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Original Article

Diagnostic pediatric cardiac catheterization: Experience of a tertiary care pediatric cardiac centre

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ABSTRACT

Background: Cardiac catheterization was considered gold standard for confirmation of diagnosis and analyzing various management issues in congenital heart diseases. In spite of development of various non invasive tools for investigation of cardiac disorders diagnostic catheterization still holds an important place in pediatric patients.

Methods: 300 consecutive diagnostic cardiac catheterization performed since April 2007 were included in this study. The study was undertaken to evaluate the profile of patients undergoing diagnostic cardiac catheterization, its results, assess its safety and its contribution toward solving various management issues.

Result & Conclusion: Children who underwent cardiac catheterization ranged in weight from 1.6 kg to 35 kg, with their age range 0 day–12 years. The information obtained was of great importance for further management in over 90% cases. The procedure of cardiac cath is invasive, still it was proved to be quite safe even in smallest baby.

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Introduction

Congenital heart diseases (CHD) occur in almost 8–10 per 1000 babies. Diagnosis of CHD is done by clinical examination, chest radiograph and electrocardiogram. Echocardiography helps in confirmation of diagnosis and in solving most of the management issues. In earlier years of pediatric cardiology, cardiac catheterization was the major diagnostic tool but in recent years, the use of catheterization for the diagnosis of congenital heart diseases has limited applications. Angiographic cardiac imaging is required for those areas inaccessible to echocardiography, such as the distal great arteries, abnormal venous connections, complex congenital heart diseases and patients with poor echo window such as in post

operative conditions. Trans-esophageal echo, MRI, Radio-nuclide angiography and spiral CT have been employed in defining the structural heart lesions. Of these modalities MRI appears to be most promising. The increased imaging versatility offered by these new modalities has important financial consequences and requires a responsible economic approach.¹ Cardiac centers where MRI facilities are not available in house the cardiac catheterization is still the investigation of choice. MRI centers who are not performing cardiac MRI for congenital heart diseases on a regular basis can not provide all relevant information in detail as it is possible with cardiac catheterization.

Cardiac catheterization (cath) in children is now more applicable for therapeutic reasons; still role of diagnostic

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Table 1 – Profile of acyanotic patients.

Diagnosis (n = 94) M 55, F 39	<6 Months	>6 Months–1 year	>1 Year–5 years	>5 Years
VSD (n = 30)		3	12	15
AP window (n = 10)	6	2		2
ASD (n = 15)		3	6	6
Truncus (n = 2)	2			
AVSD (n = 1)			1	
PDA (n = 11)		1	6	4
Coarctation (n = 10)	2	1	1	6
AS (n = 1)				1
PAH (n = 1)			1	
DCRV (n = 11)			7	4
RSOV (n = 1)			1	
Renal angio (n = 1)				1

VSD – Ventricular septal defect, AP – Aortic pulmonary, ASD – Atrial septal defect, AVSD – Atrio ventricular septal defect, PDA – Patent ductus arteriosus, AS – Aortic stenosis, PAH – Pulmonary arterial hypertension, DCRV – Double chambered right ventricle, RSOV – Ruptured sinus of valsalva.

cardiac catheterization can not be undermined in difficult cases where it is still the gold standard. Meaningful and accurate data must be acquired for the pre surgical evaluation of patients with CHD to better guide clinical decisions.² This study was undertaken to evaluate various issues related to diagnostic cardiac catheterization in children.

Material and methods

A prospective study was conducted to examine the profile of patients, indications of catheterization, analyze the available information, contribution of the available information in further management of the patient and safety issues related to diagnostic cardiac catheterization procedure.

Consecutive diagnostic cardiac catheterization performed in 300 children since April 2007 were included in this study. Patient where catheter based cardiac intervention was done, were not included in this study. All these children were referred from various hospitals with a provisional diagnosis of congenital heart disease. Detailed clinical examination was

done at our center. Echocardiography was performed in all patients by iE 33 Philips machine, and majority of patients were assigned either medical or surgical management based on their diagnosis and clinical condition. In patients where for various reasons clear decision was not possible cardiac catheterization was performed.

