Original Article

Cardiac Arrest in Pediatric Patients with Congenital Heart Diseases Undergoing Cardiac Catheterization: A Retrospective Study

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Objective: Cardiac catheterizations are frequently performed in patients with congenital heart diseases. Cardiac arrest is the serious complication that may affect the overall outcomes. The study was designed to report the incidence of in-procedure cardiac arrest and potential contributing factors.

Materials and Methods: We conducted a single-center, retrospective cohort study by chart review in pediatric patients undergoing cardiac catheterization in a large tertiary referral cardiac care center between January 2011 to June 2016. Patient demographic data, diagnosis, incidence of cardiac arrest, outcome of cardiopulmonary resuscitation [CPR] and their final disposition were collected and analyzed.

Results: A total of 726 catheterizations performed during the study period and reported incidence of cardiac arrests were 14 cases (1.9%). Successful CPR in 11 patients (84.6%, 1 patient was with Do Not Resuscitate status), but only 8 patients (57.1%) survived to hospital discharge. Univariate analysis identified the following factors to be contributing to cardiac arrest: age <1 year, weight <5 kg, American Society of Anesthesiologists [ASA] classification III-V, children with other comorbidities, cyanotic type defect and emergent catheterization.

Conclusion: The incidence of cardiac arrest during pediatric catheterization remains high. Special precautions should be exercised for patients at risk.

Keywords: Cardiac catheterization, Pediatric catheterization, Congenital heart disease, Cardiac arrest

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Children with congenital heart defects are undergoing cardiac catheterization globally on a daily basis. The therapeutic interventions have been expanding which have broadened the role of catheterizations far beyond just a diagnostic tool[1-3]. Various pathologies in certain complex congenital cardiac defects can be cured or ameliorated by therapeutic catheterization[1]. Low mortality complications have been reported between 4 to 10% but serious complications i.e. cardiac arrest can also occur since the work of catheters and wires are inside the heart[4-7]. Previous reports estimated the incidence of cardiac arrest during catheterization as 0.96 to 1.6%[8-10] with moderate success of cardiopulmonary resuscitation [CPR] (69% return to perfusing rhythms)[10]. Possible causes had been identified i.e. acute onset of arrhythmias, catheter perforation, severe hypotension, respiratory failure, airway obstruction, hypoxemia, hyperkalemia, acute air embolism, etc. Previous literatures also indicated the contributing factors to cardiac arrest as age less than 1 year, body weight less than 6.2 kg, cyanotic heart disease, interventional catheterization and co-existing morbidities[8-10].

Maternal access to fetal echocardiography is generally limited in Thailand. Many children with congenital cardiac defects were born without prenatal diagnosis and frequently not prepared for life supports.

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Furthermore, pediatric cardiologists are not uniformly distributed nationwide, mostly clustered in large referral hospitals. Unaccounted numbers of perinatal deaths are related to undiagnosed congenital heart diseases while certain children have fortunately grown up with uncorrected defects. These children frequently present late and occasionally are beyond repairable stage. Multiple cardiac imaging modalities i.e. echocardio graphy, cardiac magnetic resonance imaging [MRI] and catheterization are often required to a make plan for treatments. Multidisciplinary teams which consist of pediatric cardiologists, cardiac surgeons, intensivists, anesthesiologists, nurses, etc are working collabora tively to facilitate toward an excellent outcome. Among these cardiac imaging techniques, catheterization remains the procedure with highest risk[10].

There are currently no national studies regarding peri-catheterization cardiac arrest in children. The available data was a report of cardiac arrest in patients required anesthesia service which mainly involves patients undergoing non-cardiac surgeries[13]. We looked into this topic to report such an incidence in a large tertiary referral pediatric cardiac center and its potential contributing factors.

