J Pediatr Rev. 2017 July; 5(2):e10815. doi: 10.5812/jpr.10815.

Published online 2017 May 5.

Review Article

Cardiac Catheterization and Intervention in Pediatric Cardiac Disease: A Narrative Review of Current Indications, Techniques, and Complications

Bahram Pishgoo,[1] Amin Shahmoradi,[2] and Leila Asadian[3,*]

[1]Department of Cardiovascular Diseases, School of Medicine and Cardiovascular Research Center, Baqiyatallah University of Medical Sciences, Tehran, IR Iran
[2]Residence of Cardiology, Department of Cardiovascular Diseases, School of Medicine and Cardiovascular Research Center, Baqiyatallah University of Medical Sciences, Tehran, IR Iran
[3]Orthopedic Research Center, Mazandaran University of Medical Sciences, Sari, IR Iran

[*]*Corresponding author*: Leila Asadian, MD, Orthopedic Research Center, Mazandaran University of Medical Sciences, Sari, IR Iran. Tel/Fax: +98-1133377169, E-mail: leilaasadian@ymail.com

Received 2017 February 01; **Revised** 2017 March 15; **Accepted** 2017 April 12.

Abstract

Context: In the past 20 to 30 years, the area of pediatric interventional cardiology has had noteworthy development. Technological revolutions have significantly progressed management of cardiovascular disease in both children and adults with congenital heart disease (CHD). This article reviews the current indications, techniques and complications of interventional therapy for CHD.
Evidence Acquisition: Training and publications in this field are rare. Overall, 64 article from January 1953 to February 2014 were studied. A total of 26 articles were involved in pediatric evaluation.
Results: There have been several catheter-based interventions for congenital heart disease. Percutaneous intervention in pediatric cardiac disease has been established in the past 2 to 3 decades. There are currently devices accepted for percutaneous closure of ASDs, patent ductus arteriosus (PDAs), and muscular ventricular septal defects (VSDs). The period of percutaneous valve implantation is just beginning, and the next few years may bring about advances in miniaturized valve distribution methods to allow insertion in smaller children.
Conclusions: Completely prepared catheterization laboratory, surgical holdup, and extracorporeal membrane oxygenation support capabilities must be accessible at any center to achieve interventional cardiac catheterization. Additional understanding of normal history of interventions more than 2 decade post process, novel strategies and methods will certainly lead to an increase in the methods for managing of congenital heart disease.

Keywords: Cardiac, Pediatric, Catheterization, Intervention

1. Context

In the past 20 to 30 years, the area of pediatric interventional cardiology has had noteworthy Development. Technological revolutions have significantly progressed management of cardiovascular disease in both children and adults with congenital heart disease (CHD). Interventional treatment has developed a suitable substitute management for numerous CHD, counting ventricular septal defects (VSDs), closing of atrial defects, Coarctation of the Aorta (COA), dilation of stenosis vessels (branch pulmonary arteries and patent ductus arteriosus (PDA)). A hybrid approach could be used in a number of cases wherever the percutaneous method is problematic or the patient still needs repair of additional related cardiac abnormalities (1).

By means of advances in echocardiography, the character of cardiac catheterization (CC) in examining congenital heart disease (CHD) has been re-directed to either creating a detailed hemodynamic training, or device some interventional processes (2).

Diagnostic heart catheterization was described in the 19th century and interventional cardiac catheterization was pronounced by Rubio-Alvarez in 1954 for the handling of pulmonary valve stenosis (3). In several centers, magnetic resonance imaging (MRI) is progressively used for analytic imaging (3). To guarantee security and superiority of images, most of these processes in children require general anesthesia. Cardiac catheterization might be interesting once commerce by multifaceted congenital cardiac lesions. Noble statement among the team members is vital so that cardiovascular variations could be expected and diminished as far as probable. This comprises of the complete team, including an anesthetist, radiographer, cardiologist, cardiac physiologist and scrub team (CHD) (4, 5).

