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REVIEW

# Interventional Treatment of Cardiac Emergencies in Children with Congenital Heart Diseases

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**ABSTRACT**

Cardiac emergencies in children represent an extremely important issue in medical practice. In general, interventional treatment could be optional in many situations, however it can be indicated in emergency conditions. There are many diseases at pediatric age that can benefit from interventional treatment, thus reducing the surgical risks and subsequent complications. Balloon atrioseptostomy, patent ductus arteriosus (PDA) closure, percutaneous or hybrid closure of a ventricular septal defect, pulmonary or aortic valvuloplasty, balloon angioplasty for aortic coarctation, implantation of a stent for coarctation of the aorta, for severe stenosis of the infundibulum of the right ventricle, or for PDA correction are among the procedures that can be performed in emergency situations. This review aims to present the current state of the art in the field of pediatric interventional cardiology.

**Keywords:** pediatric cardiac emergencies, congenital heart disease, interventional treatment

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## INTRODUCTION

Cardiac emergencies in children represent a pathology that is not very common, most of these critical conditions being recorded in newborns and small infants. Emergency treatment requires rapid intervention, any delay being associated with a high morbidity and mortality in these cases. Interventional treatment in emergency situations should be carefully considered, taking into account the indications but at the same time all risk factors associated with this type of treatment such as rhythm or conduction disorders, risk for perforation and cardiac tamponade, risk of heart failure (HF) aggravation, and cardiogenic shock.[1] Contrast media administration may also increase procedural risk, especially when associated with other previously discovered risk factors such as acute kidney injury, pre-existing hypotension, infection or sepsis, requiring the administration of potentially nephrotoxic substances (e.g., gentamicin).[2–4]

In newborns, cardiac emergencies that can be managed with interventional therapies include transposition of the great arteries (TGA), simple valvular obstructive diseases such as critical pulmonary stenosis (PS), critical aortic stenosis (AS), aortic coarctation (AC) with contraindica-

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tions for surgical treatment; complex obstructive disorders such as tetralogy of Fallot (TOF) or pulmonary atresia with intact ventricular septum (APSI); and left-to-right shunt diseases such as large ventricular septal defects (VSD) or patent ductus arteriosus (PDA) associated with HF and pulmonary hypertension (PH).

All these cardiac emergencies are extreme forms of congenital heart disease (CHD), and should be approached with great discernment and following the establishment of a protocol between the pediatric interventional cardiologist and the cardiovascular surgeon. The approach to these critical types of CHD may vary from one center to another, depending on the cardio-surgical collaboration protocol. This review aims to present the current state of the art in the field of pediatric interventional cardiology.

## INTERVENTIONAL TREATMENT IN TRANSPOSITION OF THE GREAT ARTERIES

### ANATOMICAL AND CLINICAL ASPECTS

TGA is a cyanogenic heart malformation that occurs in 5% of children with CHD. Anatomically, the origin of the great arteries is inverted at the exit level of the two ventricles, resulting in parallel circulation of the systemic and the pulmonary blood as a pathophysiological consequence. Cellular oxygenation is the engine of growth and development, and in this condition growth is severely impaired, survival being impossible in the absence of an adequate atrial, ventricular or arterial mixing of the blood through an atrial septal defect (ASD), ventricular septal defect (VSD), or PDA.[5]

In this situation, patient stabilization and correction of hypotension and metabolic acidosis should be ensured by maintaining good cellular perfusion with increased blood oxygenation. If the continuous infusion of prostaglandin E1 (PGE1) is not effective, or if there are contraindications for this drug, balloon atrioseptostomy (Rashkind procedure) should be performed.

### PROCEDURAL ASPECTS

The Rashkind procedure was first performed more than 50 years ago by Rashkind in order to obtain a better mixing of blood in patients with TGA. The procedure can be performed in the cardiac catheterization laboratory or in the neonatal intensive care unit with the patient under deep sedation, preferably under general anesthesia using femoral or umbilical venous approach. The procedure consists in the mechanical augmentation of the ASD or patent foramen ovale (PFO), either by rupture of the septum with an inflated balloon, or by using alternative techniques (a blade that cuts the septum or a puncture needle).[5] Figure 1 presents an angiographic image during the Rashkind procedure of septal atrioseptectomy, showing the balloon inflated into the left atrium before the maneuver of atrial septal rupture.

