CRIMSON PUBLISHERS
Wings to the Research

Open Journal of
Cardiology & Heart Diseases

ISSN 2578-0204

Mini Review

Pediatric Cardiac Catheterization

Hala Agha*

Cairo University, Egypt

***Corresponding author:** Hala Agha, Cairo University, 1 Aly Basha Ibrahim-Kasr Aini, Egypt, Tel: 0202-01000113284; Email: halaazza@gmail.com

Submission: January 06, 2018; **Published:** August 31, 2018

Abstract

The purpose of this review is to discuss the common diagnostic and intervention pediatric cardiac catheterizations; their indications and timing for the most common congenital heart defects. Balloon pulmonary valvuloplasty is the treatment of choice for valvular pulmonary stenosis and the indication for intervention is peak-to-peak systolic pressure gradient >50mmHg across the pulmonary valve. For aortic valve stenosis, the indications for balloon dilatation of aortic valve are peak-to-peak systolic pressure gradient across the aortic valve more than 70mmHg irrespective of the symptoms or a gradient ≥50mmHg with either symptoms or electrocardiographic ST-T wave changes indicative of myocardial perfusion abnormality. The indications for intervention in coarctation of the aorta are significant hypertension and/or a pressure gradient in excess of 20mmHg across the coarctation. For post-surgical aortic recoarctation, balloon angioplasty in young children and stents in adolescents and adults are treatment options. Transcatheter closure methods are currently preferred for secundum type of atrial septal defects (ASDs); the indications for occlusion are right ventricular volume overload by echocardiogram. Muscular VSDs may be closed with Amplatzer muscular occluder device. Patent ductus arteriosus (PDA) may be closed with Amplatzer Duct Occluder if they are moderate to large and Cook detachable or PFM coils if they are small. The development of an increasingly wide range of interventional devices in a variety of sizes has led to a significant increase in the number of conditions which are now amenable to treatment in the cardiac catheter laboratory.

Introduction

Over the last half century, cardiac catheterization laboratories have evolved from highly specialized research laboratories into heavily used procedure rooms in which an extensive array of diagnostic tests and therapeutic interventional procedures are performed on millions of patients yearly [1].

Diagnostic Catheterization

With the development of cross-sectional echo-cardiography and the subsequent introduction of MRI and fast computed tomographic methods, truly diagnostic cardiac catheterization is a thing of the past for both children and adults. "Diagnostic" catheterization is reserved for resolving unanswered questions from the less-invasive techniques and measuring hemodynamics [2]. However, the diagnostic cardiac catheterization remains the "final authority" for definitive anatomic and hemodynamic information for many of the very complex lesions [3]. Catheterizations usually include right and left heart catheterization, multi-chamber oximetry assessments, calculations of left-to-right and right-to-left shunts, and pulmonary and systemic vascular resistance [4].

Indications of Diagnostic Catheterization in Pediatrics

A. Assessment of pulmonary hypertension and its responsiveness to medical therapy. This may be the case in patients with CHD in whom an accurate assessment of pulmonary resistance is needed to make surgical and medical decisions [5].

B. In patients with complex pulmonary atresia for the detailed characterization of lung segmental pulmonary vascular supply, especially when noninvasive imaging methods incompletely define pulmonary artery anatomy [3].

C. In determination of coronary circulation in pulmonary atresia with intact septum [4].

D. Evaluation of specific problems after surgical management of congenital defects as in situations in which excessive desaturation occurs after a systemic-to-pulmonary artery shunt has been created, catheterization is useful to exclude branch pulmonary artery stenosis and shunt stenosis or occlusion.

E. To determine pulmonary pressure/resistance and transpulmonary gradient in palliated single-ventricle patients before a staged Fontan procedure [6].

F. Low-flow lesions for which calculation of pulmonary arteriolar resistance can be misleading may be best studied by combining angiographic assessment of pulmonary artery anatomy and transit time with pulmonary artery pressures. This is often the case in the assessment of patients after cavopulmonary anastomosis and after Fontan completion [7].

G. In patients being assessed for cardiac transplantation unless the patient's risk for catheterization outweighs the

potential benefit [8].

H. For surveillance of graft vasculopathy after cardiac transplantation [9].

I. Assessment of coronary circulation in some cases of Kawasaki disease in which coronary involvement is suspected or requires further delineation or in the assessment of suspected congenital coronary artery anomalies [10].

Interventional Catheterization for Pediatric Congenital Heart Disease

Most pediatric cardiac catheterizations are now done for therapeutic purposes. Transcatheter therapeutic techniques are available for a wide array of congenital cardiac malformations [10]. Therapeutic catheter procedures in congenital heart diseases.

