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## Role of Interventional Cardiology in the Treatment of Neonates - Part II - Balloon Angioplasty/Valvuloplasty

By P. Syamasundar Rao, MD

*"Role of Interventional Cardiology in the Treatment of Neonates – Part II" is the second in a series of three articles by P. Syamasundar Rao, MD, Professor of Pediatrics and Medicine, Director, Division of Pediatric Cardiology, University of Texas-Houston Medical School. Part I of the series was published in December 2007, and Part III will be published in February 2008. All issues will be available on the website in PDF files.*

### INTRODUCTION

There are many catheter-based interventional procedures (Table I) that are useful in the treatment of a neonate. In Part I [1] of this series of articles, non-surgical atrial septostomy was discussed. In the current presentation, balloon angioplasty/valvuloplasty for critical cardiac obstructive lesions will be reviewed, leaving the remaining items for discussion in the third part.

Until late 1970s, the entire transcatheter armamentarium in pediatric cardiac practice was limited to atrial septostomy. In 1980s, Gruntzig's balloon angioplasty technique [2] was extended to treat pulmonary valve stenosis [3], native aortic coarctation [4], post-surgical aortic recoarctation [5], aortic valve stenosis [6,7], mitral valve stenosis [8], subaortic membrane [9], branch pulmonary

artery stenosis [10], pulmonary vein stenosis [11], stenotic bioprosthetic valves [12,13] and other obstructive vascular lesions [14-19]. Neonatal applications followed [5,20-23].

### CRITICAL PULMONARY STENOSIS

The term critical pulmonary stenosis is applied when pulmonary valve obstruction results in supra-systemic right ventricular systolic pressure with resultant right to left shunt at the atrial level; these infants often have ductal-dependent pulmonary circulation. Following initiation of PGE1 infusion, percutaneous balloon pulmonary valvuloplasty should be undertaken. If the obstruction is less severe, the procedure may be performed at a later time, beyond the neonatal period.

Rubio-Alvarez and Limon-Lason [24,25] utilized a modified ureteral catheter to produce relief of pulmonary valve stenosis in the early 1950s. Semb and associates in 1979 [26] forcefully withdrew an inflated Berman angio-

**Table I. Catheter Interventional Techniques Used in the Neonate**

- Non-surgical atrial septostomy
- Balloon angioplasty/valvuloplasty
- Radiofrequency perforation of atretic pulmonary valve
- Transcatheter occlusion of shunts
- Stents

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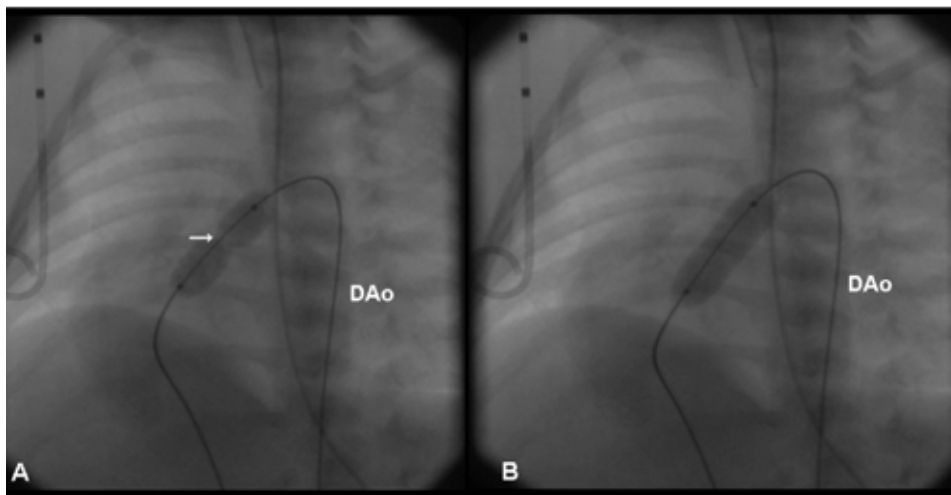


Figure 1. Selected cinefluorographic frames in a sitting-up ( $15^{\circ}$  LAO and  $35^{\circ}$  cranial) view demonstrating an angioplasty balloon across the stenotic pulmonary valve with waisting of the balloon (arrow) during the initial phase of balloon inflation (A); the waist has completely disappeared with further balloon inflation (B). Note the guide wire is passing through the ductus into the descending aorta (DAo).

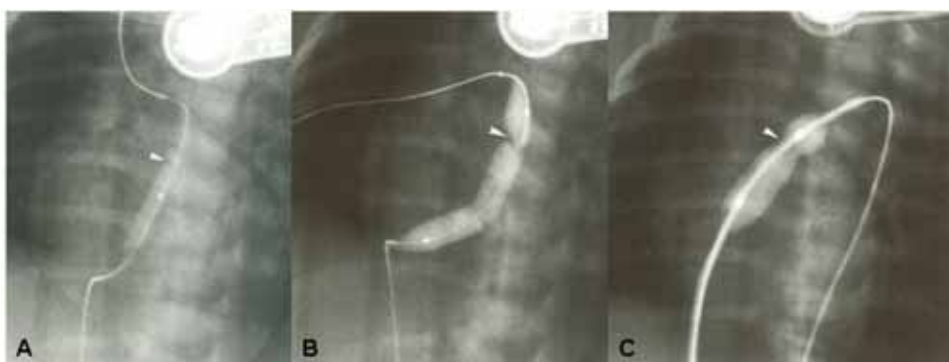


Figure 2. Selected cinefluorographic frames in a sitting-up view illustrating use of progressively larger balloons in a one-day-old baby with critical pulmonary stenosis. A coronary guide wire was positioned across the pulmonary valve and a 3.5-F catheter carrying 4 mm diameter balloon was used to dilate the pulmonary valve (A); this is followed by a 6 mm (B) and an 8 mm (C) diameter balloons. Waisting of the balloons in the initial phases of balloon dilatation are shown. Further inflation of the balloons resulted in abolition of the waiting (not shown).

graphic catheter across a stenotic pulmonary valve, causing relief of obstruction. In 1982, Kan et al [3] extended the techniques developed by Dotter [27], Gruntzig [2] and their associates and balloon di-

lated stenotic pulmonary valve with a double-lumen catheter carrying a non-elastic balloon [3]. This type of static balloon dilatation is what is used today and has become a standard therapy for

pulmonary valve stenosis. The technique was initially used in neonatal critical pulmonary stenosis by Tynan et al [20]; subsequently several groups of cardiologists [28-33] applied balloon valvuloplasty to treat the neonates with success.