### RESULTS AND COMPLICATIONS

The results of the Rashkind procedure are favorable in most of the cases, sometimes requiring reintervention to consolidate the result. In the case of an effective Rashkind maneuver, the surgical arterial switch correction can be postponed for an optimal duration of 4 weeks after the intervention. However, a number of complications have been reported as associated with this maneuver including balloon rupture with consequent embolization, air embolism, cardiac damage with rupture of the atrial appendage, mitral valve injury, vascular injury (of the pulmonary veins or the inferior vena cava), or thrombosis of the umbilical vein.[5–14]

## INTERVENTIONAL TREATMENT IN CRITICAL PULMONARY STENOSIS

### ANATOMICAL AND CLINICAL ASPECTS

Critical pulmonary stenosis (CPS) is an extremely severe form of pulmonary stenosis. Pulmonary stenosis is present in 8–12 % of children with CHD. In CPS there is an anatomical barrier which appears in the bloodstream ejected by the right ventricle (RV), resulting in a reduction of pul-

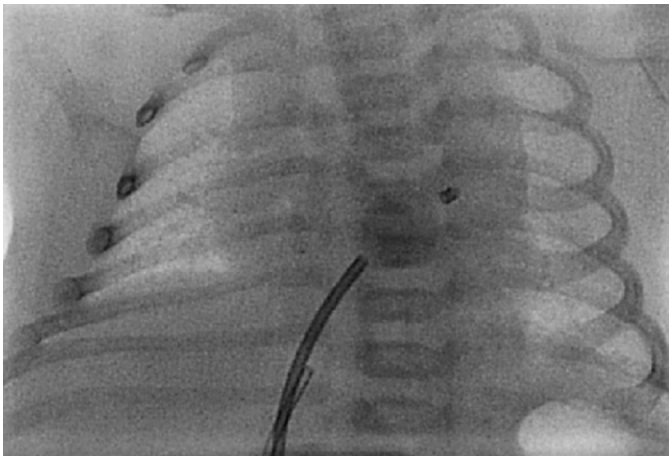

**FIGURE 1.** Rashkind balloon atrial septostomy in a newborn with transposition of the great arteries

monary blood flow, decrease of blood oxygenation, and significant alteration of the systemic cardiac flow. Being a duct-dependent malformation, it requires maintenance of the arterial duct patency.

### PROCEDURAL ASPECTS

Interventional treatment should be performed urgently and consists in pulmonary balloon valvuloplasty (PBV), which is the treatment of choice. This procedure was first performed in 1982 by Kan and colleagues.[15] The dimension of the valvuloplasty balloon should be up to 110–125% larger than the pulmonary valve diameter measured at the baseline angiography. The patient should be under general anesthesia, with orotracheal intubation and mechanically ventilated. Using a femoral or jugular venous access, the stenosis is first crossed by a catheter. This is followed by crossing the stenosis with a guidewire supporting a balloon, which will be positioned in order to alienate the area of stenosis in the middle of the balloon. Once reaching the target position, the balloon will be expanded. Figure 2 shows a right ventricle angiography in left lateral projection, illustrating a severe pulmonary stenosis alongside hypertrophy of the right ventricle, and infundibular reaction with spasm to contract media administration.

Postprocedural evaluation of the residual gradient at the stenosis level is performed by pull-back with peak-to-peak gradient measurement, while the calculation of the ratio between RV pressure and systemic pressure can offer a picture of the results obtained. A favorable result is represented by a significant reduction of the peak-to-peak gradient and by a ratio between the RV pressure and the systemic pressure lower than 0.5.[16–23]

### RESULTS AND COMPLICATIONS

The results obtained by PBV in PS are usually favorable, 84–88% of cases being free from any reintervention within 5–10 years. Among the more important complications that may arise are the failure of the procedure and the need for immediate surgery (5% for associated subvalvular or supravalvular stenosis and 1–2% for recurrent pulmonary stenosis), avulsion and annular tear or perforation (0.4%, up to 16.7% in CPS), tricuspid valve injury (0.2%), rhythm and conduction disorders (1%, up to 11.1% in CPS). Other complications include significant residual pulmonary stenosis, significant pulmonary regurgitation, right ventricular failure along with the complications associated with vascular access, materials use (circumferential balloon rupture), contrast substance, and irradiation.