Materials and Methods

Following the institutional IRB approval (Si. 450/2016), the retrospective chart reviews of patients with age under 18 years old undergoing cardiac catheterization at Her Majesty Cardiac Center [HMCC], Siriraj Hospital, between January 2011and June 2016 were conducted. The data were collected from patient's chart, anesthetic record and catheterization suite databases. We collected patient's demographic data, American Society of Anesthesiologists [ASA] physical classification, diagnosis, cardiac defect type based on presence of cyanosis, concurrent medical problems, type of catheterization, type of anesthesia service, incidence of cardiac events and nature of procedure based on urgency basis. Cardiac arrest was defined as an event with no detectable cardiac output for sustained period despite the removal of associated intracardiac wires/devices or the event that lead to external cardiac massage or uses of electrical or pharmacological intervention to restore a perfusing rhythm.

The HMCC catheterization suite consists of 6 catheterization laboratories, in which 3 labs are dedicated to adult patients, one lab is for electrophysiologic [EP] study and ablation or procedure related to cardiac rhythms i.e. pacemaker, automatic implantable cardioverter defibrillator [AICD]. One lab can be used interchangeably for either EP or interventions. All labs are equipped with monoplane fluoroscopy except for the last lab which is equipped with bi-plane fluoroscopy and mainly used for pediatric cardiac catheterization.

All of pediatric cardiac catheterizations performed with anesthesia team service. Elective cases during official hours were provided by a group of experienced anesthesiologists with cardiac anesthesia or pediatric anesthesia expertise. All urgency or emergency catheterizations after official hours will be serviced by the on-call anesthesiologists which are all junior faculty staffs with clinical experience less than 10 years. The anesthetic care to these patients was frequently consulted with the more senior on-call anesthesiologists.

All patients with cardiac arrest were retrospectively reviewed to determine their destination outcome whether they were home dischargeable or expired.

Statistical analysis

As mentioned above, reported incidence of cardiac arrest among pediatric patients undergoing cardiac catheterization was 0.96 to 1.6%[8-10], we projected that our institution may experience this event as high as 2.0%. It was calculated that a total of 615 patients was needed to achieve the 95% confidence interval.

All collected data were plotted in the spreadsheet and imported into SPSS version 18 (SPSS, Inc., Chicago, IL, USA). Discrete qualitative variables among studied patients were initially analyzed by Chi-square of Fisher's exact test. Univariate analysis was used to identify the potential risk factor pending on number of study events. Results were considered statistically significant at two-sided *p*-value of less than 0.05.

Results

There were total of 726 catheterizations conducted between the study periods. The study diagram and the incidence of cardiac arrest are shown in Figure 1. The demographic data and related details are shown in Table 1. Most patients (630/726 or 86.8%) were older than one year old and weighed more than 5 kg (670/726 or 92.3%). Majority of catheterizations were categorized as elective nature (710/760 or 97.8%) and general anesthesia was used in 94.8% of cases (Table 1). There were total of 14 cardiac arrests (1.9%)

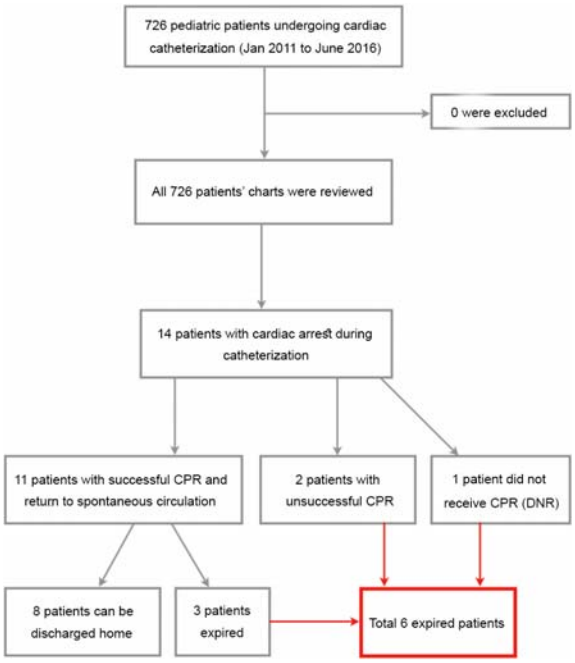

Figure 1. The enrollment of 726 children undergoing cardiac catheterization between January 2011 to June 2016.