### Balloon Pulmonary Valvuloplasty

Prostaglandin E1 infusion is begun to augment the pulmonary blood flow and to improve systemic arterial saturation. This is followed by cardiac catheterization and biplane (sitting-up and lateral views) right ventricular cineangiography, performed percutaneously via the right femoral vein. The pulmonary valve annulus is measured in both views and averaged. Both the angiographic and echocardiographic measurements are used to determine the pulmonary valve annulus diameter. A right coronary artery (Cordis), angled Glidecath (Meditech) or cobra (Cook) catheter, as per the operator's preference is placed in the right ventricular outflow tract and a floppy-tipped coronary guide wire is advanced across the pulmonary valve and then into the branch pulmonary arteries or into the descending aorta via the ductus (the latter is preferred). The catheter is then advanced across the pulmonary valve into the descending aorta. The guide wire is then exchanged with a guide wire that is suited to position the balloon dilatation catheter. While the initial recommendations were to use a balloon that is 1.2 to 1.4 times the pulmonary valve annulus, more recent recommendations are that we strive for a balloon/annulus ratio of 1.2 to 1.25 [34,35]. The selected balloon angioplasty catheter is advanced over the guide wire, but within the percutaneous sheath and positioned across the pulmonary valve. The bony landmarks, namely, ribs, sternum or other fixed landmarks, are used for this purpose. A frozen video frame of the right ventricular cineangiogram displayed on the screen is helpful in this regard. The balloon is inflated with diluted contrast material (1 in 4) using any of the commercially available inflators, while monitoring the pressure of inflation. The inflation pressure is increased up to the manufacturer-recommended pressure or until disappearance of the balloon waist

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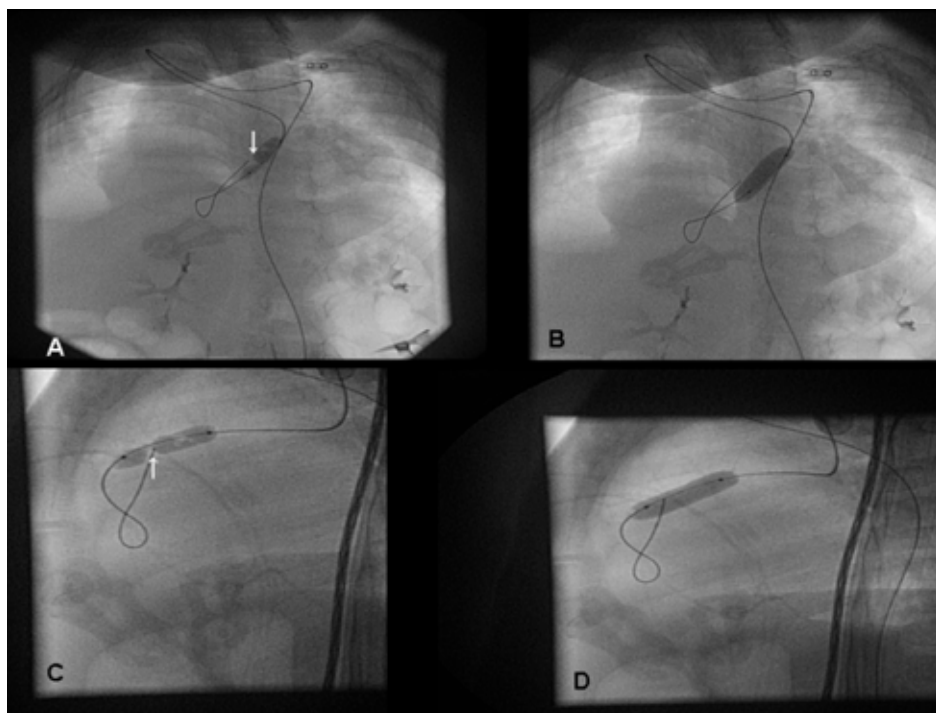


Figure 3. Selected cinefluorographic frames in sitting-up and lateral views demonstrating an angioplasty balloon across the stenotic pulmonary valve with waisting of the balloon during the initial phase of balloon inflation (A & C); the guide wire and balloon angioplasty catheter were introduced retrogradely from the aorta through the ductus and pulmonary artery into the right ventricle across the pulmonary valve. The waist has completely disappeared with further balloon inflation (B & D).

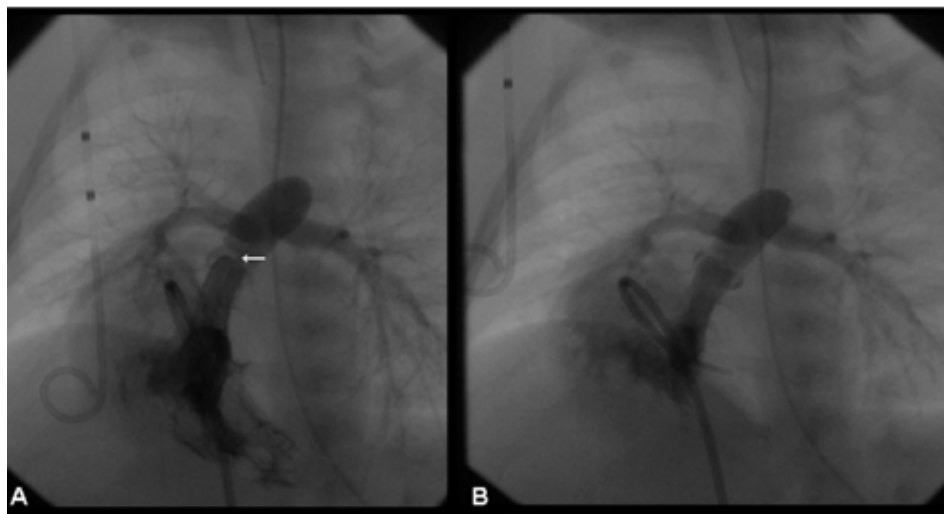


Figure 4. Selected right ventricular cineangiographic frames (from the neonate illustrated in Figure 1) in a sitting-up view prior to (A) and immediately after (B) balloon pulmonary valvuloplasty; note the thin jet of contrast (arrow) across the thickened and domed pulmonary valve (A) prior to dilatation. The jet width has markedly increased following valvuloplasty (B).