1. Balloon (or blade) atrial septostomy,
2. Pulmonary valve dilation,
3. Aortic valve dilation,
4. Pulmonary artery dilation,
5. Pulmonary artery stent,
6. Coarctation dilation,
7. Coarctation stent,
8. Ductus arteriosus stent,
9. Vena cava dilation or stent,
10. Collateral vessel occlusion,
11. Ductus arteriosus occlusion,
12. Atrial septal defect occlusion,
13. Ventricular septal defect occlusion [10].

Opening of atrial communications: transseptal techniques

An atrial transseptal approach is indicated whenever access to the left side of the heart, and in particular the left atrium, is desired and a preexisting communication between the right and left heart is not present or, when present, cannot be crossed readily from the right side of the heart. An atrial transseptal puncture/perforation from the right atrium into the left atrium provides dependable, direct access to the left atrium in the presence of a previously intact atrial septum [3]. Radiofrequency transseptal perforation is a technique that was developed relatively recently. Radiofrequency energy is used to perforate the atrial septum; this technique is particularly useful in very small patients with small left atria (such as the newborn with a hypoplastic left heart) or when there is no direct femoral approach or ability for a needle to impinge on or be pushed forcefully through the atrial septum [11]. Atrial Septostomy: The survival of patients with certain forms of CHD (eg, tricuspid valve atresia, hypoplastic left heart and D-TGA) depends on unrestricted communication between the left and right atria [3]. The creation of an atrial communication is typically performed in the cardiac catheterization laboratory. The exception is routine balloon atrial septostomy in newborns performed at the bedside with echocardiographic guidance [3].

Transcatheter defects device closure

ASD secundum: Several studies have shown outcomes from transcatheter device closure of secundum ASD to be comparable to surgical outcome in carefully selected adult and pediatric patients. Device closure of secundum ASD is associated with low complication rates, short anesthetic times and short hospitalizations but it also carries a risk of embolization, arrhythmia, thromboembolism and rarely erosion [12].

Ventricular septal defects: Surgical closure for patients with peri-membranous VSD is safe and effective and is considered the therapeutic option of choice in infants and children <3 years of age. Currently, there are no approved devices with which to close peri-membranous VSD in the United States, but the utility of membranous VSD occluding devices is being tested internationally [3]. The defects that may be suitable for percutaneous closure are located within the muscular septum (mVSD) or in the peri-membranous septum (pmVSD) with or without aneurysm, and they can be native or residual post-surgery [13].

Patent ductus arteriosus: Transcatheter closure has become a standard of care at many centers except in very low birth weight patients or those with unsuitable anatomy, such as the type B PDA (also known as the AP window type) [14]. Indications for PDA occlusion are elimination of pulmonary over circulation and subsequent development of obstructive pulmonary vascular disease, as well as prevention of endocarditis/endarteritis [15].

Patent ductus arteriosus stenting

Stenting of the ductus arteriosus as a means to establish a reliable source of pulmonary blood flow for palliation of cyanotic heart disease is a relatively new transcatheter intervention. Compared with surgical alternatives, ductal stenting is attractive because it can avoid 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 The initial results of ductal stenting were not favorable because of technical failures and early ductal restenosis., During the past decade, however, results have improved for ductal stenting in selected infants with cyanotic CHD [16].

Transcatheter balloon dilation of cardiac valves

Pulmonary valvuloplasty: First reported in 1982, it remains the treatment of choice for valvar pulmonary stenosis in patients of all ages. Balloon dilation is not useful for treatment of infundibular pulmonary stenosis unassociated with pulmonary valve stenosis [17].

Aortic valvuloplasty: First described in the early 1980s, balloon dilation has replaced open surgical valvotomy as the treatment of choice for children with severe congenital valvular AS. The technique is widely regarded as the therapy of first choice for children with valvular AS of sufficient severity to warrant intervention. However, it cannot be considered curative because important valve regurgitation will occur in some patients and valve restenosis will eventually occur in the majority of patients late after the dilation procedure.

Mitral valvuloplasty: Surgical repair of mitral valve stenosis in infants and young children has high mortality and morbidity, so, the less invasive transcatheter technique remains a reasonable alternative, although the results remain variable, in part because of the varied morphology of the mitral valve stenosis. Balloon dilation procedures can have good immediate and even midterm relief of gradients, but progressive mitral regurgitation and restenosis remain problematic [3].

Transcatheter balloon angioplasty and/or stent placement for obstructive lesion

Native coarctation and recoarctation: Treatment of coarctation of the aorta has evolved over the years. For native coarctation of the aorta, initially, surgical repair has been the primary treatment at most centers and remains the "gold standard" therapeutic option. However, in recent years, balloon angioplasty with or without stent implantation has emerged as an alternative, less invasive option. For most patients with discrete recurrent/residual coarctation after surgical repair, balloon angioplasty has been shown to be the best therapeutic option. Stent implantation for native coarctation or recoarctation of the aorta has also emerged as a beneficial therapeutic option for patients who can receive a stent that can be expanded to an adult size (minimum of 2cm in diameter). In theory, stent implantation provides the potential for long-term repair with less chance of coarctation recurrence or aneurysm formation, but of course, the long-term benefit has yet to be proven.