Meanwhile the former American heart association (AHA) methodical declaration in 1998 announced a focus on tools technology and development of interventional procedures for congenital heart disorders (6, 7). However, training programs that examine the security and value of catheterization are infrequent in the field, due to the trouble in recognizing a control populace, the comparatively minor amount of pediatric patients with congenital heart disease (CHD), and the extensive range of experimental manifestation (8).

This article reviewed current indications, techniques, and complications of interventional therapy for CHD.

2. Evidence Acquisition

The following data bases were used for the literature search: Medline, PubMed, and Ovid. The key words included cardiac, pediatric, catheterization, intervention, and congenital heart diseases. Publications from journals that described cardiac catheterization and intervention in pediatric patients (age < 18 years) were included in the study. Exclusion criteria were: 1) training available in any language other than English, and 2) patients older than 18 years during the period of study. Training programs and publications in this field was rare. Overall, 64 articles from January 1953 to February 2014 were studied. A total of in 26 articles were involved in the pediatric evaluation.

3. Results

3.1. Imaging

The main type of imaging for interventional catheterization over the past era, accompanied by a decrease in radiation, is 2D fluoroscopy. Flat panel detectors and advances in imaging consist of rotational angiography and 3D imaging that in certain complex cases supports anatomical gratitude (9, 10). Imaging for interventions will probably lead to more modalities than ionizing radiation, such as ultrasound and MRI (11, 12). Moreover, imaging in the catheterization laboratory, imaging advances in echocardiography, CT and MRI will carry on to diminish the quantity of hemodynamic and angiographic techniques (12).

3.2. Catheterization

3.2.1. Diagnostic Catheterization

Diagnostic catheterization is becoming less used due to technological progresses in non-invasive imaging, such as cardiac CT and MRI, permitting angiographic valuation. Aggressive studies are still essential to measure intracardiac and intravascular pressures and to permit direct measurement of arterial, mixed venous, pulmonary venous and pulmonary arterial saturations and derive shunt fraction, flows and resistance (4, 5). Dynamic studies, such as dobutamine stress challenging and pulmonary vascular resistance training, are similarly probable. Myocardial biopsies, coronary angiography, and endosonography are done as part of regular observation after cardiac transplantation. Myocardial biopsies are irregularly used to identify myocarditis and cardiomyopathy (13, 14).

3.2.2. Interventional Catheterization

3.2.2.1. Valvuloplasty

A fluid-filled cardiac catheter is delivered through stenotic pulmonary or aortic valves. This is replaced over a guide wire for a balloon catheter, which is then swollen for a few seconds to divide the attached valve leaflets. Balloon dilatation is repetitive numerous intervals pending a satisfactory decrease in gradient is attained 18. Pulmonary valvuloplasty has effectively been done for several years. It is the management of choice for isolated pulmonary stenosis with a gradient of more than 50 mm Hg. Neonates are cyanosed by dangerous pulmonary stenosis, regularly demanding ventilation and a prostaglandin infusion to preserve duct patency. Serious aortic stenosis could be related to severe cardiovascular failure. Untreated severe aortic stenosis brings a high risk of unexpected death. Aortic valvuloplasty has a great risk of hemodynamics variability and cardiac arrest from ischemia and arrhythmias. Vasodilatation and hypovolemia are poorly accepted. Recovery medications must be freely accessible to converse hemodynamics compromise due to recurrent obstruction of the aortic valve (15, 16).

3.2.2.2. Atrial Septostomy

This practice is achieved to permit fraternization of blood to recover oxygen saturation in cardiac lesions, such as transposition of great arteries or single-ventricle circulations reliant on tolerable mixing at atrial level. These children are frequently very ill with systemic hypotension, hypoxaemia, and metabolic acidosis. They will frequently have prostaglandin (PGE1) infusion to preserve a patent ductus arteriosus. A balloon-tipped catheter is distributed from the right atrium through the foramen ovale and into the left atrium below trans-thoracic echocardiographic imaging (17, 18). The balloon is then inflated and dragged crossways the septum to expand the septal communication. It is regularly done with numerous intervals till the atrial communication is sufficient to let free mixing of blood at atrial level. Difficulties include arrhythmias, perforation of the myocardium, embolization, and physical injury to the valvular apparatus (17).