reported during catheterization in which 11 patients were successfully resuscitated to perfusing rhythm while 1 patient was not resuscitated owing to the DNR (Do Not Resuscitate) status, hence, the success rate of resuscitation was at 84.6%. There was 1 patient required support from the extracorporeal membrane oxygenator (ECMO). Two patients (14.3%) with cardiac arrest did not return to spontaneous circulation. The details of 14 patients with cardiac arrest including age, weight, diagnosis and type of procedures, CPR outcomes and final disposition were shown in Table 2. Of all these 14 catheterizations with cardiac arrest, 9 of them were classified as diagnostic catheterization (64.3%) while 5 procedures were therapeutic intervention or combined (35.7%). All of these patients with cardiac arrest were with relatively complex congenital cardiac defects or with multiple abnormalities and they were all under 1 year of age.

The patient factors and possible associated variables are shown in Table 3. The univariate analysis identified the contributing factors to in-procedure cardiac arrest as followed; neonate catheterization (age less than 30 days) (OR 148.0, 95% CI 15.7 to 1,395.3, $p<0.001$), patients with body weight less than 5 kilograms (OR 18.44, 95% CI 6.15 to 55.32, $p<0.001$),

Table 1. Demographic data and patient characteristics

Variables	n = 726
Gender: male	348 (47.9)
Age	
<1 month (0 to 30 day)	21 (2.9)
>1 month to 1 year (31 to 365 day)	75 (10.3)
>1 year (>365 day)	630 (86.8)
Mean body weight (kg)	25.4±19.4
Patient size by weight	
≤5 kg	56 (7.7)
ASA physical status	
Class I	11 (1.5)
Class II	293 (40.4)
Class III	337 (46.4)
Class IV	78 (10.7)
Class V	7 (1.0)
Other comorbidities	
Yes	69 (9.5)
No	657 (90.5)
Type of congenital heart disease	
Cyanotic	332 (45.7)
Acyanotic	394 (54.3)
Category of catheterization	
Diagnostic	352 (48.5)
Interventional	374 (51.5)
Urgency setting	
Emergent catheterization	16 (2.2)
Elective catheterization	710 (97.8)
Anesthetic techniques	
General anesthesia	638 (94.8)
Intravenous sedation	38 (5.2)

The data are presented as mean ± standard deviation or n (%)
ASA = American Society of Anesthesiologists

ASA physical classification >3 (OR 31.61, 95% CI 8.62 to 115.89, $p<0.001$), patients with other concurrent medical problems (OR 3.98, 95% CI 1.22 to 13.05, $p = 0.023$, patients with cyanotic heart diseases (OR 16.02, 95% CI 2.08 to 123.09, $p = 0.008$), patient undergoing emergency catheterization (OR 14.66, 95% CI 3.65 to 58.85, $p<0.001$).

Discussion

Cardiac arrest is not uncommon in catheterization suite for both adult and pediatric catheterizations owing to nature of the patients and the procedures, which involve placing wires, catheters or therapeutic devices inside the ailing heart[11]. Since grave risks are undeniable, most of cardiac catheterization suites mandate the proximity to cardiac operating theater,

Table 2. Demographic data, diagnosis, type of procedure and outcome of patients with cardiac arrest

No.	Diagnosis	Type of catheterization	Age	Weight (kg)	CPR outcome	Status
1	dTGA, VSD	BAS	9 months	5.1	Successful	Discharged
2	CACV, severe pulmonary stenosis	Diagnostic	6 months	6.7	Successful	Discharged
3	CACV, severe pulmonary stenosis	Diagnostic	6 months	4.8	Successful	Death
4	UVH, TA, PA, obstructed TAPVC	Diagnostic	4 months	4.7	Unsuccessful	Death
5	dTGA, UVH, post pulmonary artery banding	Diagnostic	6 months	5.6	Successful	Discharged
6	UVH, pulmonary stenosis, DORV	Diagnostic	8 months	6.9	Successful	Discharged
7	Severe pulmonary stenosis, severe tricuspid regurgitation	PBPV	3 months	3.9	Successful	Discharged
8	HLHS s/p Norwood	Diagnostic	6 months	5.5	Unsuccessful	Death
9	dTGA, CACV, pulmonary stenosis	Diagnostic	11 months	7.2	Successful	Discharged
10	PA, IVS, severe tricuspid regurgitation	BAS	1 day	3.3	Successful	Death
11	UVH, PA, MAPCAs	Diagnostic	22 days	3.2	Successful	Death
12	HLHS	BAS	15 days	2.8	No CPR	Death
13	UVH, PA, MAPCAs	Diagnostic	7 days	2.3	Successful	Discharged
14	dTGA, UVH, TA	Balloon angioplasty	6 months	4.5	Successful	Discharged

