

Is it Safe to Perform Cardiac Catheterizations on Adults With Congenital Heart Disease in a Pediatric Catheterization Laboratory?

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Objective: To determine the complication rate during the catheterization in adults with congenital heart disease (CHD) in a pediatric catheterization laboratory (PCL). **Background:** An increasing number of patients with CHD are surviving into adulthood, with diagnostic and interventional cardiac catheterization being essential for the management of their disease. The complication rate during the catheterization of adults with CHD has not been reported. **Methods:** A retrospective chart review was performed on all adult patients (>18 years) with CHD who underwent diagnostic or interventional catheterization in our PCL within the past 8.5 years. **Results:** A total of 576 procedures were performed on 436 adult patients (median age 26 years). Complex heart disease was present in 387/576 (67%) procedures. An isolated atrial septal defect or patent foramen ovale was present in 115/576 (20%) procedures, and 51/576 (9%) procedures were performed on patients with structurally normal hearts with arrhythmias. Interventional catheterization was performed in 378/576 (66%) procedures. There were complications during 61/576 (10.6%) procedures; 19 were considered major and 42 minor. Major complications were death (1), ventricular fibrillation (1), hypotension requiring inotropes (7), atrial flutter (3), retroperitoneal hematoma, pneumothorax, hemothorax, aortic dissection, renal failure, myocardial ischemia and stent malposition (1 each). The most common minor complications were vascular entry site hematomas and hypotension not requiring inotropes. Procedures performed on patients ≥ 45 years of age had a 19% occurrence of complications overall compared with 9% occurrence rate in patients of age < 45 years ($P < 0.01$). **Conclusions:** The complication rate during the catheterization of adults with CHD in a PCL is similar to the complication rate of children with CHD undergoing cardiac catheterization. The older subset of patients are more likely to encounter complications overall. The encountered complications could be handled effectively in the PCL. With screening in place, it is safe to perform cardiac catheterization on most adults with CHD in a PCL. © 2005 Wiley-Liss, Inc.

Key words: congenital heart disease; cardiac catheterization; complications

INTRODUCTION

During the last two decades, dramatic advances have been made in the management of congenital heart disease (CHD). Approximately 85% of infants born today

with CHD are expected to live into adulthood [1–5]. Many of these adult patients will require diagnostic or interventional cardiac catheterization for management of their CHD. Furthermore, adults with atrial septal defect (ASD) and patent foramen ovale (PFO) are

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undergoing cardiac catheterization for percutaneous closure of these defects [6]. Although the safety of performing catheterization in pediatric and adult patients has been reported, there is no data on the complication rate in performing cardiac catheterization in adults with CHD. The following study evaluates the overall complication rate during diagnostic and therapeutic cardiac catheterization of adults with CHD in a pediatric catheterization laboratory (PCL).

METHODS

A retrospective chart review was performed on all patients aged ≥ 18 years who underwent cardiac catheterization in our PCL situated in a free-standing children's hospital, between January 1996 and October 2004. Technical and nursing staffs in the PCL were ACLS certified. Informed consent was obtained prior to the catheterization in all patients. Patients older than 30 years were initially screened by either an adult or pediatric cardiologist for evidence of ongoing ischemic heart disease with a complete medical history, electrocardiogram, echocardiogram, and stress testing as applicable. Patients with poorly controlled ischemic heart disease were referred to an adult cardiologist for management of the ischemic heart disease; after which they could be sent back to the PCL for the procedure. Patient age, weight, gender, diagnosis, history of arrhythmias, hypertension, stroke, NYHA classification, and other comorbid conditions were noted. Diagnoses were classified into complex CHD, minor CHD (ASD/PFO/patent ductus arteriosus/aorto-pulmonary collaterals), or anatomically normal hearts with arrhythmias. The procedures were classified as either diagnostic or interventional. Complications associated with the catheterization were considered major (unanticipated complications within 24 hr of the procedure that required intervention, close observation, or resulted in death) or minor (all other complications). Arrhythmias occurring during electrophysiology study or with catheter manipulation were not included. Other data including use of general anesthesia and length of hospital stay were noted. Patients were arbitrarily divided into two groups based on age (group 1: patients < 45 years of age, and group 2: patients ≥ 45 years of age).