3.2.2.3. Septal Defect Closure

Atrial septal defect closure is a supreme frequently achieved process. Trans-Esophageal Echocardiography

(TOE) is used to evaluate the limits of the defect and to assist X-ray-guided device assignment. It is usually well accepted, however, dislodgement and embolization of the device, impingement on the nearby constructions, and damage of the heart or great vessels could occur. Ventricular septal defect closure is typically done surgically on cardiopulmonary bypass, nonetheless they can occasionally be sealed with a percutaneous device (19, 20).

3.2.2.4. Percutaneous Valve Placement

Severe pulmonary regurgitation or mixed pulmonary valve disease has occasionally led to mandatory major operation on bypass. The transcutaneous employment of pulmonary valves prepared from bovine jugular vein and titanium has distorted the organization of these patients. Via a femoral venous sheath, the valve, attached in a balloon-expandable stent, is negotiated alongside a guide wire in the precise location below fluoroscopic and TOE supervision. Patients need complete aggressive monitoring and suitable venous access in research for potential worsening that may need vital surgery on cardiopulmonary bypass (20).

3.2.2.5. Angioplasty and Employment of Stents

Angioplasty encompasses dilatation of constricted blood vessels via a balloon catheter delivered through the stenosed zone. This is seldom shadowed through endovascular stenting, for instance in branch pulmonary artery stenosis, coarctation of aorta, and superior vena cava obstruction. Stenting could comprise passage of large catheters by risk of vascular injury, dislodgement, and embolization of the stent (19, 20).

3.2.2.6. Coarctation of the Aorta

Trans-catheter intervention on coarctation of the aorta has been a multifaceted and powerfully deliberated subject matter. Important factors include the age of the patient, the anatomic site and anatomy of the obstacle, the preceding history of the obstruction (post-surgical or innate), and the comorbidities of the patient (6).

3.2.2.7. Patent Ductus Arteriosus Stent

The surgical public has erudite ended the decades in PDA which patients have high risk for death for shunt surgery in lone ventricles. This includes prematurity, low birth weight, other congenital abnormalities, and sepsis. In these high-risk infants following an interventional approach with the aim of providing a superior long-term surgical applicant makes common sense. An important factor for success is suppleness with access; selecting each path will give the greatest entry to the PDA e.g. carotid or axillary arterial access often offers a better catheter passage. The PGE1 should be stopped previous to the designation of the case and anticoagulation. There is no general approval of newborn PDA stents, and multi-center trials are necessary for this patient population to match by surgical shunts (21, 22).

3.2.2.8. Closure of Systemic to Pulmonary Shunts

This is frequently achieved outdoor the neonatal retro to bound extreme pulmonary blood flow, for instance, in patent ductus arteriosus. Helical wires are recycled to close small vessels; more compound devices are necessary to obstruct large vessels. There is a danger of device dislodgement and embolization (23).

3.2.2.9. Fetal Cardiac Interventions

Fetal interventions are much less investigated when compared to adults. Although the first processes were done in the UK, over the past 10 years, Boston children's hospital has occupied the arena of fetal cardiac interventions to a new level. It remains unknown whether this attempt will change the natural history of severe congenital heart disease and involve other centers around the world (24, 25).

3.2.2.10. Hybrid Procedure

Surgical and endovascular procedures may be able to be joined in convinced situations, such as the first phase in palliation of hypoplastic left heart disease. It is typically accomplished rapidly after delivery with the goal of evading cardiopulmonary bypasses in particular high-risk cases. This is a new management done in a few professional hospitals. Hybrid techniques contain a sternotomy, shadowed by operating banding of both pulmonary arteries and catheterization through straight cannulation of the pulmonary trunk to residence a stent in the ductus arteriosus. Patients want complete invasive observing and satisfactory venous access in preparation for potential worsening that might need crucial operation on cardiopulmonary bypass (26).