Patients were hospitalized a day prior to cardiac catheterization. They were kept fasting for 3–4 h prior to procedure. Procedure was done under deep sedation with Midazolam (0.1 mg/kg) and Ketamine (1–2 mg/kg). Groin was cleaned and local anesthesia was given. Smaller children were also restrained by tying them over the board so as to avoid unnecessary movements. Arterial and venous access was obtained after puncturing right or left femoral artery and vein by Seldinger's technique. Heparin was given 100 units/kg at the beginning of the procedure. Angiographic pictures were recorded on Siemen's machine. Total contrast used for angiography was non ionic (Omnipaque) with total dose limited to 3–4 ml/kg.

Indications for cardiac catheterization in acyanotic heart diseases

Table 2 – Profile of cyanotic patients.

Diagnosis (n = 206) M134,F72	<6 Months	1 Year–3 years	3 Years–5 years	5 Years–10 years	>10 Years
TOF (n = 101)	12	47	18	18	6
TOF, pulm atresi (n = 26)	8	8	2	3	5
TOF absent pulm valve (n = 5)	3		2		
DORV, VSD, PS (n = 8)	2	3	1	2	
TA/VSD (n = 13)		6	2	4	1
Post PA band (n = 7)	2	2		3	
TGA (n = 4)		3			1
Post Glenn (n = 14)		2	6	1	5
Single ventricle, PS (n = 4)		1	1	2	
TAPVC (n = 5)	2	1		2	
Complex (n = 9)	5	2		1	1
Dextrocardia with CCHD (n = 8)		1	3	2	2
CTGA, VSD, PS (n = 2)			1	1	

TOF – Tetralogy of Fallot, DORV – Double outlet right ventricle, TGA – Transposition of great arteries, PS – Pulmonary stenosis, TAPVC – Total anomalous pulmonary venous connection, CCHD – Congenital cyanotic heart disease, CTGA – Corrected transposition of great arteries.

Table 3 – Interpretation of catheterization findings in acyanotic patients.

Acyanotic heart disease	No	Interpretation (additional lesions, assessment of pulmonary artery pressures and operability)
VSD	30	LSVC 6, additional VSD 2, operable 16, inoperable 14
AP window	10	AP window 9, associated PDA 1, no AP window 1, operable 9, inoperable 1
ASD	15	Associated PAPVC 4, LSVC to CS 3, scimitar syndrome 1, suitable for device closure 6, operable 8, inoperable 1
Truncus arteriosus	2	Diagnosis confirmed in both, Type I – 1, Type III – 1
AVSD	1	Operable
PDA	11	Suitable for device 4, operable 6, inoperable 1
Coarctation	10	Interrupted arch 1, associated arch hypoplasia 3, long segment coarct 1, short segment suitable for catheter based intervention 5
Aortic valve stenosis	1	Supravalvular aortic stenosis, no valvular stenosis
Pulm arterial hypertension cause?	1	Primary PPH, no shunt lesion
DCRV	11	Associated lesion – VSD 9, no VSD 2, mild valvular PS 2, gradient in mid RV cavity 50–90 mm
RSOV	1	RSOV from non coronary sinus to right atrium suitable for device closure
Renal angio	1	Severe left renal artery stenosis with long segment mild narrowing in abdominal aorta

PAPVC – Partial anomalous pulmonary venous drainage, LSVC – Left superior vena cava.