Statistical Analysis

All data are presented as sample number with percentages in parenthesis, unless otherwise indicated. Continuous variables are expressed as mean (\pm SD) or median (range). Comparisons on categorically scaled variables between groups were examined using a non-parametric Fisher's exact χ^2 test. Statistically significant differences in means or proportions were considered achieved at a P -value ≤ 0.05 , two-tailed. All statistical

TABLE I. Demographics and Clinical Characteristics

	<i>N</i>
Age (yrs) Median (range)	26 (18–78)
Males (%)	285 (49)
Weight (kg) Median (range)	67 (31–164)
Reason for cardiac catheterization	
Diagnostic (%)	193 (34)
Interventional (%)	378 (66)
Missing data (%)	5 (0.7)
Disease classification	
Minor CHD (%)	134 (23)
Complex CHD (%)	387 (67)
Arrhythmias only (%)	51 (9)
Assumed PFO (%)	4 (0.7)
Hypertension (%)	39 (7)
Stroke/transient ischemic attack (%)	86 (15)
NYHA Classification III and IV (%)	73 (16)
General anesthesia (%)	310 (53)
Medications (at least three medications) (%)	135 (23)

analyses were performed using Microsoft Excel and SPSS Version 11.5.

RESULTS

Baseline demographic and clinical data for the patient population are given in Table I.

A total of 576 catheterizations were performed on 436 adult patients during the 8.5-year study period. Complex CHD was present in 387/576 (67%) procedures. The most common complex CHDs were: Tetralogy of Fallot with complete repair, 74/387 (19%); Fontan palliation for single ventricle, 62/387 (16%); simple transposition of the great arteries with Mustard palliation, 55/387 (14%); and semilunar valve stenosis, 44/387 (11%). Minor CHD was present in 134/576 (24%) procedures, including 115/576 (20%) isolated ASD/PFO. In addition, there were four procedures in which a transesophageal echocardiogram (TEE) performed at an outside institution indicated a PFO, but no PFO was seen upon repeating a TEE in our PCL prior to cardiac catheterization. Arrhythmia diagnosis/treatment was performed in 51/576 (9%) procedures in patients with structurally normal hearts. Only 3/576 ($< 1\%$) procedures were performed on patients with known stable coronary artery disease. There were no patients with poorly controlled ischemic heart disease that required an urgent/semiurgent CC in the PCL. General anesthesia was used in 310/576 (54%) procedures of which 237 (76%) were interventional procedures.

Interventional catheterization was performed in 378/576 (66%) procedures (Table II). Percutaneous closure of ASD/PFO was the most common interventional procedure. General anesthesia was used during 75% of the ASD/PFO procedures. Intracardiac echocardiography was not available during the study period.

TABLE II. Distribution of Interventional Cardiac Catheterizations

Procedures	<i>n</i> (%)
ASD/PFO closure	115 (30.6)
Pacemaker placement	86 (23)
Radio-frequency ablation	49 (13)
Angioplasty (pulmonary artery or systemic vein)	49 (13)
Others ^a	26 (7)
Valvuloplasty	21 (5.6)
Biopsy	20 (5.3)
Coarctation stent/angioplasty	6 (1.6)
Angioplasty + pacemaker placement	5 (1.3)
Biopsy + pacemaker placement	1 (0.3)

^aIncludes PDA or aortopulmonary collateral coil embolization, balloon pericardiotomy, and thrombectomy.

Patients in group 1 (age < 45 years) made up 480/576 (83%) procedures and patients in group 2 (age ≥ 45 years) made up 96/576 (17%) procedures (Table III). The occurrence of NYHA class 3 or 4 failure was not statistically different between group 1 and group 2. The presence of complex CHD was significantly greater in group 1 than in group 2 (77% vs. 19%; $P < 0.01$).

Patients older than 30 years were transferred from the PCL to the adjacent adult hospital if overnight stay was required for recovery (hospital policy). This occurred in 17.5% of the procedures.

Discharge from the hospital within 24 hr of the procedure was accomplished in 508/576 (89%) procedures.

Complications. A total of 61 (10.6%) complications were encountered. There were 19 (3.2%) major and 42 (7.3%) minor complications. Hypotension was classified under major complications if inotropic support was required in addition to fluid resuscitation and under minor complications if fluid resuscitation alone was sufficient.

Major complications. Major complications (Table IV) were encountered during 10/387 (2.5%) procedures in patients with complex CHD, in comparison to 9/189 (4.8%) procedures in patients without complex CHD ($P = \text{NS}$). More than half of the major complications (12/19) occurred during interventional procedures. The only death occurred in a 26-year-old patient during pacemaker placement because of postoperative complete atrioventricular block. The patient developed ventricular tachycardia that degenerated into fatal ventricular fibrillation. Major complications during device closure of ASD/PFO occurred in 7 patients of whom 3 had atrial flutter and 2 encountered hypotension. At follow-up of patients encountering atrial flutter, all 3 patients were in sinus rhythm and off anti-arrhythmic medication. Hypotension as a complication was seen in 7 procedures of which 6 were performed under general anesthesia. All episodes of hypotension are resolved by

the end of the catheterization procedure with use of inotropic drips. ST segment elevation in the inferior leads was observed during closure of a PFO in one patient with a history of coronary artery bypass surgery. The elevation was transient and responded to administration of nitroglycerin and oxygen. There was no correlation between NYHA class and major complications.