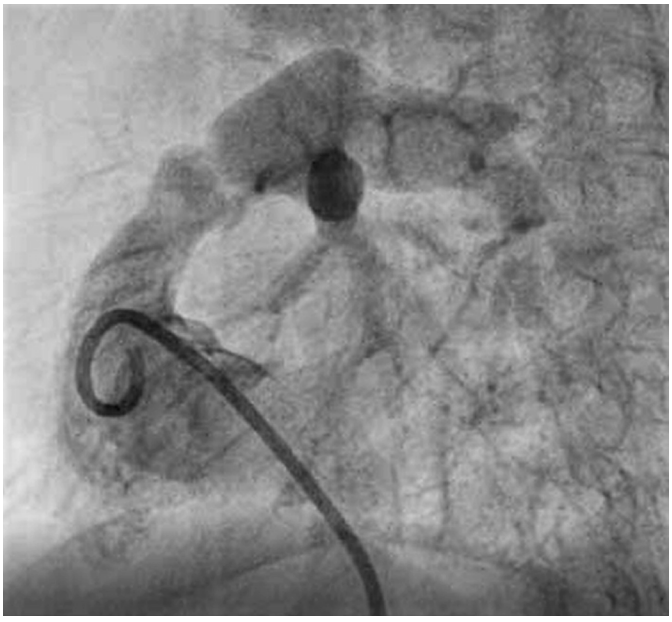

**FIGURE 2.** Severe pulmonary stenosis during lateral right ventricle angiography

Extreme bradycardia to asystole and cardiac arrest, as well as severe desaturation during the procedure may lead to death, the mortality rate associated with this procedure being reported at 0.2% (5.5% in CPS). The frequency of adverse events in the interventional correction of CPS is higher in neonatal CPS (up to 38.9%) in comparison to all other cases (4.5%).[15–23]

## INTERVENTIONAL TREATMENT IN CRITICAL AORTIC STENOSIS

### ANATOMICAL AND CLINICAL ASPECTS

Critical aortic stenosis (AS) appears in 3–5% of all CHD. The anatomical lesion consists of an obstacle in the left ventricular (LV) ejection pathway, having as consequence extreme hypertrophy and severe LV systolic dysfunction. It can generate hypotension, HF, or acute kidney injury (AKI). AS is a duct-dependent malformation in which the first recommended intervention is the pharmacological one, consisting in patient stabilization by administering PGE1 and inotropic drugs in order to provide inotropic support.

This is followed by correction intervention performed either surgically (valvotomy) or via interventional treatment (valvuloplasty). The decision to choose between these two treatment options belongs to the cardiosurgical team according to the local intervention protocol for treating AS.[24–26]

### PROCEDURAL ASPECTS

The interventional procedure, described for the first time in 1983, may be associated with serious complications that may require immediate surgical intervention, for instance in the event of severe aortic regurgitation.[25] In several centers, surgery is the method of choice because postoperative results after a failed interventional procedure (in the event of a complication such as valve rupture) are inferior to those obtained by per primam valvulotomy.

The interventional procedure consists in crossing the stenosis area with a catheter, positioning of the supportive guidewire, and balloon expansion at the stenosis level. The size of the balloon is usually established on the basis of angiographic measurements performed at the beginning of the procedure. Access to the aorta can be achieved by a retrograde approach via the femoral artery or carotid artery, but the insertion sheath must be carefully chosen, and it should be large enough to allow the introduction of a balloon without obstructing the flow towards the lower limb or brain. Also, in the presence of PFO, vascular access can be performed in an anterograde fashion, by accessing the femoral vein and crossing the PFO, the mitral valve and the aortic valve. This approach should be also carefully considered because crossing the mitral valve with a balloon can be associated with traumatic damage of the mitral valve (0.7%), requiring mitral valve surgery in one-month interval.[25–32]

### RESULTS AND COMPLICATIONS

Complications associated with interventional procedures of AS are more frequent in neonates. Mortality varies between 2% in older children to 38% in neonatal critical AS.[25] Complications may be related to vascular damage, such as aneurysm formation, dissection, rupture, thrombosis or perforation (0.2%), but valvular or myocardial complications have been also described.[25] Severe acute aortic regurgitation may appear in 1.6% of cases, aortic avulsion in 0.2%, and aortic perforation in 0.5%.[24,25] LV perforation may appear in 1.1% of all cases, from which 17% are neonatal CAS and traumatic VSD. Other complications that may appear are those related to embolism: stroke or myocardial infarction. However, these types of complications have rarely been described. Different types of arrhythmias may also appear, such as asystole or ventricular fibrillation related to the obstruction of flow into the coronary arteries during balloon inflation. A high incidence of re-intervention was reported, varying from 25% to 50% in children (in the following 4 to 8 years after intervention) to 40% in neonates in the following 4.3 years. This high rate of complications, together with the need for surgical intervention in 30% of the cases, made this intervention a second-choice procedure for treating critical AS in many of the centers.[24–32]

