completed successfully). Of the 88 patients who had arterial sheaths, 12 (14%) developed some degree of hypoperfusion to their lower limb requiring the institution of anticoagulation. No reported major limb ischemia for any patient in our cohort.

The most common complication in the ICU was signs and symptoms of low cardiac output (LCO), mainly in patients post-PDA stenting. LCO occurred in 10 patients (7%). Other complications include over shunting after PDA stent in one patient, and sepsis in two. Two patients had significant mitral regurge after PDA stenting which prolonged their ICU stay.

Table 2. Descriptive statistics for the patients (age, weight at intervention) as well as ICU and hospital data.

	Mean	Median	Std. Deviation	Minimum	Maximum
Age In Days	43.3	30.0	40.3	1.0	120.0
Ht. at intervention	50.5	52.0	16.4	2.7	60.0
Wt. at Intervention (In Kg)	3.6	3.4	1.1	1.9	11.0
Fluoro time (minutes)	16.1	11.0	15.5	0.0	89.0
Procedure time (minutes)	78.3	71.5	42.4	0.0	180.0
Contrast given ml	26.9	12.5	29.0	0.0	120.0
Contrast amount ml/kg	8.0	4.1	9.0	0.0	30.8
Ventilation hours	14.7	0.0	34.7	0.0	240.0
ICU stay hours	76.2	24.0	111.9	2.0	762.0
Hospital stay days	6.5	3.0	12.6	1.0	89.0
FU period days	4139.6	811.0	11446.7	39.0	42946.0
Time of Reintervention From First Intervention	130.2	128.0	118.1	1.0	368.0
Time of Death From Intervention	13.7	5.0	15.3	1.0	40.0

Of the total cohort, 4 patients (2.3%) died in the ICU (Early mortality) and 6 patients (3.5%) died after hospital discharge with a total of 10 mortality cases (5.7% mortality rate) (Table 3).

The rate of reintervention varies according to the patient's diagnoses. For patients who had palliative procedures, like PDA stenting for augmentation of the pulmonary blood flow, all of them required surgical intervention in the course of their illness (either bidirectional Glenn, BTS or Rastelli). For patients with pulmonary stenosis, aortic stenosis and coarctation of the aorta, some required reintervention in the first year after the primary intervention. 5 out of 51 patients (9.8%) required re-balloon pulmonary valvuloplasty, one out of 12 (8.3%) required re-balloon aortic valvuloplasty, and 4 out of 19 patients(21%) required re-balloon CoA angioplasty.

Comparison between the two centers revealed no significant differences in the patient's variables apart from some differences in the procedure time, amount of contrast given as well as the ventilation hours.

Comparison between stenting procedures and other interventions reveals that: stent procedures were performed at an earlier age, with more fluoro and procedure time. More contrast was given to patients who had stenting procedures (Table 4).

Comparison between interventions for patients with single ventricle versus biventricular pathologies revealed that: procedures for single ventricle pathologies where performed at an earlier age, with more fluoro and procedure time. More contrast was given also to patients who had procedures for single ventricle pathology.

The overall survival after cardiac catheterization interventions in our cohort was 93% (one early mortality and 9 late mortality). Most of the deaths occurred in the first 3 months after the intervention. Six patients died after PDA stenting, 5 of them had PDA stenting as the first stage of single ventricular palliation. One patient died 24 h after PDA stenting due to over shunting and LCO (patient with pulmonary atresia/VSD and PDA). Survival post-PDA stenting was 83% (6 patients died out of 35). Survival post balloon pulmonary and aortic valvuloplasty was 98% (1 death out of 51) and 92% (1 out of 12 cases) respectively. Two patients died after CoA angioplasty (89.5% survival rate). No reported intra-procedure mortality (Table 4), (Fig. 1)

4. Discussion

Cardiac lesions do not always exist in isolation, and patients with solitary or multiple lesions may be deemed better served by surgery. Cardiologists and

Table 3. Details of the died patients.