1. To define complete anatomy where echo window was poor
2. To assess pulmonary artery pressure so as to plan suitability for surgery
3. To assess feasibility and plan intervention procedure

Indications for cardiac catheterization in cyanotic heart diseases

1. To assess pulmonary artery anatomy in terms of size, confluence, any stenosis at origin or any peripheral pulmonary stenosis
2. To assess pulmonary artery pressures
3. To assess aorto pulmonary collaterals
4. In post operative patients e.g. Post PA banding, Post Glenn shunt – to assess PA pressures and in Post BT shunt – to assess PA anatomy and any distortion due to previous surgery

Fig. 1 – Aortic root injection showing rupture sinus of valsalva into right atrium.

After the procedure children were monitored for next 12 h in intensive care unit and then were shifted to ward. All patients were sent home in next 24–48 h.

Results

Performing cardiac catheterization in small children is particularly challenging in view of obtaining vascular access. In our patients we could get required vascular access in all but 2 patients where the procedure had to be postponed for the next day. Though Doppler tipped introducer needle are used at several centers, with experience we still managed with usual pediatric puncture needle or intracath using Seldinger's technique. Surgical cut down was not required in any patient.

As evident in [Table 1](#) the majority of acyanotic patients (80%) were more than 1 year age. At less than 1 year age (20%) the issue of operability was decided based on clinical findings and echocardiography only. Males were more in number with male to female ratio of 1.4:1. Detailed interpretation of cath findings was as per [Table 2](#). Information obtained in almost all

Fig. 2 – Coarctation of aorta in anteroposterior view.

Fig. 3 – Coarctation of aorta in lateral view.

patients which covered most of the acyanotic heart diseases, contributed significantly for further management (Figs. 1–3).

As depicted in Table 3 amongst cyanotic patients which included complex lesions also, majority were of less than 3 years age (69%) out of which 16% were even lesser than 6 months. Males were more in number with male to female ratio of 1.9:1. Detailed interpretation of cath findings was as per Table 4. Information obtained was of important significance for further management of these cases (Figs. 4–7).

The catheterization procedures were performed with all safety precautions to prevent radiation hazards to operator and patient. Fluoroscopy time was kept as low as possible. It was 2.4–11 min in study of acyanotic patients while it ranged between 8 min and 28 min in cyanotic patients. Quantity of contrast was kept within safe limit of 3–4 ml/kg. Contrast used in acyanotic patients was much less (Nil to 1.5 ml/kg) as the studies involve mainly recording of the pressure data

while in cyanotic patients recording anatomy of pulmonary artery, collaterals, various chambers etc the quantity of contrast used was more (2–4 ml/kg). In 4 cases the study was not completed in one sitting and was performed in two steps with an interval of 2 weeks so as to limit contrast load to less than 4 ml/kg. Renal functions were checked after 24 h and in patients where contrast load was near upper limit of 4 ml/kg renal functions were monitored after 72 h and later after a week. No patient had altered renal function in our study.

Catheterization procedure being invasive can have complications related to arterial and venous puncture, reactions due to contrast and complications related to the heart disease itself. The observed complications in this study are listed in Table 5. No major complication or death occurred due to catheterization procedure in this study. Only 1 patient in this study had to be sent for emergency palliative shunting as the baby had recurrent cyanotic spells after cardiac catheterization procedure and failed medical management.

Discussion

Since 1929 when Werner Forsman, a young surgeon in Germany performed first catheterization of the living human heart on himself cardiac catheterization opened the way for study of heart in a manner analogous to what electrocardiography had done for its electrical function a half century earlier.³ In recent years, catheterization has shifted from a diagnostic tool to an interventional one still, non interventional pediatric cardiac catheterization continues to have an important role in the assessment and treatment of patients with congenital heart diseases.²

In acyanotic patients cardiac catheterization is still an essential method for the precise calculation of cardiovascular hemodynamic status.⁴ With intra cardiac shunts cath data is

Table 4 – Interpretation of catheterization findings in cyanotic patients.