## INTERVENTIONAL TREATMENT IN COARCTATION OF THE AORTA

### ANATOMICAL AND CLINICAL ASPECTS

Aortic coarctation (AC) is present in 7% of children with CHD. This malformation consists in a narrowing of the isthmic descending aorta in the region of the arterial duct/ligamentum arteriosum insertion. It can be associated with diffuse hypoplasia of the aortic arch and isthmus and duct-dependent circulation.[33,34] The hemodynamic consequences of this lesion are represented by a pressure gradient across the obstruction with repercussions on LV contractility, as well as the presence of systemic and pulmonary hypertension. On the other hand, the severe reduction of the downstream flow is associated with an increased risk of pre-renal AKI.

### PROCEDURAL ASPECTS

Indications for treatment in AC are represented by severe coarctation (evaluated by CT angiography, magnetic resonance imaging, or invasive angiography) and congestive heart failure in neonates and infants in the presence of a systolic gradient higher than 20 mmHg between the upper and the lower limbs.[1,33]

In severe forms, usually encountered in newborns and infants, urgent intervention is mandatory, and the first option for corrective treatment, after initial stabilization, is the surgical one. Surgery is the gold-standard treatment method in children that are weighing less than 15 kg and have a risk for recurrence between 8–35%.[33] Percutaneous interventions are reserved for situations in which surgery is contraindicated.[1] Another therapeutic option is represented by balloon angioplasty, which is recommended even in the case of recurrence after surgical correction, or as palliation in infants with left ventricle dysfunction and increased surgical risk. However, the risk of aneurysm formation is high, limiting this type of intervention to specific cases.[1] In case of balloon angioplasty, the most frequent severe complications include aortic wall dissection, small/larger/increasing aneurysm formation, aortic rupture (all these requiring covered stent implantation),