(Figure 1). If the balloon is not appropriately centered across the pulmonary valve, the position of the catheter is read-

justed and balloon inflation repeated. Once satisfactory balloon inflation is achieved, one additional balloon inflation

may be performed, as per the operator's preference. The balloon catheter is removed, leaving the guide wire in place, over which a multipurpose catheter is positioned which is used to record post-balloon pullback pressures. This is followed by right ventricular angiography.

Sometimes it may not be possible to advance an appropriately-sized balloon catheter across the severely stenotic pulmonary valve. In such instances, smaller 3 to 6 mm diameter balloon catheters may be used initially to predilate, then, use a larger, more appropriately-sized balloon catheter (Figure 2).

On rare occasions, especially with hypoplastic right ventricle or in the presence of severe infundibular obstruction, it may not be feasible to cross the pulmonary valve anterogradely. In such situations, the guide wire and balloon catheter may be positioned across the pulmonary valve retrogradely from the aorta through the ductus and pulmonary artery into the right ventricle across the pulmonary valve; an example is shown in Figure 3.

## Results

Immediate success, as judged by decrease in pulmonary valve gradient, right ventricular peak systolic pressure and right ventricle to aortic systolic pressure ratio and improved flow across the right ventricular outflow tract by angiography (Figure 4) has been noted [20,28-33]. After a successful balloon procedure, extubation and discontinuation of PGE1 infusion are possible in the majority of patients. However, some neonates do not tolerate stopping prostaglandin infusion, developing severe arterial desaturation. As many as 25% patients [30,31] may require prostaglandin infusion for 3 to 21 days after balloon dilatation. Right to left shunt across the patent foramen ovale, presumably related to poor right ventricular compliance, is the reason for hypoxemia. Some of these infants may require prolonged infusion of PGE1 or creation of an aorto-pulmonary shunt to maintain adequate pulmonary flow. Placement of ductal stent is an alternative [36] but, the experience with ductal stents is limited.

Several studies demonstrated favorable intermediate-term outcome, paralleling surgical results [30,31,37]. For example, Tabatabaei et al [31] showed remodeling of the right ventricle and appropriate growth of all three component parts of the right ventricle. The residual gradients across the pulmonary valve ( $15 \pm 9$  mmHg) at follow-up six months to 8 years

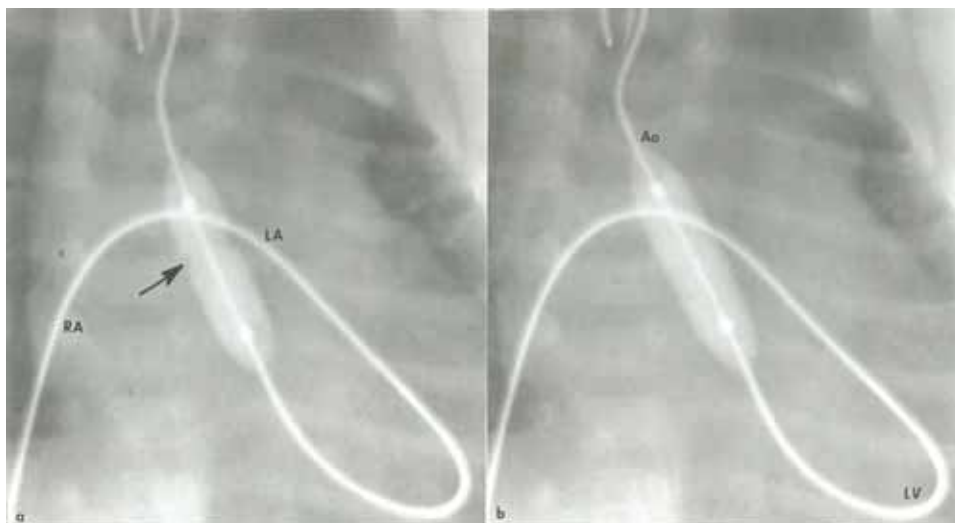


Figure 5. Selected cinefluorographic frames demonstrating the position of the balloon across the aortic valve introduced anterogradely from the umbilical vein, right atrium (RA), left atrium (LA), left ventricle (LV) and aorta (Ao). Note the waist (arrow) of the balloon (a) which was completely abolished after further inflation of the balloon (b).

after balloon valvuloplasty were low. While the results of this approach are reasonably good, the need for re-intervention is higher (25%) than that in older children (8 to 10%), to address the complications associated with the procedure, hypoxemia due to right-to-left interatrial shunt secondary to decreased right ventricular compliance, residual obstruction or associated defects.

### CRITICAL AORTIC STENOSIS

Very severe aortic valve stenosis with a high gradient, congestive heart failure or ductal-dependent systemic circulation may be labeled as critical obstructions. Balloon aortic valvuloplasty is an acceptable alternative to surgery in the treatment of critical aortic stenosis in the neonate [38,39]. After administering supportive therapy, including initiation of PGE1 infusion, if necessary, percutaneous balloon aortic valvuloplasty should be performed. Balloon aortic valvuloplasty may be performed at a later time, beyond neonatal period, in less severe obstructions.

Following successful application of Gruntzig's technique [2] to aortic coarctation [4,5,40] and pulmonary valve stenosis [3], Lababidi and his associates [6,7] utilized the technique of balloon dilatation to relieve aortic valve stenosis. His group further extended the technique to neonatal aortic valve stenosis [21]. Initially retrograde femoral arterial route was used for balloon aortic valvuloplasty [21,23,38,39]. Because of potential for injury of the femoral artery, alternative routes, namely, carotid [41], axillary [42], umbilical [43], or subscapular [44] artery and antero-grade femoral venous [45,46] approaches for accomplishing the procedure have been attempted. More recently, antero-grade, transumbilical venous route [47,48] has been introduced. Our preference is to use antero-grade, transumbilical venous route initially and if that is not successful, retrograde, transumbilical arterial route is attempted, followed by carotid artery cut-down. Antero-grade femoral venous and retrograde femoral arterial routes are the other available options.