Minor complications. Minor complications (Table V) occurred in 42/576 (7.3%) catheterizations. The most frequent minor complications were vascular access site hematoma ($n = 20$) and isolated transient hypotension ($n = 5$) that was responsive to volume resuscitation. All vascular site hematomas resolved spontaneously within 1 week of the procedure.

Comparison between groups 1 and group 2. Complications, overall, were significantly more likely to occur in group 2 in comparison to group 1 ($P < 0.01$). There were no significant differences between group 1 and group 2 with regard to number of major complications (Table V). Group 2 had a significantly higher incidence of minor complications ($P < 0.05$). Group 2 was also significantly more likely to have hypotension (requiring fluid and/or inotropes) (7/96) compared with that of group 1 (5/480), $P = 0.001$. There was no significant difference in the incidence of hematomas between the two groups.

DISCUSSION

Cardiac catheterization of adults with CHD presents a unique situation. Although adult cardiologists are clearly more experienced in performing adult catheterizations and in dealing with other comorbid adult issues, pediatric cardiologists have more experience in catheterization of patients with CHD. Also, a PCL has biplane imaging with its obvious advantages for a patient with complex CHD. With the prevalence of adults with CHD becoming greater, the question arises as to who is better equipped to treat this growing population. The optimal place to perform catheterization on adults with CHD has also not been determined. Additionally, although the complication rate for cardiac catheterizations in infants and children with CHD [7–11] and in adults with acquired heart disease is known [12,13], there is no information on the complication rate in performing cardiac catheterizations in adults with CHD.

In this study of adults with CHD catheterized in a pediatric facility, the overall complication rate was 10.6% with a mortality rate of 0.17%. This is similar to the reported complication rate of 8–12% and mortality rate of 0.14–0.5% for pediatric patients with CHD catheterized in a pediatric facility [7–11]. However, it must be noted that this comparison is with studies per-

TABLE III. Comparison of Procedures Performed on Patients <45 Years or ≥45 Years

	Group 1 (age <45 yrs; <i>n</i> = 480) (%)	Group 2 (age ≥ 45 yrs; <i>n</i> = 96) (%)	<i>P</i>
Mean age ± SD (yrs)	26 ± 7	54 ± 7.7	<0.01
Males	250	34	<0.01
NYHA failure class 3 or 4	58 (12)	15 (16)	0.31
Coronary artery disease	0	3 (3)	<0.01
Complex CHD	369 (77)	18 (19)	<0.01
Procedures on patients with TGA with Mustard repair or Tetralogy repair or Fontan palliation in the complex CHD group	189 (39)	2 (2)	<0.01
Number of interventional catheterizations	300 (63)	78 (80)	<0.01
ASD/PFO closure (% of all procedures)	47 (9.8)	68 (70)	<0.01
Pacemaker placement	83 (17)	3 (3)	<0.01
Complications	43 (9)	18 (19)	<0.01
Minor Complications	30 (6.3)	12 (11.5)	0.04
Major Complications	13 (2.7)	6 (6.3)	0.10
Hypotension (requiring fluids and/or inotropes)	5 (1)	7 (7)	<0.01