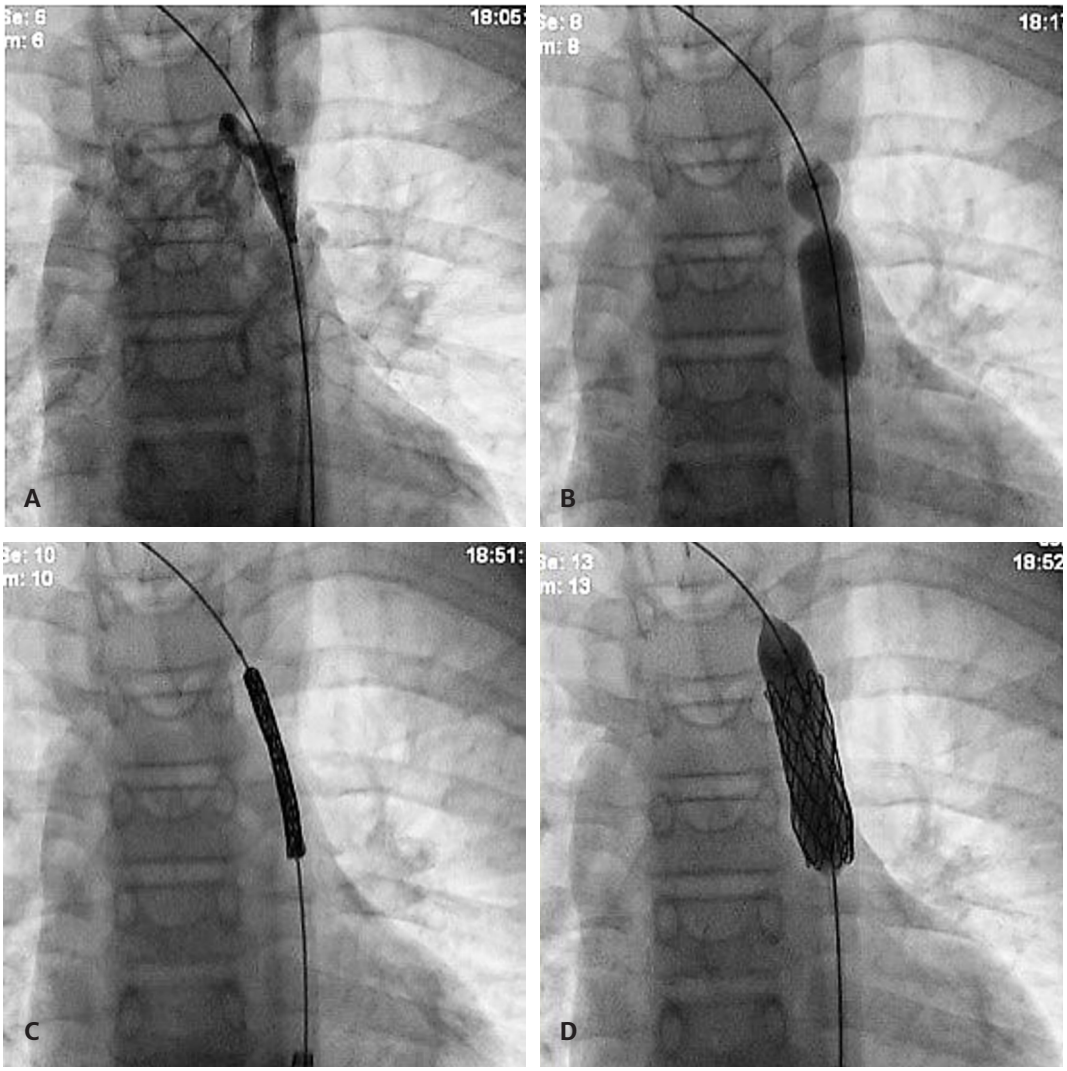


**FIGURE 3.** Severe aortic coarctation during stent implantation using an intermediate predilatation balloon

or femoral artery occlusion necessitating thrombolysis or surgical repair. Balloon angioplasty may be also associated with a high risk of recurrence, which can be prevented by temporary implantation of a stent that may be used even in infants.[1,33–42]

Stent implantation in AC was performed for the first time in 1991 and is usually reserved for children weighing more than 20 kg.[33] Stents can be bare or covered with expanded polytetrafluoroethylene (e-PTFE) material. The trend is to expand the use of covered stents to all adolescents and adults with native aortic coarctation or recoarctation.[33–42] Figure 3 presents a succession of steps in implantation of a stent in a native aortic coarctation in an adolescent. Figure 3A shows the passing of the guidewire through the coarctation, which in this case is almost atretic. Figure 3B shows the predilatation with a 4-mm balloon, and Figure 3C demonstrates positioning of the stent at the coarctation level, which is postdilated (Figure 3D) to obtain a better apposition to the aortic wall.

## RESULTS AND COMPLICATIONS

The results of stent implantation for coarctation of the aorta are usually very good. Complications associated with interventional procedures are related to pre-existent co-morbidities (low weight, low age, genetic diseases), vascular access, pre-existing renal insufficiency, systolic dysfunction, and pulmonary hypertension. Complications related to stent implantation may include aortic wall dissections, ruptures or aneurysm formation (0–16%); technical complications include stent migration (5%), balloon rupture with inadequate stent expansion, side branch occlusion (in the case of covered stents), restenosis (by neointimal hyperplasia or by somatic growth

in severe aortic coarctation), stent fracture, ischemic stroke (in case of carotid access) etc.[33–42]

## INTERVENTIONAL TREATMENT IN TETRALOGY OF FALLOT

### ANATOMICAL AND CLINICAL ASPECTS

Tetralogy of Fallot (TOF) is the most common cyanogenic CHD, representing 5% of all CHD in children. TOF is anatomically defined by the presence of several cardiac malformations: stenosis in the RV ejection tract (infundibular, valvular, or supravalvular), VSD, aortic dextroposition, and RV hypertrophy. The hemodynamic consequences of this association are various depending on the anatomic particularities of the anomalies.

The severity spectrum varies depending on several factors, among which the most important are the severity degree of the RV ejection tract stenosis, the confluence of the pulmonary branches, and their hypoplasia. Most of the patients have cyanosis (sometimes severe) due to right-left shunt at the VSD level and may experience anoxic crisis marked by severe desaturations on the background of pre-existing cyanosis. In the context of chronic generalized cyanosis, they may associate polycythemia with an increased risk of thrombosis and embolization in the systemic circulation (via passage at VSD level).

### PROCEDURAL ASPECTS, RESULTS, AND COMPLICATIONS

Percutaneous interventions for this condition have been developed in some cardiovascular centers, in close collaboration with cardiac surgery. Stents can be implanted either in the RV outflow tract (RVOT) to prevent anoxic crises or in the arterial duct to ensure a good and steady flow up to the operatory moment.[43–45] Thus, the corrective surgical intervention is delayed, and the palliative surgery with modified Blalock-Taussig shunt is excluded.