Pulmonary artery stent placement: Pulmonary artery stents are indicated in main or branch pulmonary artery stenosis that is not expected to have, or has not had, an adequate or persistent response to primary pulmonary artery balloon dilation. Intravascular stents are effective for congenital stenosis, surgically created stenosis of vessels, or stenosis due to compression from an adjacent structure.

Systemic venous balloon angioplasty and stenting: Systemic venous stenosis occurs as a congenital defect, subsequent to surgery on the venous system, from indwelling lines in the veins or from external compression. Isolated balloon angioplasty is seldom indicated as the definitive treatment of systemic venous stenosis/occlusions, with most of these lesions currently being treated with intravascular.

Pulmonary veins: Pulmonary veins stenosis can present as an isolated congenital lesion or in association with other cardiac defects. It can also be acquired after corrective surgery for various anomalous pulmonary venous connection or after lung transplantation. The use of stents for treatment of pulmonary veins stenosis has been limited to children who either develop pulmonary vein stenosis after surgical repair of associated CHD or those with congenital pulmonary vein stenosis.

Conduit intervention: Primary intravascular stent implantation is indicated for the treatment of significant stenosis of an RV-to–main pulmonary artery/pulmonary artery conduit when there is a predominant and significant stenosis of the conduit and it is believed that the stent will significantly prolong the life of the conduit before further intervention becomes necessary, the pulmonary regurgitation created will be tolerated better than the stenosis and the stent definitely will not impinge on the pulmonary artery bifurcation or compromise the coronary circulation by compression.

Transcatheter vascular occlusion

Aortopulmonary collateral vessels: Transcatheter occlusion of the aortopulmonary collateral vessels is indicated for treatment of aortopulmonary collateral vessels in the followings:

1. Aortopulmonary collateral vessels with documented large left-to-right shunting in biventricular or single ventricle physiology that results in congestive heart failure, pulmonary overcirculation and respiratory compromise or development of pleural effusion or protein-losing enteropathy

2. In the presence of moderate-sized collaterals found in asymptomatic single-ventricle patients undergoing routine pre-Glenn or pre Fontan cardiac catheterization

3. In association with surgical consultation in patients with pulmonary atresia and aortopulmonary collaterals that have adequate dual supply from native pulmonary arteries

Surgically created systemic-to–pulmonary artery shunts: The use of surgical aortopulmonary shunts such as the Blalock-Taussig shunt (BTS) for palliation of cyanotic CHD has waned in favor of more definitive surgical repair. As patients progress through more advanced surgical correction, alternate flow may become unnecessary and with prolonged patency, shunts may compromise more anatomically and physiologically (surgically) corrected blood flow.

Transcatheter occlusion of other vascular abnormalities:

1. Coronary fistulae may arise from the right or left coronary artery and drain most commonly into the right atrium, ventricle, or pulmonary artery. Thrombosis within the fistula is rare but may cause acute myocardial infarction, paroxysmal atrial fibrillation and ventricular arrhythmias. Embolization can be performed with coils or other occluding devices.

2. Pulmonary arteriovenous malformations (PAVMs) are abnormal direct connections between the pulmonary arteries and veins (bypassing the capillaries); although uncommon, they

may be life-threatening. Transcatheter occlusion is recommended for all symptomatic patients and for asymptomatic patients with discrete lesions with feeding arteries ≥3mm in diameter to prevent neurological complications and progressive cyanosis

3. Paravalvar Leaks: Occlusion of paravalvular leak (PVL) from a surgically placed artificial mitral or aortic valve is indicated for a significant leak that causes heart failure or hemolysis that requires recurrent blood transfusions

Electrophysiologic Catheterization

The diagnosis and treatment of arrhythmias in children is challenging, since the knowledge for arrhythmias in pediatric patients is borrowed from data retrieved from the adult population. However, the causes of arrhythmias in adult groups are considerably different, where in children, arrhythmias are closely associated with changes in the development of the cardiac conduction system. For many years, antiarrhythmic drugs were the only available treatment for arrhythmias. In 1987, radiofrequency (RF) catheter ablation was introduced for treatment of adult patients, and since 1989 has been performed as a treatment modality for tachyarrhythmias in pediatric patient. The success rate associated with RF ablation is high and the rate of severe complications is low.