### Transumbilical Venous Balloon Aortic Valvuloplasty [47]

The umbilical venous catheter is exchanged with a 5-F sheath and the sheath tip positioned in the low right atrium. After obtaining the usual catheterization data including left ventricular angiography, the diameter of the aortic annulus is measured. A 4-F multi-A2 catheter (Cordis) with a slightly curved tip (special order) is introduced through the umbilical venous sheath and advanced into the left atrium across the patent foramen ovale and then into the left ventricle across the mitral valve. With the help of a J-shaped and/or a straight, soft-tipped 0.035-in Benston guide wires (Cook), the catheter is advanced into the aorta and the catheter tip positioned in the proximal descending aorta. At this juncture, the guide wire is

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exchanged with a 0.025-in J-tipped Amplatz extra stiff wire (Cook). A 6 to 8 mm diameter ultrathin (Meditech) or Tyshak II (Braun) balloon angioplasty catheter is advanced over this guide wire antero-grade into the right atrium, left atrium, left ventricle and aorta, while maintaining a wide loop of the wire in the left ventricle. The balloon diameter should be

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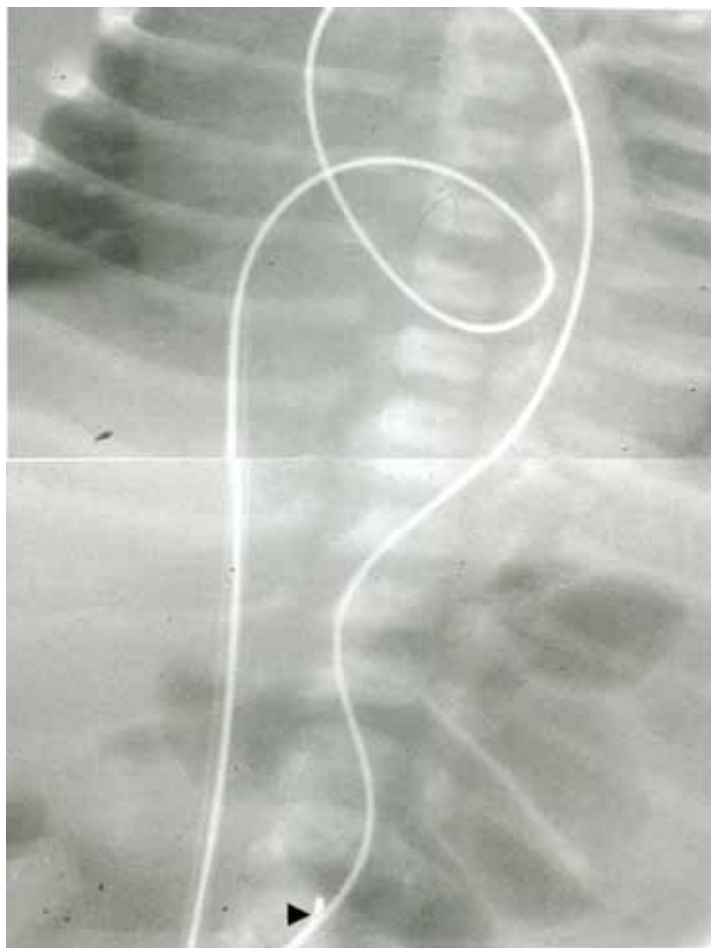
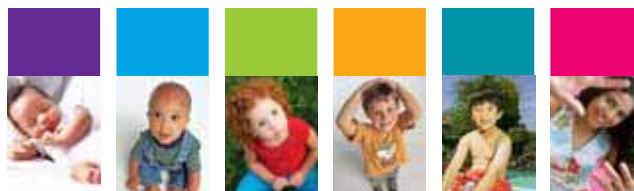


Figure 6. Selected cinefluorographic frames showing guide wire rail from the umbilical vein, right atrium, left atrium, left ventricle, ascending aorta and descending aorta. Note the snare (arrow-head at the bottom) holding the wire.

80 to 100% of the aortic valve annulus. Once the balloon is positioned across the aortic valve, the balloon is inflated with diluted contrast material (1 in 4) up to the manufacturer's recommended balloon inflation pressure, or until the waist of the balloon is abolished (Figure 5). Then the balloon dilatation catheter is removed and replaced with a 4-F multi-A2 (Cordis) catheter and its tip positioned in the aorta. After performing aortic root angiography, a pressure pullback recording across the aortic valve is undertaken. Left ventricular angiography is optional. Heparin is administered during the procedure to maintain adequate anticoagulation and Vancomycin for antibiotic coverage prophylactically because of extensive manipulation of the umbilical area during the procedure.



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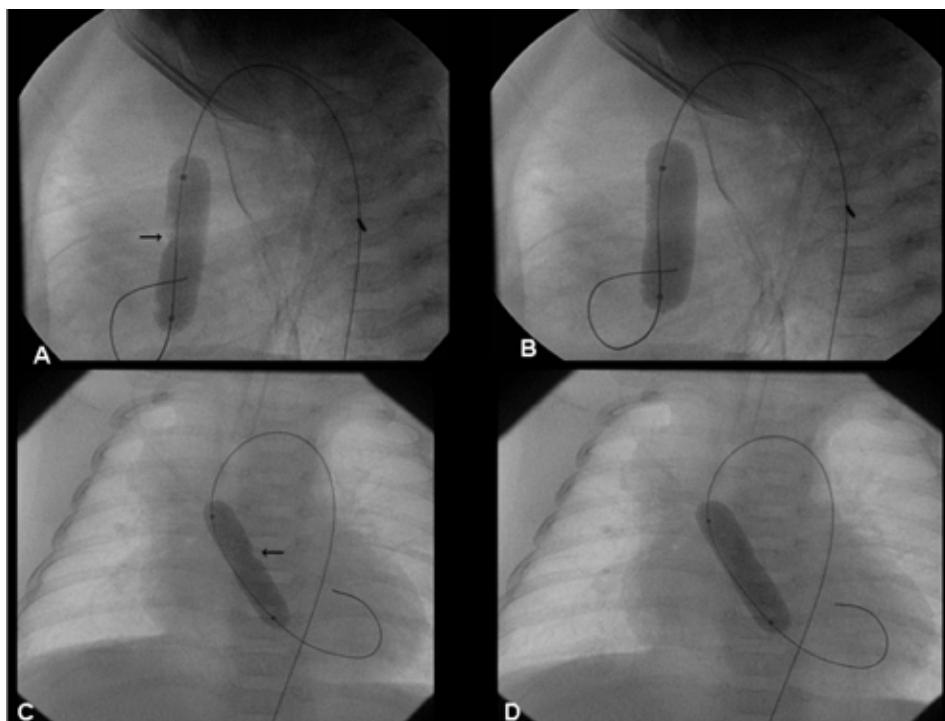


Figure 7. Selected cinefluorographic frames in lateral (A & B) and antero-posterior (C & D) views demonstrating an angioplasty balloon across the stenotic aortic valve with waisting of the balloon (arrows) during the initial phase of balloon inflation (A & C); the waist has completely disappeared with further balloon inflation (B & D).