Patent ductus arteriosus (PDA) stenting is an interventional solution for pulmonary duct-dependent circulation replacing the palliative aortopulmonary shunts. They can be maintained open for a period of 6–12 months, compared with the surgical shunt, which is open for a longer period.[43]

Stenting of an opened ductus arteriosus may be necessary for different situations. Usually, this can be indicated in the case of pulmonary atresia in biventricular hearts associated with tetralogy of Fallot, double outlet right ventricle (DORV), and transposition of the great arteries. Also, pulmonary atresia in univentricular circulation may need PDA stenting when associated with single ventricles, unbalanced atrioventricular defects, or PA with right ventricle-dependent coronary circulation. Transitory PDA stenting (for a few weeks to months) may be required for inadequate pulmonary flows after a successful neonatal pulmonary valvotomy/valvuloplasty in case of pulmonary atresia with intact ventricular septum, in critical pulmonary stenosis, or before regression of a high fetal pulmonary vascular resistance in neonates with severe forms of Ebstein's anomaly, a tricuspid valve dysplasia associated with regurgitation.[43]

The stent can be inserted from the aortic or the pulmonary side. Complications that may appear in relation to the duct include cannulation failure, ductal spasm, ductal dissection, stent thrombosis, stent embolization, heart failure caused by overflow, asymmetrical flow towards the lungs, in-stent intimal proliferation, and stent stenosis.[43]

RVOT stenting is a relatively new interventional alternative in TOF, used to increase the flow towards the lungs. Studies comparing it to the modified Blalock-Taussig shunt are showing a lower thirty-day mortality rate (1.7% versus 4.9 %), but mortality until corrective surgery was 8.4% for RVOT stenting compared to 4.9% for modified Blalock-Taussig shunt.[44,45] The major complications related to this procedure are perforation of the RVOT and hemopericardium, damage of the tricuspid valve apparatus, stent dislodgement into the right ventricle, stent embolization into the aortic arch followed by moderate to severe aortic valve regurgitation, or stent thrombosis.[44–53]

## INTERVENTIONAL TREATMENT IN PULMONARY ATRESIA WITH INTACT VENTRICULAR SEPTUM

### ANATOMICAL AND CLINICAL ASPECTS

Pulmonary atresia with intact ventricular septum (PAIVS) is a rare CHD, representing 1–3% of all CHD cases. The anatomical abnormality consists in the absence of the membrane perforation of the pulmonary valve (60–70%) that can be associated with varying degrees of right ventricle development disorders.[54,55] Anatomically, the RV is structured into three parts: the inlet, the outlet, and the trabecular area. Thus, the RV may be classified into monopartite, bipartite, and tripartite ventricle. The assessment of RV development is an important factor for the therapeutic decision, which could also be influenced by other cardiac abnormalities associated with this CHD, such as stenotic coronary fistulas to RV.

### PROCEDURAL ASPECTS

In case of pulmonary atresia with a thin membrane-like appearance, no significant pulmonary branch hypoplasia, a well-developed tripartite RV, and no associated coronary abnormalities, several lifesaving percutaneous interventions can be performed urgently. Radiofrequency pulmonary valvuloplasty followed by successive dilatations of the pulmonary valve with progressively increasing balloons is the procedure of choice in these cases. Figure 4 presents a RV ventriculography performed in left lateral projection showing a quasi-atretic pulmonary valve. Also, PDA stenting may be useful in these cases for a period of time to ensure adequate pulmonary flow, especially in the event of poor pulmonary valve dilation or in patients who are candidates for Blalock-Taussig modified shunt operation.[54]

### RESULTS AND COMPLICATIONS

The complications of these complex procedures are relatively common and are similar to those recorded in valvuloplasty of critical pulmonary stenosis.[55] Perforation of the pulmonary valve by radiofrequency may be associated with perforation of the pericardium in 9–20% of cases, cardiac tamponade, rhythm and conduction disorders, hypotension, and cardiac arrest. Procedural death rates have been reported around 3.3–6%. Other rare complications may appear as well, such as tricuspid lesions, aneurysmal dilatation of the pulmonary artery, or decompressing the RV into a coronary-dependent RV circulation. Stenting of the arterial duct (especially the tortuous type) is a procedure for which a good previous experience is required. For this condition, choosing a smaller stent increases the risk for spontaneous closure of the PDA in the uncovered part of the stent, while choosing a larger stent can cause aortic or pulmonary artery obstruction.[55–63]