Complications of Cardiac Catheterization

Over the last decade, the use of cardiac catheterization as a primary treatment modality in children with congenital cardiac lesions has increased. However although there has been a considerable improvement in device design, equipment and the skills of the interventionalist, associated risks continue to complicate these procedures. This is particularly true with the expansion of the pediatric cardiac catheterization which has been shifted from a primary anatomic hemodynamic diagnostic tool to therapeutic intervention one. So, the anesthesiologist together with catheterization team needs to be familiar with all types of emergent adverse events and their specific management protocols to maintain a high level of patient care with minimal complications. These adverse events may be catheterization related events, access related events, sedation related events, transfusion related events and events related to special intervention technique. Adverse events were defined as adverse events related to the catheterization procedure, identified during or after the procedure resulting in a change in patient condition, life-threatening if not treated, requiring major intervention, such as invasive monitoring or major transcatheter bailout procedure, and resulting in death and emergency surgery or failure to wean from extracorporeal membrane oxygenation.

Complications encountered in cardiac catheterization laboratory

Cardiovascular complications: Arrythmias, cardiac Perforation, low cardiac output & hypotension, embolism, valvular damage, paroxysmal pulmonary artery hypertension crisis (PPHC)

Respiratory complication hypoventilation, pneumothorax

Vascular complications: Bleeding, hematomas, acute arterial occlusion, vascular thrombosis, retroperitoneal hemorrhage, arteriovenous fistula, pseudoaneurysm, infection: cellulitis at the site of access is rare

Others: Hypothermia, blood Loss, complications related to contrast injection.

References

1. Bashore T, Balter S, Barac A (2012) American college of cardiology foundation/society for cardiovascular angiography and interventions expert consensus document on cardiac catheterization laboratory standards update a report of the american college of cardiology foundation task force on expert consensus documents developed in collaboration with the society of thoracic surgeons and society for vascular medicine. J Am Coll Cardiol 59(24): 2221-2305.
2. Roest AW, de Roos A (2012) Imaging of patients with congenital heart disease. Nature Reviews Cardiology 9(2): 101-115.
3. Feltes TF, Bacha E, Beekman RH (2011) Indications for cardiac catheterization and intervention in pediatric cardiac disease: a scientific statement from the American heart association. Circulation 123(22): 2607-2652.
4. McLean KM, Pearl JM (2006) Pulmonary atresia with intact ventricular septum: initial management. Ann Thorac Surg 82(6): 2214-2219.
5. Mourani PM, Sontag MK, Younoszai A (2008) Clinical utility of echocardiography for the diagnosis and management of pulmonary vascular disease in young children with chronic lung disease. Pediatrics 121(2): 317-325.
6. Nakanishi T (2005) Cardiac catheterization is necessary before bidirectional Glenn and Fontan procedures in single ventricle physiology. Pediatr Cardiol 26(2): 159-161.
7. Kumar P, Joshi VS, Madhu PV (2014) Diagnostic pediatric cardiac catheterization: Experience of a tertiary care pediatric cardiac centre. Med J Armed Forces India 70(1): 10-16.
8. Mehra MR, Kobashigawa J, Starling R (2006) Listing criteria for heart transplantation: international society for heart and lung transplantation guidelines for the care of cardiac transplant candidates--2006. J Heart Lung Transplant 25(9): 1024-1042.
9. Pahl E, Naftel DC, Kuhn MA (2005) The impact and outcome of transplant coronary artery disease in a pediatric population: a 9-year multi-institutional study. J Heart Lung Transplant 24(6): 645-651.
10. Schroeder VA, Shim D, Spicer RL (2006) Surgical emergencies during pediatric interventional catheterization: is surgical backup necessary? J Pediatr 140(5): 570-575.
11. Babaliaros VC, Green JT, Lerakis S (2008) Emerging applications for transseptal left heart catheterization. Journal of the American College of Cardiology 51(22): 2116-2122.
12. Moore J, Hegde S, El-Said G (2013) Transcatheter device closure of atrial septal defects, a safety review. J Am Coll Cardiol Intv 6(5): 433-442.
13. Chessa M, Butera G (2015) Ventricular septal defects in: cardiac catheterization for congenital heart disease from fetal life to adulthood. Butera G, Chessa M, Eicken A, Thomson J (Eds.), 28: 465-487.
14. Lin C, Hsieh K, Huang T (2009) Closure of large patent ductus arteriosus in infants. Am J Cardiol 103(6): 857-861.
15. Ussia GP, Mule M, Caruso E (2007) Combined endothelin receptor antagonist and transcatheter interventional therapy of patent ductus arteriosus with severe pulmonary artery hypertension. Int J Cardiol 116(3): 427-429.

16. Silvilairat S, Cabalka AK, Cetta F (2005) Echocardiographic assessment of isolated pulmonary valve stenosiswhich outpatient Doppler gradient has the most clinical validity? J Am Soc Echocardiogr 18(11): 1137-1142.

17. Baruteau AE, Hascoët S, Baruteau J (2014) Transcatheter closure of patent ductus arteriosus: past, present and future. Arch Cardiovasc Dis 107(2): 122-132.