dTGA = dextro-Transposition of the Great Arteries, VSD = Ventricular Septal Defect, BAS = Balloon Atrial Septostomy, CACV = Complete Atrio-Ventricular Canal, UVH = Uni-Ventricular Heart, TA = Tricuspid Atresia, PA = Pulmonary Atresia, TAPVC = Total Anomalous Pulmonary Venous Connection, DORV = Double Outlet Right Ventricle, PBPV = Percutaneous Balloon Pulmonary Valvuloplasty, HLHS = Hypoplastic Left Heart Syndrome, IVS = Intact Ventricular Septum, CPR = Cardiopulmonary Resuscitation, MAPCAs = Major Aorto-Pulmonary Collateral Arteries

equipment readiness i.e. extracorporeal membrane oxygenator [ECMO], intra-aortic balloon pump [IABP], mechanical compression devices, inhaled nitric oxide [iNO], etc, and also team supports i.e. nurse, radiologist, perfusionist, anesthesiologist, cardiac surgeon, etc.

During informed consent, possible serious cardiac events need to be mentioned to the patient (adult) or parents (pediatric patients). Fortunately, majority of dysrhythmias associated with the procedure are often predictable and also self-limited while cardiac arrest remains the ultimate unwanted complication which can lead to death[10]. The incidence of cardiac arrest during pediatric catheterization from this report is 1.9% which nearly double the number (0.96%) reported by Kirsten et al in 2014[10]. The number of post cardiac arrest with overall survival to discharge from this study is also less than that was previously reported (57% vs. 68.6%)[10]. Notably, the ECMO were employed in 26% of event in Kirsten's report[10] while only one patient in our study (7.1%) received ECMO.

Pediatric catheterization usually requires sedation or anesthesia. In certain scenario, a very few co-operative grown-up children may undergo a short procedure i.e. cardiac biopsy with no or minimal sedation from non-anesthesiologists[12]. Some institutions even have nurse-managed sedation program[10,12]. However, in our institution, all pediatric catheterizations were performed under care of the anesthesiologists. We performed general anesthesia in more than 94.8%.

The 1.9% incidence of cardiac arrest in this study is considered more prevalent than 8.2 in 10,000[13] which was reported as an overall peri-operative cardiac arrest between 1999 and 2001 in the same hospital where majority of patients and procedures were non-cardiac. This is consistent with the report from literatures[8,9]. However, the time frame is nearly a decade apart. Hence, a fair comparison can only be made if the new report becomes available.

Effective CPR remains an important key to restore spontaneous circulation[14]. Over the past few decades, the CPR training has evolved tremendously. As of current, nearly all healthcare providers at our hospital stay updated with their ACLS (Advanced Cardiac Life Support) certificate. In the present study, the success rate of CPR was at 84.6%. Only 1 case required an ECMO support which is a low number when compared to the other reports[10,15]. However, this CPR success does not represent the overall survival.