Cyanotic heart disease	No	Interpretation (additional lesions including collaterals)
TOF	101	Pulmonary artery confluent and of adequate size 82, hypoplastic but confluent pulm arteries 18, LPA stenosis 4, absent LPA 1, RPA stenosis 2, major collaterals 40, right aortic arch 20, LSVC to CS 4, coronary anomalies 4
TOF, pulm atresia	26	PDA 12, confluent adequate size pulmonary arteries 10, multiple collaterals 16, only LPA present 2
TOF, absent pulm valve	5	MPA aneurysmal 5, confluent normal size PA's 3, bilateral dilated proximal PA's 2, LSVC 1
DORV, VSD, PS	8	Hypoplastic LV 2, malposed vessels 3, hypoplastic pulmonary arteries 2, confluent adequate size pulmonary arteries 6, collaterals 5
TA/VSD	13	Hypoplastic RV 9, pulmonary atresia 6, malposed vessels 2, collaterals 5
Post PA band	7	PA pressure mean <12 mm 6, mean PA pressure 29 – 1, confluent normal size PA's 7
TGA with severe PAH	4	Inoperable 3, operable 1
Post Glenn	14	PA mean pressure <12 mm – 11 suitable for Fontan, PA press >20 mm – 2 not suitable for Fontan, PA mean 15 mm +/- for Fontan, severe LPA stenosis – 1, major collaterals 5
Single ventricle, PS	4	Confluent adequate size PA's 3, large bilateral collaterals 1
TAPVC	5	TAPVC to CS 2, supracardiac TAPVC 2, mixed TAPVC 1, no obstruction – 5, all were found operable
Complex CHD	9	Interrupted IVC 3, azygos system 5, DOLV 2, TAPVC 1, LSVC 4, PS 5, severe PAH 4, multiple collaterals 4
Dextrocardia (n = 8)	8	AV & VA concordant 4, VA discordant 2, DORV 2, confluent adequate size PA's 7, RPA absent 1, TAPVC 1, LSVC 3, collaterals 3
CTGA (n = 2)	2	Coarctation of aorta 1, PA's confluent normal size 2, PA pressures mean 15 with acquired PS due to VSD aneurysm projecting in LVOT 1

LV – Left ventricle, RV – Right ventricle, DOLV – Double inlet left ventricle.

Fig. 4 – Left pulmonary artery filling through PDA in a case of pulmonary atresia.

Fig. 6 – Multiple collaterals to both lung fields.

employed for calculation of shunt and for precise recording of pulmonary arterial pressure. In our study 17 patients were declared inoperable due to severe pulmonary arterial hypertension. In these patients shunt and pulmonary vascular resistance (PVR) were calculated after giving 100% oxygen for 10 min. Additional lesions were also demonstrated in about 50% patients. In patients with unexplained pulmonary hypertension right heart catheterization is usually needed to confirm the diagnosis, estimate any reversibility of elevated vascular resistance and exclude any other treatable cause.⁵ In this study we had only one such patient where no shunt could be demonstrated and PAH was labeled as Primary or Idiopathic.

In management of cyanotic heart disease clinical, non invasive laboratory features including echocardiography are sufficiently characteristic for diagnosis. Invasive cardiac cath and angio studies are mostly needed to define pulmonary

blood flow in relation to size and confluence of pulmonary arteries (Figs. 8–10) and assessment of systemic–pulmonary collateral arteries.⁶ Several studies have also demonstrated associated coronary and cardiac anomalies in Tetralogy of Fallot which can be of importance during surgery.⁷ In this series 82% of TOF patients had confluent and adequate size of pulmonary arteries. 20% patients had right aortic arch and 4% patients had left superior vena cava. Coronary anomalies were also seen in 4% cases. In a study where MDCT was used for the evaluation of systemic–pulmonary collateral arteries (SPC), conventional angio findings were used as gold standard. In as many as 23% cases MDCT was unable to identify SPC arteries and in several cases it resulted in false identification of vessels.⁸ In this study 40% of our patients with TOF had significant collaterals. These collaterals were embolized by coils or particulate materials prior to surgery.