Sometimes, despite multiple attempts, the tip of the guide wire may not be maneuvered into the descending aorta, or the balloon catheter positioned across the aortic valve. In such situations gooseneck micro-snare (Microvena, White Bear Lake, MN) is introduced through the 4-F multi-A2 catheter (Cordis) in the descending aorta via the umbilical artery. The snare and the catheter are advanced into the aortic arch and the tip of the antegradely placed 0.025-in Amplatz guide wire is snared and brought down into the descending aorta and held in place (Figure 6). Thus, an umbilical venous-to-umbilical arterial wire "rail" is established. With a gentle traction on the umbilical artery component of the rail and while maintaining the wire loop in the left ventricle, the balloon dilatation catheter may easily be advanced antegradely across the aortic valve and balloon valvuloplasty per-

formed. Once the procedure is successfully performed, the guide wire is released from the snare, and withdrawn from the umbilical vein; the presence of a catheter over the entire course of the guide wire within the heart protects the intra-cardiac structures from injury [47].

#### Transumbilical Arterial Balloon Aortic Valvuloplasty

The umbilical arterial catheter is exchanged with a 4-F multi-A2 catheter (Cordis) and positioned in the ascending aorta. A floppy-tipped coronary guide wire or a 0.035-in straight Benston guide wire (Cook), is advanced into the left ventricle across the aortic valve and the catheter advanced over the wire into the left ventricle and a left ventricular angiogram performed. Sometimes it may be difficult to cross the aortic valve and in such situation

a number of other catheters and wires may have to be used, as per the operator's choice. The remaining procedure is similar to that described in the preceding section. With the availability of balloon catheters that track well (for example Tyshak II), silicone-coated catheters, initially described for use in transumbilical arterial approach [43], are no longer necessary.

#### Retrograde Femoral Arterial Balloon Aortic Valvuloplasty

In this technique, a #4-F sheath is placed percutaneously in the femoral artery and a #4-F multipurpose catheter is advanced into the ascending aorta and the remaining procedure is similar to transumbilical arterial procedure described in the preceding section. An example of balloon angioplasty catheter across the aortic valve is shown in Figure 7.

#### Balloon Aortic Valvuloplasty via Carotid Artery

Cut-down and isolation of the right carotid artery is performed by the cardiovascular surgery colleagues, and a #4-F sheath is placed via a purse string suture. The remaining procedure is similar to transumbilical arterial procedure described in the preceding section. Because of the straight course of the catheter, it is much more easy to position the catheter/guide wire into the left ventricle across the aortic valve [41]. Following balloon aortic valvuloplasty, the catheters and sheaths are removed and the arteriotomy is closed by tightening the purse-string suture and the skin incision sutured; this may be performed either by the cardiovascular surgeon or the pediatric cardiologist depending upon the institutional practices.

#### Anterograde Femoral Venous Balloon Aortic Valvuloplasty

The femoral venous access is achieved with #5-F sheath. The procedure is essentially similar to that described in the section on "Transumbilical venous balloon aortic valvuloplasty" except for the site from which the catheters are introduced.

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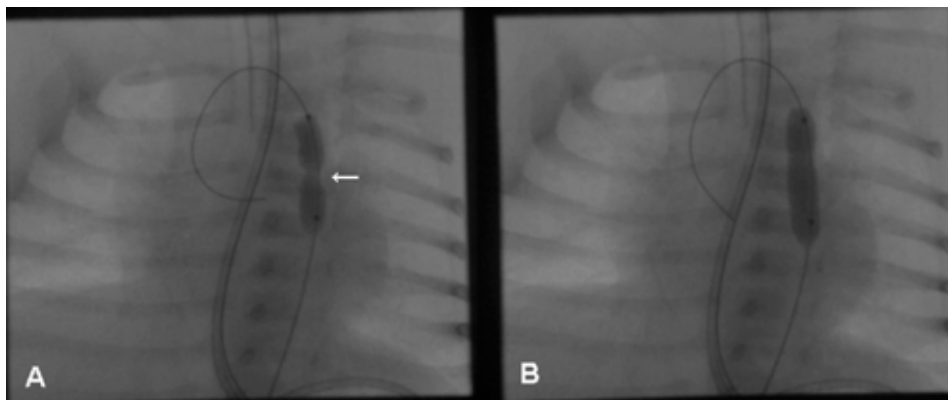


Figure 8. Selected cinefluorographic frames in 20° left anterior oblique projection demonstrating an angioplasty balloon across the aortic coarctation with waisting (arrow) of the balloon (A) during the initial phases of balloon inflation. With further balloon inflation, the waist has completely disappeared (B).

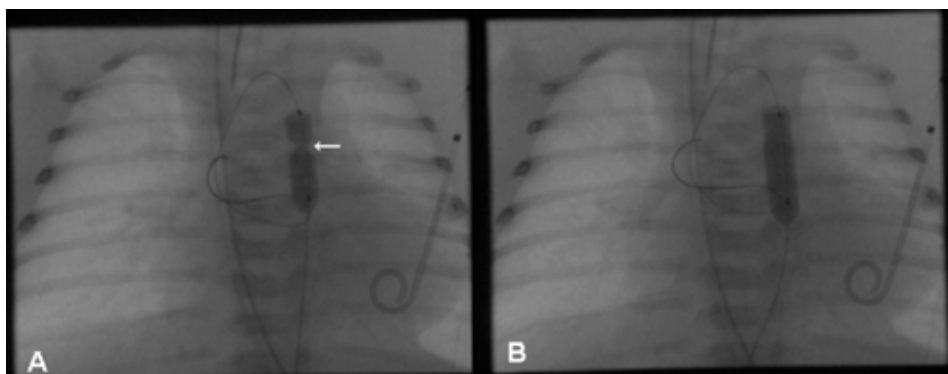


Figure 9. Selected cinefluorographic frames in 20° left anterior oblique projection demonstrating balloon angioplasty of aortic coarctation using a 3-French system. The waisting (arrow) of the balloon in A and its disappearance in B are shown.