3.2.2.11. Percutaneous Coronary Intervention

Percutaneous coronary intervention (PCI) in children and teenagers could be applied to expand coronary blood flow in a diversity of clinical conditions. It might be possible in cases of postsurgical coronary compression, yet lengthier follow-up is required to control the permanence of these interferences in pediatric patients (27).

4. Complications

The general occurrence of problems in pediatric cardiac catheterization is 7.3%, of which the mainstream are vascular, associated with femoral access. These comprise of bleeding, retroperitoneal and local hematoma, arteriovenous fistula, pseudo-aneurysm, neuropathy, and thrombosis, caused by lower extremity ischemia (15).

Death has been reported as 0.2% (15). Self-governing risk factors include younger age of the patient, low body weight, and interventional processes. Thus, it is logical to perform an intervention procedure with surgical support.

4.1. Arrhythmias

Arrhythmias are most frequently produced by mechanical motivation by tubes and are typically temporary, solving once the catheter is reserved. Perseverance might show cardiac ischemia or harm to the conducting system or myocardium. Activate elements, such as acidosis and electrolyte disproportion, must be evaded. Anti-arrhythmic or pacing are infrequently required (15, 28).

4.2. Vascular Complications and Cardiac Perforation

Large vascular sheaths could effect vascular injury, most frequently at the insertion site. This is typically accomplished conventionally. Other technical hitches such as damage of blood vessels, myocardium or heart valves could produce cardiac tamponade, sometimes necessitating operational mediation (15).

4.3. Thrombosis and Cerebrovascular Accidents

The occurrence of foreign bodies and injury to the endothelium will trigger creation of thrombus, which might be principal to embolic problems. To escape this, heparin is assumed on an amount of 50 to 100 units per kilogram, after arterial cannulation pointing for an activated clotting time of $\geq$ 200. Extraordinary points of ACT might source bleeding and hematoma (15).

4.4. Hypotension

The reasons are frequently multifactorial and include anesthetic mediators, contrast agents, hypovolemia, arrhythmias, and bleeding. In aortic and pulmonary valvuloplasty, balloon inflation will effect abrupt diminution in the cardiac output and hypotension (15, 28).

4.5. Ischemia

Ischemic electrocardiography alterations are communal throughout coronary angiography and might occur in little cardiac output conditions. These know how to generally be upturned by procedures to recover coronary perfusion pressure such as augmented diastolic perfusion pressures, decreasing the heart rate, elimination of the catheter or managing coronary dilators similar to glyceryl trinitrate (28).

5. Conclusions

In the current review, several current catheter interventions for congenital heart disease have been discussed counting predictable future developments. Percutaneous interventions in pediatric cardiac disease have been established in the past 2 to 3 decades. There are devices accepted for percutaneous closure of ASDs, PDAs, and muscular VSDs. The period of percutaneous valve implantation is just beginning, and in the following few years, advances in miniaturized valve distribution methods may become evident to allow insertion in smaller children. Accomplishment of interventional cardiac catheterization in children needs high expertise and exercise. Completely prepared catheterization laboratory, surgical holdup, and extracorporeal membrane oxygenation support capabilities must be accessible at any center organization to achieve interventional cardiac catheterization. Additional understanding of normal history of interventions more than 2 decade post process, novel strategies and methods will certainly result in an increase in the number of choices for managing congenital heart disease.

Footnotes

Financial Disclosure: None.

Funding/Support: None.