A study done in 2003 revealed that based on commonly acquired echo parameters, a low risk subgroup of patients can be identified who can safely avoid pre operative cardiac catheterization⁹ still traditionally most of the patients

Fig. 5 – Large collateral to right lung from descending aorta.

Fig. 7 – Right ventricular angiogram showing transposition of great vessels.

Table 5 – Complications observed with catheterization procedure.

SN	Complication	Number of patients	Outcome
1	Transient loss of pulsation	8	Improved after 12–72 h of heparin infusion at rate of 25 units/kg/h
2	Hematoma at puncture site	6	Improved after 24 h, blood transfusion not required in any patient
3	Bleeding from puncture site	4	Controlled by applying pressure in 10 min
4	Rigors	12	Responded to medical management in 5–15 min
5	Urticaria	2	Controlled in 30 min
6	Seizures	2	Responded to single dose Inj diazepam 0.2 mg/kg, no recurrence of seizures
7	Recurrent cyanotic spells	5	Responded to medical management 4, emergency palliative surgery 1
8	Fever	12	Controlled in 30 min to 4 h

requiring cavo-pulmonary anastomosis or Fontan surgery undergo cardiac catheterization to define pulmonary artery pressure and pulmonary artery anatomy. In our series all patients taken up for Fontan surgery underwent cath study prior to surgery. 4 out of 14 patients had mean PA pressure more than 15 mm and were not considered suitable for Fontan surgery. Five patients also had major aorto pulmonary collaterals which were embolized by coils prior to surgery.

As with any other invasive technique, cardiac catheterization has certain risks but with currently available hardware and safer non ionic contrast media, the risks of pediatric cardiac catheterization are relatively low. Reported adverse event rate for patients with CHD undergoing cardiac cath vary considerably due to non comparable standards of data inclusion and highly variable case mix. In congenital cardiac catheterization outcome project (C3OP) data was analyzed from 6 pediatric institutions. Incidence of adverse events for diagnostic cath was approximately 10% (6–16%).¹⁰ As per a study in Switzerland where cardiac catheterization in children was considered as an outpatient procedure – over 77% patients were stable at 5 h and were found suitable for discharge same day. Only 23% patients in their study required overnight observation.¹¹

In another study, clinical records of 11,073 children who underwent cardiac catheterization were reviewed to identify procedure associated complications within first 24 h. A total of

850 patients (7.3%) had complications of which vascular complications represented the majority (32.4%). Death was recorded in 0.23% of total cases. Independent risk factors for a complication included young patient age (<6 months), male gender, inpatient status and year of catheterization.¹² No independent risk factors could be identified.

Side effects like rigors and fever were observed in few cases which can occur due to reuse of disposables which is a practice followed at most of the centers as it leads to substantial cost saving which enables the delivery of sophisticated advanced treatment to many needy patients.¹³ In another study involving 4952 consecutive pediatric catheterization procedures one or more complication occurred in 8.8% with vascular complications observed in 3.8% of procedures. Death was recorded in 7 patients (0.18%) in this series.¹⁴

Use of Ketamine and Midazolam during cardiac cath is quite safe¹⁵ and during our study we had no problem in sedating the babies with this combination. Though facility for providing general anesthesia was available at all time in cath laboratory, it was not required in any patient for diagnostic catheterization.

This study provides for the first time a comprehensive database on the spectrum of children with various heart diseases undergoing diagnostic cardiac catheterization in Indian Armed forces. It also highlights the safety profile and its

Fig. 8 – Right ventricular angiogram showing stenosis of both pulmonary arteries at origin.

Fig. 9 – Contrast injection into BT shunt depicting confluence and size of both pulmonary arteries.

Fig. 10 – Multiple collaterals to both lung fields.

positive contribution in decision making for further medical and/or surgical management.

Conflicts of interest

All authors have none to declare.

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