Gender	Age at intervention	Diagnosis	Maturity	Planned future Intervention	Intervention performed	Time of death after intervention Days	Cause of death
Male	10	Critical Aortic valve Stenosis	FT	Biventricular repair	Balloon Aortic valvuloplasty	30	Sepsis, endocarditis
Male	10	Critical Pulmonary Valve Stenosis	PT	Biventricular repair	Balloon pulmonary valvuloplasty	20	Sepsis
male	40	Dextrocardia, LTGA, VSD, Hypoplastic RV, PA, RAA, PDA from RCC	PT	Single V. repair	PDA stenting	60	Bronchiolitis, Sepsis
Female	27	Ebstein Anomaly of the Tricuspid Valve with Pulmonary Atresia	FT	Single V. repair	PDA stenting	40	Bronchiolitis,
Male	3	Mitral atresia, PA, TGA, Hypoplastic LV	FT	Single V. repair	PDA stenting	45	Bronchiolitis, Sepsis
male	5	PA Intact Ventricular septum	FT	Single V. repair	PDA stenting	60	Bronchiolitis, Sepsis
Male	23	PA, VSD, PDA	FT	Biventricular repair	PDA stenting	1	LCO, Stealing
Male	83	Re CoA post CoA repair	FT	Biventricular repair	Balloon CoA angioplasty	20	Sepsis
male	61	Re CoA post CoA repair	FT	Biventricular repair	Balloon CoA angioplasty	20	Sepsis
Female	120	Tricuspid Atresia, PA, PDA	FT	Single V. repair	PDA stenting	40	Bronchiolitis, Sepsis

Abbreviations: CoA= Coarctation of the aorta, LV = left ventricle, L-TGA = L-transposition of great arteries (corrected transposition), PA + Pulmonary atresia, PDA= Patent ductus arteriosus, RAA = Right aortic arch, RCC = right common carotid artery, TGA = Transposition of great arteries, VSD= Ventricular septal defect.

Table 4. Group Statistics, Comparison between Stenting procedure (Group 1) Vs other non-stent procedures (Group 2).

	Stenting procedure (G1) Vs other procedures (G2)	Mean	Std. Deviation	Sig. (2-tailed)
Age in days	G 1	33.75	36.41	
	G 2	48.25	39.38	0.04
Wt. at intervention (in kg)	G 1	3.49	0.93	0.08
	G 2	3.92	1.24	0.04
Fluoro Time Minutes	G 1	24.78	19.63	0.00
	G 2	11.92	11.04	0.00
Procedure Time Minutes	G 1	98.64	37.23	0.00
	G 2	69.90	41.77	0.00
Contrast Given ml	G 1	44.64	35.75	0.00
	G 2	18.57	20.88	0.00
Contrast Amount ml/kg	G 1	15.23	11.61	0.00
	G 2	4.78	5.05	0.00
Ventilation Hours	G 1	19.80	30.25	0.60
	G 2	11.85	33.06	0.60
ICU Stay Hours	G 1	48.00	19.60	0.67
	G 2	76.49	129.83	0.19
Hospital Stay Days	G 1	3.25	2.06	0.57
	G 2	7.69	15.19	0.07
FU period Days	G 1	675.16	372.39	0.33
	G 2	1785.18	6328.25	0.11
Time Of Reintervention From First Intervention	G 1	220.90	112.38	0.00
	G 2	86.96	98.40	0.01
Time Of Death From Intervention	G 1	18.50	19.50	0.25
	G 2	5.50	5.45	0.28

Non-stenting procedures include Atrial Septestomy, Balloon aortic valvuloplasty, Balloon CoA angioplasty, Balloon pulmonary valvuloplasty, Diagnostic cath, Hybrid VSD device closure, and arch repair. Stenting procedures include: BTS Stenting, LPA stenting, LVOT Stenting, PDA stenting, RVOT stenting, Stenting of the vertical vein.

surgeons must work together to formulate an interventional approach to patients based on the center program and the expertise of the medical team. Individual centers must assess their capabilities and limitations in doing pediatric cardiac interventions [1, 2].