References

1. Miyague NI, Cardoso SM, Meyer F, Ultramari FT, Araujo FH, Rozkowisk I, et al. Epidemiological study of congenital heart defects in children and adolescents. Analysis of 4,538 cases. *Arq Bras Cardiol.* 2003;**80**(3):269–78. [PubMed: 12856270].
2. Carlgren LE. The incidence of congenital heart disease in children born in Gothenburg 1941-1950. *Br Heart J.* 1959;**21**(1):40–50. [PubMed: 13618461].
3. Rubio-Alvarez V, Limon R, Soni J. [Intracardiac valvulotomy by means of a catheter]. *Arch Inst Cardiol Mex.* 1953;**23**(2):183–92. [PubMed: 13066260].
4. Feltes TF, Bacha E, Beekman R3, Cheatham JP, Feinstein JA, Gomes AS, et al. Indications for cardiac catheterization and intervention in pediatric cardiac disease: a scientific statement from the American Heart Association. *Circulation.* 2011;**123**(22):2607–52. doi: 10.1161/CIR.0b013e31821b1f10. [PubMed: 21536996].
5. James I, Wilmshurst S. In: Core Topics in Paediatric Anaesthesia. James I, Walker I, editors. Cambridge: Cambridge University Press; 2013. pp. 314–21.Anaesthesia for cardiac catheterisation and other investigative procedures in children.
6. Allen HD, Beekman R3, Garson AJ, Hijazi ZM, Mullins C, O'Laughlin MP, et al. Pediatric therapeutic cardiac catheterization: a statement for healthcare professionals from the Council on Cardiovascular Disease in the Young, American Heart Association. *Circulation.* 1998;**97**(6):609–25. [PubMed: 9494035].
7. Tworetzky W, McElhinney DB, Brook MM, Reddy VM, Hanley FL, Silverman NH. Echocardiographic diagnosis alone for the complete repair of major congenital heart defects. *J Am Coll Cardiol.* 1999;**33**(1):228–33. [PubMed: 9935035].