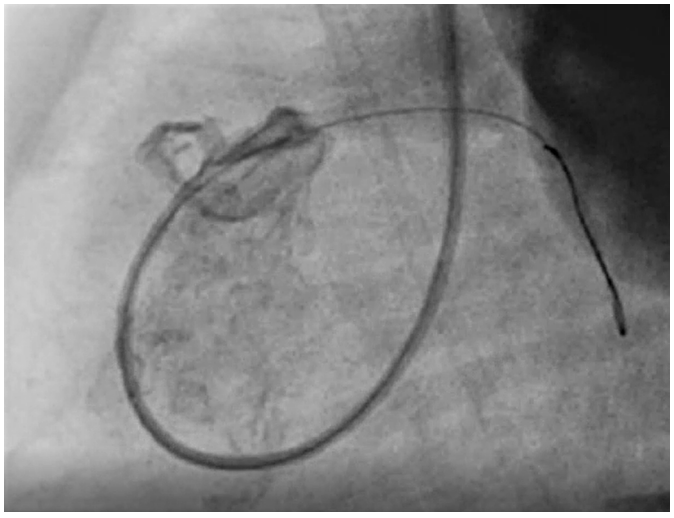

**FIGURE 4.** Quasi-atresia of the pulmonary valve during predilatation evaluation in left lateral right ventricle angiography

## INTERVENTIONAL TREATMENT IN PERSISTENT DUCTUS ARTERIOSUS

### ANATOMICAL AND CLINICAL ASPECTS

Persistent ductus arteriosus (PDA) is a relatively frequent form of CHD, accounting for 5% of all CHD. The abnormality consists in persistence of the patency of the arterial ductus beyond the first 10 days of life. The pathophysiological consequence is hypervascularization of the lungs, at systemic pressures. This can contribute to severe HF and PH. In the first 10 days, the pharmacological closure of the PDA using ibuprofen, indomethacin, or paracetamol may be attempted in the presence of severe manifestations and in the absence of contraindications.[64] The percutaneous interventional closure of the PDA is limited by the presence of at least 6 months of age or weight over 6 kg. However, in emergency situations, it is possible to close the PDA even at an earlier age, after carefully evaluating all the possible risks and the risk-benefit ratio.

### PROCEDURAL ASPECTS

The PDA closure procedure is a standard one; however, a particular attention is required in case of a large PDA, which neccesitates a large-size device, due to the risk of descending aortic obstruction and generation of an iatrogenic aortic coarctation, as well as to the risk of pulmonary artery branches obstructions. Conical-type (type A), window-type (type B), tubular (type C), complex with multiple constrictions (type D), and elongated conical (type E) are described as different anatomical varieties of PDA with particular approaches for interventional correction. The procedure was performed for the first time by Porstmann, in 1968, and for many years, the standard approach included the use of detachable or controlled-released coils. Currently, a large number of devices of different shapes and sizes can be used, based on either a pulmonary-to-aorta approach with pulmonary catheterization first, or a direct aortic-to-pulmonary approach.[65] Figure 5 presents the closure of a PDA – in panel A the PDA is imaged by angiography in right anterior oblique 30 degrees before closure, while panel B shows a PDA closed by implantation of a Cocoon duct occluder.