Multiple contributing factors to cardiac arrest

Table 3. Patient's variables and association with in-procedure cardiac arrest

Variables	Cardiac arrest		Crude OR (95% CI)	*p*-value
	No (n = 712)	Yes (n = 14)		
Age				
<1 month (0 to 30 day)	17 (81.0)	4 (19.0)	148.0 (15.7, 1395.3)	<0.001*
>1 month to 1 year (31 to 365 day)	66 (88.0)	9 (12.0)	85.8 (10.7, 687.6)	<0.001*
>1 year (>365 day)	629 (99.8)	1 (0.2)	1	
Size				
≤5 kg	48 (85.7)	8 (14.3)	18.44 (6.15, 55.32)	<0.001*
>5 kg	664 (99.1)	6 (0.9)	1	
Sex				
Male	340 (97.7)	8 (2.3)	1.46 (0.50, 4.25)	0.489
Female	371 (98.4)	6 (1.6)	1	
ASA Classifications				
ASA I-III	638(99.5)	3 (0.5)	1	
ASA IV-V	74 (87.1)	11 (12.9)	31.61 (8.62, 115.89)	<0.001*
Comorbidities				
Yes	65 (4.2)	4 (5.8)	3.98 (1.22, 13.05)	0.023*
No	647 (98.5)	10 (1.5)	1	
Types of congenital heart disease				
Acyanotic	393 (99.7)	1 (0.3)	1	
Cyanotic	319 (96.1)	13 (3.9)	16.02 (2.08, 123.09)	0.008*
Types of procedure				
Diagnostic	343 (97.4)	9 (2.6)	1	
Interventional	369 (98.7)	5 (1.3)	0.52 (0.17, 1.56)	0.240
Anesthetic techniques				
General anesthesia	674 (98.0)	14 (2.0)	-	0.468
Intravenous sedation	38 (100)	0		
Urgency grading				
Emergent catheterization	13 (81.3)	3 (18.8)	14.66 (3.65, 58.85)	<0.001*
Elective catheterization	699 (98.5)	11 (1.5)	1	

The data are presented as n (%)
* $p<0.05$ indicates statistical significance
ASA = American Society of Anesthesiologists, OR = Odds Ratio, CI = Confidence Interval

were identified from this study include neonates, small children (weight less than 5 kg), emergency cases, the sicker children (ASA III-V, cyanotic, patients with comorbidities). We found no associations between anesthetic technique and cardiac arrest. All of these findings are consistent with those reported previously[10]. However, we are unable to identify the interventional catheterization as a contributing factor to cardiac arrest.

Limitations

The present study had several limitations. First, the retrospective chart review rendered us to have no control of many variables. The quality and clarity of individual chart and note and completeness of database had direct influence on the data collection. There is a concern of the under-reported cardiac events since brief episode of no perfusion can be missed easily. Majority of non-perfusing rhythms were transient and self-terminated upon removal of wires and catheters. However, the events that lead to an obvious cardiac massage were not missed. Only the brief episode of cardiac events that resolved spontaneously, by electrical or pharmacological intervention could be under reported. Secondly, the low incidence nature of cardiac arrest is one of the prohibitive factors to perform a multivariate analysis which may have a better predictability. Lastly, the authors were unable to clarify the causes of cardiac arrest. There are multiple criteria of how to determine the cause of cardiac arrest in terms

of procedure or anesthesia related[16-18]. We are also unable to probe into the correlation between experienced anesthesiologists versus the junior staffs or between those with subspecialty training compare to those with none. The larger multi-center cohort study may be required to provide those answers.

Conclusion

The incidence of cardiac arrest among children with congenital heart undergoing cardiac arrest is higher than the incidence in general population undergoing non-cardiac procedure. The event can lead to morbidity and mortality. The potential associating factors are small neonates and children, those with comorbidities or cyanotic cardiac defects and emergent catheterization.

What is already known on this topic?

Cardiac arrest during catheterization in pediatric patients with congenital heart diseases is high when compared with pediatric non cardiac surgery. While majority of patients responded to standard CPR and Pediatric Advanced Life Support [PALS] and resume spontaneous circulation, there are number of patients who require ECMO or do not survive to hospital discharge. The identified contributing factors include patient at young age, patient with small size, patient with co-morbidities.

What this study adds?

This is the first national report of cardiac arrest in pediatric catheterization. There are some similarities when compare to reports from western population i.e. the incidence is higher when compare to the incidence of overall cardiac arrest in patients undergoing surgery. However, this study found cardiac arrest during pediatric catheterization in our institution is nearly doubled of those previously reported. Limited ECMO uses may affect the survival.

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Potential conflicts of interest

The authors declare no conflict of interest.

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