## Results

The results of balloon aortic valvuloplasty were tabulated elsewhere [49]; most authors found it useful in the management of sick babies with critical aortic stenosis with improvement in gradient and clinical status. However, poor results were found in 38 to 81% patients. The vast majority of failures appear to be related to either technical difficulties or are secondary to poor

anatomic substrate, namely aortic valve dysplasia, aortic valve annular hypoplasia, hypoplastic left ventricle, mitral valve abnormalities and endocardial fibroelastosis. With the availability of miniaturized balloon angioplasty catheters and other materials, the technical difficulties have largely been eliminated.

Careful comparison of antegrade and retrograde techniques by Magee and

associates [50] suggested similar results in terms of feasibility and gradient reduction. But, the retrograde approach resulted in higher mortality, more severe aortic insufficiency and greater incidence of arterial complications than with antegrade approach. They concluded that antegrade approach should be considered for neonates with severe aortic stenosis. More recent evaluation of this issue suggests that large balloon/annulus ratios are likely to be causing the aortic insufficiency, rather than route of balloon catheter entry.

Comparison between surgical and balloon methods has been made, but the issue is not settled [39,51]. However, based on the available data, balloon valvuloplasty appears attractive in view of high surgical mortality at initial or repeat surgical aortic valvotomy in the neonate with critical aortic stenosis.

## COARCTATION OF THE AORTA

Neonates with severe aortic coarctation causing congestive heart failure are candidates for intervention. An open ductus arteriosus may sometimes permit bypassing the obstruction and make it difficult to evaluate the degrees of obstruction should the ductus close spontaneously. Surgical intervention has been the main approach to treat these babies since first description of surgery by Crafoord and Nylin [52] and Gross and Hubbard [53] in mid 1940s. More recently, balloon angioplasty techniques have been utilized in the management of aortic coarctation.

Gruntzig's technique of balloon angioplasty [2] was adopted by Sos [40], Singer, [5] and Sperling[4] and their associates, to enlarge coarcted aortic segments in a postmortem specimen, post-surgical recoarctation and native coarctation respectively. This is followed by reports of successful use of this technique by several groups of investigators, including our own group. Because of the high rate of recurrence seen in neonates [54-57] and the as-



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sociation of varying degrees of hypoplasia of the transverse aortic arch and isthmus in coarctations presenting in the neonatal period, most groups of cardiologists prefer surgical treatment at this age.

However, balloon angioplasty in neonates and young infants has been very useful in critically ill babies, particularly in those in whom avoidance of anesthesia or aortic cross-clamping required for surgery is beneficial in the overall management. Such special circumstances include infants with shock-like syndrome [58], severe myocardial dysfunction and hypertensive cardiomyopathy [59], prior spontaneous cerebral hemorrhage [60] and biliary atresia awaiting liver transplantation [60,61].

### Balloon Coarctation Angioplasty

The conventional retrograde femoral arterial approach for balloon angioplasty of aortic coarctation may produce arterial damage especially in neonates. Therefore, umbilical artery approach [58,62] and antegrade approach transvenously [63] via a transposed aorta or through the ventricular septal defect, when feasible, should be undertaken. When a femoral artery is catheter entry site, low profile balloons (for example Tyshak II balloons) that can be introduced through 4-F sheaths should be utilized; even Mini-Tyshack via 3-F sheaths may be appropriate [56].

If balloon angioplasty is contemplated, PGE<sub>1</sub> should not be started since an open ductus may interfere with the effectiveness of balloon angioplasty. Cardiac catheterization and selective cineangiography are performed to confirm the clinical diagnosis, to exclude other cardiac defects and to assess suitability for balloon angioplasty. Once balloon angioplasty is decided upon a # 4-F multi-A2 (Cordis) catheter is introduced into the femoral artery percutaneously and is positioned across the aortic coarctation. If umbilical arterial route is used, the umbilical arterial catheter is exchanged with a 4-F multi-A2 catheter (Cordis) and positioned across the aor-

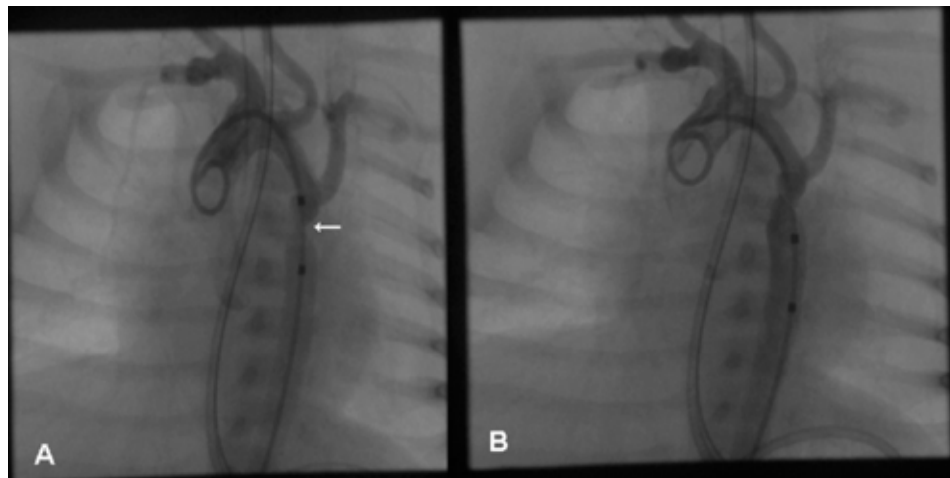


Figure 10. Selected aortic cineangiographic frames in 20° left anterior oblique projection demonstrating narrowed coarcted aortic segment (arrow) prior to balloon angioplasty (A) which increased following balloon angioplasty (B).