8. Sands A, Craig B, Mulholland C, Patterson C, Dornan J, Casey F. Echocardiographic screening for congenital heart disease: a randomized study. *J Perinat Med.* 2002;**30**(4):307–12. doi: 10.1515/JPM.2002.045. [PubMed: 12235719].
9. Schwartz JG, Neubauer AM, Fagan TE, Noordhoek NJ, Grass M, Carroll JD. Potential role of three-dimensional rotational angiography and C-arm CT for valvular repair and implantation. *Int J Cardiovasc Imaging.* 2011;**27**(8):1205–22. doi: 10.1007/s10554-011-9839-9. [PubMed: 21394614].
10. Glatz AC, Zhu X, Gillespie MJ, Hanna BD, Rome JJ. Use of angiographic CT imaging in the cardiac catheterization laboratory for congenital heart disease. *JACC Cardiovasc Imaging.* 2010;**3**(11):1149–57. doi: 10.1016/j.jcmg.2010.09.011. [PubMed: 21071003].
11. Hijazi ZM, Shivkumar K, Sahn DJ. Intracardiac echocardiography during interventional and electrophysiological cardiac catheterization. *Circulation.* 2009;**119**(4):587–96. doi: 10.1161/CIRCULATIONAHA.107.753046. [PubMed: 19188519].
12. Ghasemi A, Haddadi K, Shad AA. Comparison of Diagnostic Accuracy of MRI with and Without Contrast in Diagnosis of Traumatic Spinal Cord Injuries. *Medicine (Baltimore).* 2015;**94**(43):e1942. doi: 10.1097/MD.0000000000001942. [PubMed: 26512624].
13. Wilkinson JL. Haemodynamic calculations in the catheter laboratory. *Heart.* 2001;**85**(1):113–20. [PubMed: 11119478].
14. Saraiya B, Arnold R, Tulsky JA. Communication skills for discussing treatment options when chemotherapy has failed. *Cancer J.* 2010;**16**(5):521–3. doi: 10.1097/PPO.0b013e3181f28800. [PubMed: 20890150].
15. Mehta R, Lee KJ, Chaturvedi R, Benson L. Complications of pediatric cardiac catheterization: a review in the current era. *Catheter Cardiovasc Interv.* 2008;**72**(2):278–85. doi: 10.1002/ccd.21580. [PubMed: 18546231].
16. Friedrich MG. Tissue characterization of acute myocardial infarction and myocarditis by cardiac magnetic resonance. *JACC Cardiovasc Imaging.* 2008;**1**(5):652–62. doi: 10.1016/j.jcmg.2008.07.011. [PubMed: 19356496].
17. Razavi R, Hill DL, Keevil SF, Miquel ME, Muthurangu V, Hegde S, et al. Cardiac catheterisation guided by MRI in children and adults with congenital heart disease. *Lancet.* 2003;**362**(9399):1877–82. doi: 10.1016/S0140-6736(03)14956-2. [PubMed: 14667742].
18. Diab KA, Cao QL, Bacha EA, Hijazi ZM. Device closure of atrial septal defects with the Amplatzer septal occluder: safety and outcome in infants. *J Thorac Cardiovasc Surg.* 2007;**134**(4):960–6. doi: 10.1016/j.jtcvs.2007.06.018. [PubMed: 17903514].
19. Amin Z, Danford DA, Pedra CA. A new Amplatzer device to maintain patency of Fontan fenestrations and atrial septal defects. *Catheter Cardiovasc Interv.* 2002;**57**(2):246–51. doi: 10.1002/ccd.10308. [PubMed: 12357531].
20. Cheatham JP, Hill SL, Chisolm JL. Initial results using the new cribriform Amplatzer septal occluder for transcatheter closure of multifenestrated atrial septal defects with septal aneurysm. *Catheter Cardiovasc Interv.* 2003;**60**:126.
21. Armsby LR, Keane JF, Sherwood MC, Forbess JM, Perry SB, Lock JE. Management of coronary artery fistulae. Patient selection and results of transcatheter closure. *J Am Coll Cardiol.* 2002;**39**(6):1026–32. [PubMed: 11897446].
22. Behera SK, Danon S, Levi DS, Moore JW. Transcatheter closure of coronary artery fistulae using the Amplatzer Duct Occluder. *Catheter Cardiovasc Interv.* 2006;**68**(2):242–8. doi: 10.1002/ccd.20811. [PubMed: 16819766].
23. Hill SL, Mizelle KM, Vellucci SM, Feltes TF, Cheatham JP. Radiofrequency perforation and cutting balloon septoplasty of intact atrial septum in a newborn with hypoplastic left heart syndrome using transesophageal ICE probe guidance. *Catheter Cardiovasc Interv.* 2005;**64**(2):214–7. doi: 10.1002/ccd.20256. [PubMed: 15678458].
24. Masura J, Bordacova L, Tittel P, Berden P, Podnar T. Percutaneous management of cyanosis in Fontan patients using Amplatzer occluders. *Catheter Cardiovasc Interv.* 2008;**71**(6):843–9. doi: 10.1002/ccd.21540. [PubMed: 18412082].
25. Kan JS, White RJ, Mitchell SE, Gardner TJ. Percutaneous balloon valvuloplasty: a new method for treating congenital pulmonary-valve stenosis. *N Engl J Med.* 1982;**307**(9):540–2. doi: 10.1056/NEJM198208263070907. [PubMed: 7099226].
26. Michel-Behnke I, Ewert P, Koch A, Bertram H, Emmel M, Fischer G, et al. Device closure of ventricular septal defects by hybrid procedures: a multicenter retrospective study. *Catheter Cardiovasc Interv.* 2011;**77**(2):242–51. doi: 10.1002/ccd.22666. [PubMed: 20517999].
27. Ashwath R, Gruenstein D, Siwik E. Percutaneous stent placement in children weighing less than 10 kilograms. *Pediatr Cardiol.* 2008;**29**(3):562–7. doi: 10.1007/s00246-007-9141-8. [PubMed: 18046599].
28. Mc Ashley E. Anaesthesia for electrophysiology procedures in the cardiac catheter laboratory. *Continu Educ Anaesth Crit Care Pain.* 2012;**12**(5):230–6. doi: 10.1093/bjaceaccp/mks032.