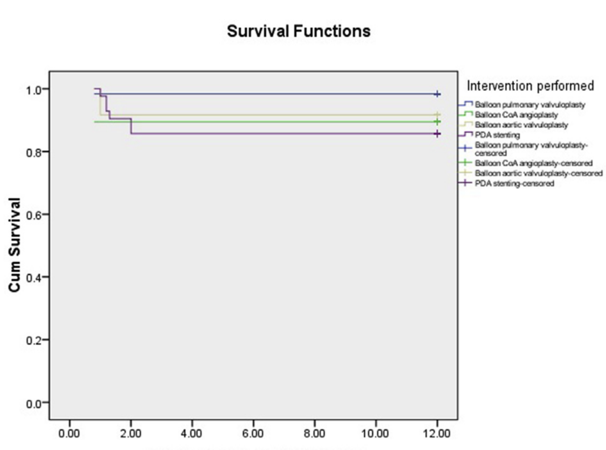

Fig. 1. Kaplan Meier Survival Curve for different cases. The overall survival was 92.5%. First-year Survival for Balloon CoA angioplasty, Balloon aortic valvuloplasty, Balloon pulmonary valvuloplasty, and PDA stenting was 89.5%, 92%, 98.4%, and 86% respectively.

The invasive nature of cardiac catheterization and the common need for anesthesia forces the clinician to at least consider non-invasive alternatives for clinical, anatomical and hemodynamic data collection. Fortunately, advances in non-invasive imaging have allowed cardiac catheterization to become increasingly a catheter-based therapeutic option rather than a diagnostic tool. Two-dimensional echocardiography and 3-dimensional imaging by echocardiography, magnetic resonance imaging (MRI), and computed tomography (CT) in many cases have replaced the need for diagnostic cardiac catheterization [2].

Balloon pulmonary valvuloplasty for congenital pulmonary valvular stenosis is a safe and effective procedure and the initial treatment of choice [8]. In our cohort, the outcome of balloon pulmonary valvuloplasty is excellent with an overall success rate of 100% with no procedure mortality. The difficulty arises in patients with critical pulmonary stenosis and high RV pressure, in whom accessing the RV and RVOT might be challenging. One of our patients had RVOT perforation by the wire while trying to cross the RVOT. Fortunately, he did not require any further intervention and the procedure was completed successfully. One patient died after 20 days of balloon pulmonary valvuloplasty with sepsis and almost 10% required re-balloon pulmonary valvuloplasty.

Balloon aortic valvuloplasty is a palliative procedure. Balloon aortic valvuloplasty for neonatal critical aortic stenosis is a useful method to improve the systemic blood flow, allow LV function to recover and stop prostaglandin infusion. The procedure is a palliative and important to delay the inevitable future surgical intervention [9].

Balloon coarctation angioplasty (BA) is an important treatment option for coarctation of the aorta. Some patients might require multiple interventions and/or stent implantation. In our series, the reintervention rate after the first balloon CoA angioplasty (for re-coarctation post-cardiac surgery) was 25% [11].

Stenting of the ductus arteriosus as a mean to establish a reliable source of pulmonary blood flow for palliation of cyanotic CHD is a relatively new transcatheter intervention. We didn't start the program of stenting the ductus arteriosus to establish the systemic blood flow in patients with systemic outflow tract obstruction (Hypoplastic left heart syndrome (HLHS)). Compared with surgical alternatives, ductal stenting might help to avoid surgery and its complications such as chylothorax, phrenic, or recurrent laryngeal nerve injury or pulmonary artery distortion, which are well described after placement of a surgical aortopulmonary shunt [12].

There is a concern regarding the short-term patency of the stented ductus arteriosus. Careful follow-up is mandatory after ductal stenting because of the early and unpredictable restenosis, putting the patient at risk of severe cyanosis and death [13–15].