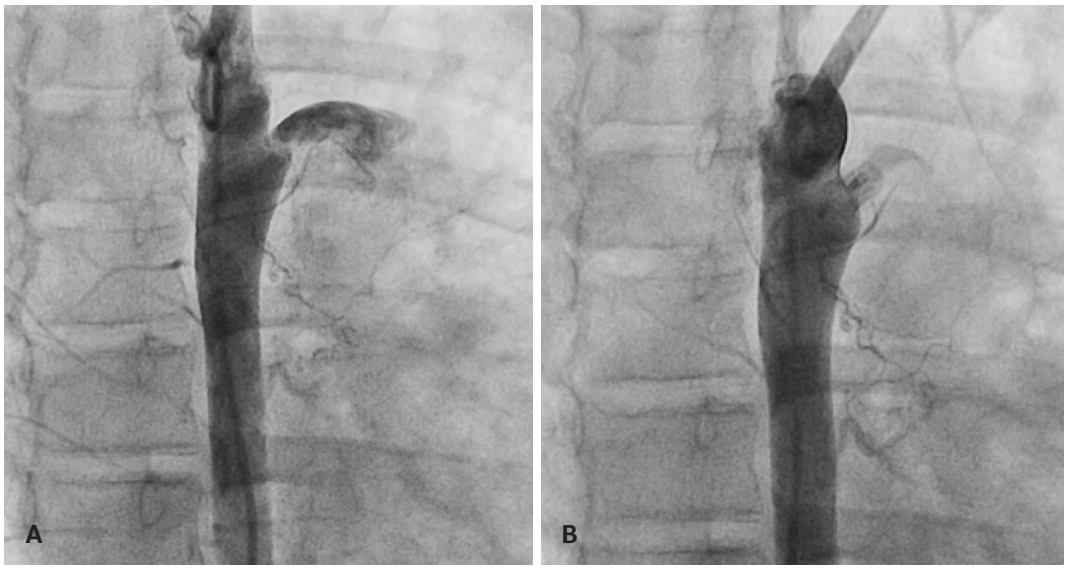


**FIGURE 5.** Large PDA before and after Cocoon device closure – angiography at right anterior oblique projection at 30 degrees

### RESULTS AND COMPLICATIONS

A residual shunt may appear in many of these cases in the first days after the procedure, but it usually disappears in a short period of time. Also, migration, malposition, or embolization (especially for coils) have been reported. The morbidity and mortality rate associated with this procedure are close to zero.[65] Obstruction of the left pulmonary artery, or of the descending aorta, rupture of the tricuspid valve, device embolization, vascular complications, the hemolysis (0.5%), or the need for transfusion (0.3%) are mentioned as rare complications of this procedure.[65–75]

## INTERVENTIONAL TREATMENT IN LARGE VENTRICULAR SEPTAL DEFECT

### ANATOMICAL AND CLINICAL ASPECTS

Ventricular septal defect (VSD) is the most common CHD in children, its prevalence being estimated at around 20–30% of all cardiac malformations. From an anatomical point of view, the disease is characterized by a ventricular discontinuation at the level of the membranous, muscular, inlet or outlet septum. Depending on the VSD diameter, the child's age, and other comorbidities, the presence of a VSD may become a cardiac emergency.

### PROCEDURAL ASPECTS

The method of choice for VSD closure is surgical. Interventional method or hybrid methods may be used in specific cases. Both interventional and hybrid procedure for closing a VSD are usually reserved for muscular VSD for which the surgery may be challenging.[76] In the past, perimembranous VSD was also closed interventionally, but due to the severity and high rate of complications, currently these indications are very rare. A perimembranous VSD can be accepted for interventional closure when the aortic rim is more than 2 mm and the weight of the child is over 8–10 kg.[76] For the muscular VSD, the weight limitation for interventional closure is 5 kg, infants who weigh less than 5 kg being candidates for hybrid procedures.

### RESULTS AND COMPLICATIONS

Interventional closure of a VSD is not a simple method, since it requires catheterization of the left heart, crossing the VSD, snaring the guidewire into the pulmonary artery, and externalization towards the venous side. Then, a right heart catheterization on the guidewire follows, with deployment of the VSD device from the left ventricle towards the right ventricle. The hybrid procedure is very complex and implies both surgical and interventional teams together with a dedicated special hybrid room.

Complications include complete atrioventricular block, which may necessitate atrioventricular pacing, valvular lesions (aortic, mitral, tricuspid), which may require emergency cardiac surgery and valvular replacement with mechanical prosthesis, cardiac perforation with hemopericardium, embolization of the device, hemolysis, stroke, and other local complications.[76–82]

## CONCLUSIONS

CHD are a special group of cardiac diseases, in which interventional treatment options are generally reserved for classical forms. Of these, many medical emergencies may occur very early, and the risks of an interventional cardiac procedure are summed up by patient-related risk factors such as age, weight, and comorbidities.

Nowadays, interventional procedures are increasingly addressed to pathologies that once were considered surgical. Several examples include the correction of superior sinus venosus atrial septal defect or unroofed coronary sinus, RVOT stenting, PDA stenting. or transcatheter pulmonary valve replacement. Currently, technological development (drug-eluting bioabsorbable vascular scaffold, ultra-high-pressure balloon angioplasty, three-dimensional rotational angiography, computer-generated real-time digital holography, multi-modal image fusion, 3D printing), together with the possibility of a hybrid approach in complex cases, are expanding the field for interventional treatment in children with CHD.

## CONFLICT OF INTEREST

Nothing to declare.

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