TABLE IV. Major Complications

Complication	Age (yrs)	Diagnosis	Procedure	Disposition
1. Sustained ventricular tachycardia/fibrillation	26	VSD repaired, complete AV block	Pacemaker placement	Death
2. Ventricular fibrillation	31	Complex single ventricle s/p Fontan	Diagnostic	Defibrillation
3. Atrial flutter	52	PFO	PFO closure	Institution of antiarrhythmic medication
4. Atrial flutter	44	ASD	ASD closure	Institution of antiarrhythmic medication
5. Atrial flutter	55	ASD	ASD closure	Institution of antiarrhythmic medication
6. Hemothorax	25	Tricuspid atresia s/p Fontan	Hemodynamic evaluation	Placement of chest tube
7. Pneumothorax	25	Truncus arteriosus repaired, AV block	Pacemaker placement	Placement of chest tube
8. Retroperitoneal hematoma	37	PFO	PFO closure	Spontaneous resolution; no intervention
9. Aortic dissection	40	Coarctation of aorta	Stent placement	Antihypertensive drips
10. Renal failure	19	DILV, s/p Fontan; congestive heart failure	Coil embolization of collaterals	Dialysis
11. Balloon rupture/stent malposition	18	L-TGA, VSD, PS s/p repair	Stent placement in conduit	Repositioning of stent
12. Hypotension	52	Assumed PFO	TEE, right heart catheterization	Inotrope infusion
13. Hypotension	22	Tetralogy of Fallot/pulmonary atresia	Hemodynamic evaluation	Inotrope infusion
14. Hypotension	65	Assumed PFO	TEE, right heart catheterization	Inotrope infusion
15. Hypotension	18	TGA/Mustard repair	Hemodynamic evaluation	Inotrope infusion
16. Hypotension	40	PFO	PFO closure	Inotrope infusion
17. Hypotension	24	Pulmonary atresia/intact ventricular septum	Hemodynamic evaluation	Inotrope infusion
18. Hypotension	52	ASD	ASD closure	Inotrope infusion
19. ST segment elevation	58	PFO	PFO closure	Nitroglycerin and oxygen

AV block= atrio-ventricular block, DILV= Double Inlet Left Ventricle, PS= Pulmonic Stenosis, TEE= Trans Esophageal Echocardiography, TGA= Transposition of the Great Arteries.

formed at least 5 years ago; there are no other recent studies available. The rate is also similar to the complication rate of 8% and a mortality rate of 0.2% in adults catheterized at an adult facility secondary to acquired

heart disease [12,13]. In our experience, major complications were not significantly associated with the older subset of patients, interventional procedures, or with procedures on patients with complex CHD.

TABLE V. Minor Complications

	<i>n</i>
Hematoma (access site) ^a	20
Hypotension	5
Urethral Trauma – Foley induced	1
Angioplasty balloon rupture	4
Atrial Flutter	2
Ventricular Tachycardia	1
Hypoxia	2
Hemoptysis	1
Airway obstruction	1
Arm numbness, back ache	1
Laceration at venipuncture site	1
Anaphylaxis not requiring intubation	1
Ileus post CC	1
Renal colic	1

^aOne patient in the study group had a hematoma along with hypotension.

One concerning complication encountered in performing cardiac catheterization in adults in our PCL was that of hypotension. Although 9 of 12 patients who developed hypotension during cardiac catheterization received general anesthesia, because of the small numbers, the use of general anesthesia did not reach statistical significance as a causative factor. In our experience, patients > 45 years old were significantly more likely to develop hypotension. A blunted heart rate response to vasodilatation secondary to anesthesia is the most likely etiology in these patients. This is a potentially significant issue in the patient having a past history of a cerebral vascular accident or ischemic heart disease. It has become our practice that during induction of anesthesia, the blood pressure is measured noninvasively every 2 min, and if there is any concern, an arterial line is placed for the patient.

Of the other major complications encountered, most were related to the technical aspects of performing the particular intervention. The incidence of atrial flutter during device closure of ASD/ PFO has been reported at 4% in the literature [14], which was similar to our experience (2.6%). In two other patients, technical complications during stent placement for treatment of native coarctation of the aorta and conduit stenosis were encountered. We believe that in each of these situations, performance of the catheterization procedure in a PCL was not felt to have played a role in encountering these particular major complications.

Only 3 patients had coronary artery disease in the study population. It is expected that with an older population we would have had a higher percentage of coronary artery disease. Our strategy, however, would have remained the same: we would have referred a poorly controlled patient to the adult cardiologist for optimization of therapy prior to taking the patient to the PCL.

Notably, none of the 96 patients with age \geq 45 years had a CHD-related urgent or semi-urgent issue that necessitated a CC in a PCL prior to optimization of therapy for other comorbid conditions.

The 32nd Bethesda Conference on adults with CHD [15] emphasized the need for creation of regional adult CHD centers where adult and pediatric cardiologists would collaborate in the care of such patients under one roof. This would be the ideal situation. Until such time that these centers are widespread, our results suggest that the PCL may be a safe place for cardiac catheterization of adults with CHD after appropriate screening.

Limitations. This study is limited by its retrospective nature.

CONCLUSIONS

This study suggests that adults patients with CHD undergoing catheterization in a PCL have a complication risk equal to that of children with CHD undergoing catheterization. The older subset of adult patients are more likely to encounter complications overall. In older patients with CHD, general anesthesia should be used only when necessary and invasive blood pressure monitoring may be prudent under certain circumstances. With screening in place, it is safe to perform cardiac catheterization on most adults with CHD in a PCL.

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