Patients with univentricular hearts palliated by ductal stenting allow adequate somatic growth before Glenn surgery. Branch pulmonary artery stenosis is a concern in such patients and most of them will require branch pulmonary artery plasty during Glenn surgery. Ductal stenting for patients with biventricular anatomy need close follow up and will require RV to PA conduit and VSD closure (Rastelli procedure) at a relatively earlier age. The reported interstage mortality for ductal stenting was 18% [14, 15]. In our series, we do have a concern regarding PDA stenting for patients with single ventricle pathologies, with higher interstage mortality in this group of patients compared with PDA stent for patients with biventricular pathologies. Low cardiac output syndrome is also a complication that might happen after PDA stent especially when using large stents for short ductus. One of our patients died in the ICU on the first day after intervention with signs and symptoms of LCO. His diagnosis was pulmonary atresia with VSD with a short PDA supplying branch pulmonary arteries. He had a PDA stent using a 4 mm × 18 mm coronary stent.

Sedation for pediatric cardiac catheterization is a common requirement in many institutions. The demand is increasing for dedicated personnel focused on monitoring and delivery of sedation in the catheterization laboratory [10].

It is reported that infants who had a femoral arterial line might develop pulse strength discrepancies between the two limbs with a reported rate of 20%. Loss of pulse in the affected limb was reported to be 3.4%. Fortunately, the resolution of limb perfusion was 100% [16]. In our series, of the 88 patients who had arterial puncture 12 (14%) developed some degree of hypoperfusion to their lower limb requiring the institution of anticoagulation for 24–48 h. No patient had major limb ischemia.

Cardiac cath with venous access only (without arterial access) is feasible and is a practice in some institutions (to avoid the risks of arterial puncture) [17].

In our cohort, to avoid the risk of vascular compromisation and limb hypoperfusion and ischemia, for right-sided cardiac lesions and interventions, we are trying to either avoid arterial puncture or put a Vaygon 20 canula in the artery (2.5 Fr size). For interventions in the aortic valve or aortic arch, we used a 4 Fr sheath in most of cases. For PDA stents we tried to stent the ductus from the venous side (if feasible) or using only a 4 Fr sheath in the artery.

Some reported factors that increase the risk of overall complications in neonatal and infantile cardiac interventions might include anticoagulant use before the procedure, prolonged prothrombin time, general anesthesia use during the procedure, prolonged total procedure time, low body weight, repetitive procedures, and long total fluoroscopy time. High activated partial thromboplastin time, the requirement for intensive care unit admission, and concomitant electrophysiological study during the procedure significantly increase the risk for severe complications [18].

In our cases, patients who required PDA stenting for single ventricle pathophysiology have a high risk of ICU complications as well as mortality.

5. Conclusion

As a result of recent technological advances, the pediatric interventional cardiology community has made attempts to develop better solutions to minimize the need for open-heart surgery and optimize the overall outcomes. Results of balloon pulmonary valvuloplasty are excellent with low mortality as well as low requirements for future reintervention. Balloon aortic valvuloplasty constitutes the first-line therapy for congenital aortic stenosis in many centers. PDA stenting, as well as interventions for single ventricle pathophysiology, carries a risk for morbidity and mortality. Patients with critical aortic stenosis have substantial risks for morbidity as well as mortality. Expert interventionists, as well as anesthetists and ICU team, are essential. The procedures should be planned well with a plan for the possible future follow up and intervention (if required). Avoiding arterial puncture or insertion of a Vaygon canula in the arterial line might help to avoid arterial line complications.

Financial & disclosure of conflicts of interest

This work did not receive any financial support from any organization or company. The authors disclose that they don't have any financial relationship with any companies. No writing assistance was utilized in the production of this manuscript.

Authorship and authors contribution

All authors have made substantial contributions to (1) the conception and design of the study, (2) acquisition of data, (3) analysis and interpretation of data, (4) drafting the article & revising it critically (5) final approval of the version to be submitted.

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