tic coarctation. A 0.021 to 0.025 inch J-tipped guide wire is passed through the catheter into the ascending aorta and the tip of the wire positioned in the ascending aorta; If transvenous (femoral vein) antegrade approach is used a 4-F multi-A2 catheter (Cordis) is advanced via the transposed aorta or through the ventricular septal defect into the descending aorta across the coarctation and an appropriate-sized guide wire positioned in the descending aorta distal to the coarctation. The size of the balloon chosen for angioplasty is two or more times the size of the coarcted segment, but no larger than the size of the descending aorta at the level of the diaphragm, as measured from a frozen video recording. We usually choose a balloon that is midway between the size of the aortic isthmus (or transverse aortic arch) and the size of the descending aorta at the level of diaphragm. If there is not an adequate relief of obstruction (pressure gradient reduction to <20 mmHg and angiographic improvement), a balloon as large as the diameter of the descending aortic at the level of diaphragm is chosen for additional dilatation. The selected balloon angioplasty catheter is positioned across the aortic coarctation

and the balloon is inflated (Figure 8) with diluted contrast material to approximately three to five atmospheres of pressure or higher, depending upon the manufacturer's recommendations. Monitoring pressure of inflation via any of the commercially available pressure gauges is recommended. The balloon is inflated for a duration of 5 seconds. A total of two to four balloon inflations are performed 5 minutes apart. Aortography and measurement of pressure gradients across the coarctation site are performed. Because of concern for femoral artery injury, a 3-French system using mini-Tyshak balloon catheters (Braun) may be worthwhile considering (Figure 9).

### Results

Reduction of peak systolic pressure gradients across the coarctation, increase in angiographic diameter of the coarcted segment (Figure 10), improvement of congestive heart failure and hypertension following balloon angioplasty, reviewed in detail elsewhere [22,60,64-66], have been observed by most workers. As pointed out earlier, the problem in the neonate is high rate of recurrence [54-57].



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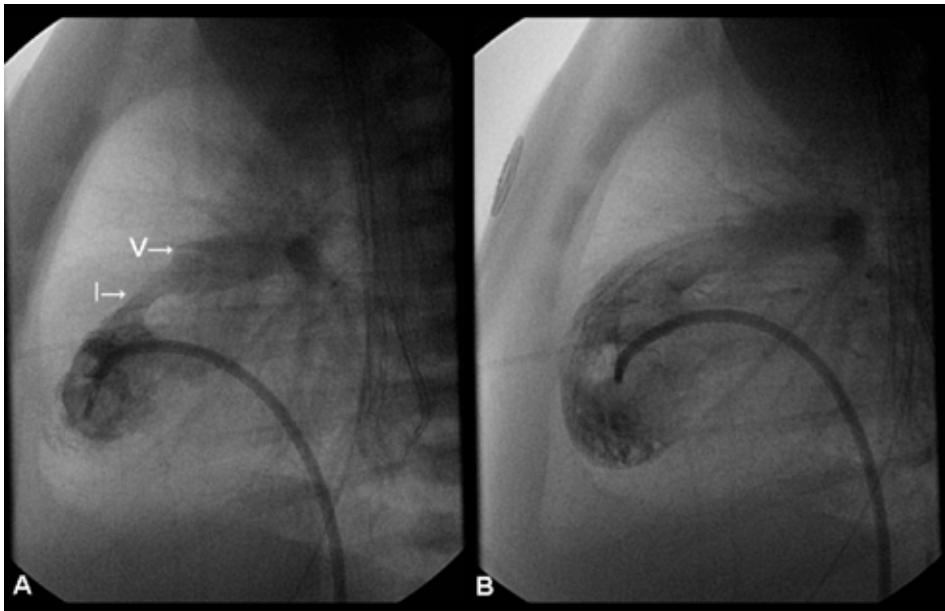


Figure 11. Selected right ventricular cineangiographic frames prior to balloon dilatation (A) demonstrating both infundibular (I) and valvar (V) stenosis. Note the thickened and domed pulmonary valve leaflets. Following balloon valvuloplasty (B), the pulmonary valve leaflets open widely. Even the infundibular obstruction appears better.

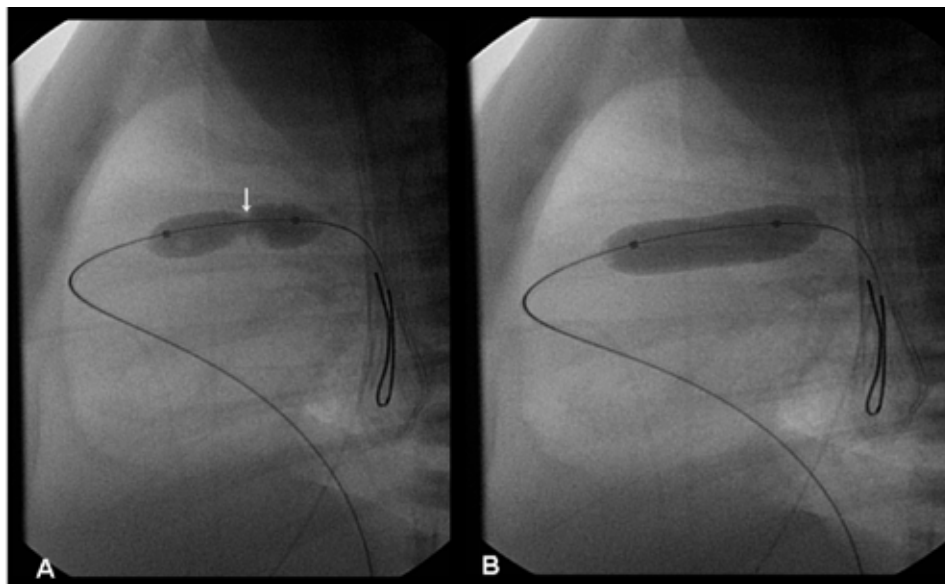


Figure 12. Selected cinefluorographic frames in lateral view demonstrating an angioplasty balloon across the stenotic pulmonary valve with waisting of the balloon (arrow) during the initial phase of balloon inflation (A); the waist has completely disappeared with further balloon inflation (B). This is the same patient whose right ventricular angiogram was demonstrated in Figure 11.

### POST-SURGICAL AORTIC RECOARCTATION

Development of recoarctation following surgery is independent of the type of surgical repair; it has been observed

following resection with end-to-end anastomosis, subclavian flap angioplasty, prosthetic patch repair, subclavian artery turn-down procedure and interposition tube grafts [67]. The younger the child at surgery, the higher is the chance for recoarctation.

Gruntzig's technique was applied to post-surgical coarctation by Singer and his associates[5]; this is followed by its use by others [68-70].

There is general agreement among cardiologists and surgeons that balloon angioplasty is the treatment of choice for post surgical aortic coarctations. However, the need for performing balloon angioplasty for recoarctation in the neonatal period is infrequent. The technique of balloon angioplasty for the management of post-surgical recoarctations is similar to that described above for native coarctation. The immediate and follow-up results of balloon angioplasty for post surgical recoarctation are essentially similar to those of native coarctations and have been reviewed in detail elsewhere [64,67,71].

### PULMONARY STENOSIS ASSOCIATED WITH COMPLEX CONGENITAL HEART DEFECTS

In cyanotic congenital heart defects obstruction to pulmonary blood flow by stenotic or atretic pulmonary valve is an integral part of the cardiac malformation causing right-to-left shunt. The most common type of defect in this group is Tetralogy of Fallot. Other defects include transposition of the great arteries, double outlet right (or left) ventricle, single ventricle, tricuspid atresia, ventricular inversion (corrected transposition of the great arteries) and other types of univentricular hearts, all with nonrestrictive interventricular communication and severe pulmonary valve obstruction. These patients usually present with symptoms in the neonatal period or early in infancy. The degree of cyanosis and the level of hypoxemia determine the symptomatology. Some cyanotic heart defects with pulmonary oligemia can be surgically treated. Total surgical correction may not be possible in some patients because of anatomic complexity. Yet, they may require palliation to augment pulmonary blood flow and to improve systemic arterial desaturation. Surgical aortopulmonary shunts have conventionally been utilized in these situations.

Since the introduction of transluminal balloon dilatation techniques in children by Kan et al [3], we and others [72-75] have utilized balloon pulmonary valvuloplasty to augment pulmonary blood flow instead of systemic-to-pulmonary artery shunt and successfully relieved pulmo-

nary oligemia and systemic arterial hypoxemia.

The indications for balloon valvuloplasty that we have used [74,76,77] were cardiac defects not amenable to surgical correction at the age and size at the time of presentation, but nevertheless required palliation for pulmonary oligemia. Relief of hypoxemia is the major reason for intervention. Hypoplasia of the pulmonary valve ring, main and/or branch pulmonary arteries are other indications even if symptoms are not present. The presence of two or more sites of obstruction (Figure 11A) is considered a prerequisite when employing balloon valvuloplasty [74,76,77], because if valvar stenosis is the sole obstruction, relief such an obstruction may result in marked increase in pulmonary blood flow and elevation of pulmonary artery pressure and resistance.

The technique of balloon pulmonary valvuloplasty is essentially similar to that used for isolated valvar pulmonary stenosis, described in the preceding section; the position of the balloon catheter in a Tetralogy of Fallot patient is illustrated in Figure 12.

## Results

Improvement in systemic arterial oxygen saturation, increase in pulmonary blood flow and pulmonary to systemic flow ratio (Qp:Qs) and decrease in pulmonary valve gradients (while infundibular and total right ventricular outflow gradients remain unchanged) following balloon valvuloplasty have been observed [74,76-79]. The pulmonary valve leaflets open better after valvuloplasty (Figure 11B).

Increase in the size of the pulmonary arteries and the left atrium/ventricle at follow-up has occurred such that some patients who were thought to have uncorrectable defects became good risk candidates for surgical correction [74-81].

***“Until late 1970s, the entire transcatheter armamentarium in pediatric cardiac practice was limited to atrial septostomy. In 1980s, Gruntzig’s balloon angioplasty technique [2] was extended to treat pulmonary valve stenosis[3], native aortic coarctation [4], post-surgical aortic recoarctation [5], aortic valve stenosis [6,7], mitral valve stenosis [8], subaortic membrane[9], branch pulmonary artery stenosis [10], pulmonary vein stenosis [11], stenotic bioprosthetic valves [12,13] and other obstructive vascular lesions [14-19]. Neonatal applications followed [5,20-23].”***

Not all cyanotic heart defect patients with pulmonary stenosis are candidates for balloon pulmonary valvuloplasty. Based on our experience and that reported by others, we [74,76,78,79] recommended this procedure be performed in selected patients. The selection crite-

ria that I recommend are, (a) the infant requires palliation of pulmonary oligemia, but is not a candidate for total surgical correction because of the size of the patient, the type of the defect or other anatomic aberrations; (b) valvar obstruction is a significant component of the right ventricular outflow tract obstruction; and (c) multiple obstructions in series are present so that there is residual subvalvar obstruction after relief of pulmonary valvar obstruction such that flooding of the lungs is prevented. Other indications are any type of contraindication for open heart surgery or refusal by parents/guardians for open heart surgical correction.

## CONCLUSIONS

Severe pulmonary and aortic valvar obstruction may occur in the neonatal period and these obstructive lesions can be successfully treated by balloon valvuloplasty techniques. Milder forms of obstruction do not need intervention in the neonate. Aortic coarctation can be successfully relieved with balloon angioplasty in the neonatal period. However, there is a high rate of recurrence. Consequently, surgical repair is the first line therapeutic option in the neonatal period. If recoarctation develops following surgical repair, balloon angioplasty is the method of choice, although the true need for such intervention in the neonatal period is infrequent. Pulmonary valve stenosis associated with complex heart defects, causing hypoxemia can be successfully treated with balloon valvuloplasty and such intervention is used in highly selected cases.

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## CCT

*P. Syamasundar Rao, MD*  
*Professor and Director*  
*Division of Pediatric Cardiology*  
*University of Texas/Houston Medical School*  
*6431 Fannin, MSB 3.130*  
*Houston, TX 77030 USA*

*Phone: 713-500-5738*

*Fax: 713-500-5751*

*P.Syamasundar.Rao@uth.tmc.edu*



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# Highlights From The 10th International Congress, Congenital & Structural Interventions – June 7-9 2007, Frankfurt, Germany

By Nicolas Majunke, MD



Congenital & Structural Interventions (CSI) is one of the largest courses of its kind dedicated to catheter treatment of congenital and structural heart disease in children and adults. It was held at the Congress Center of Frankfurt, Germany, from June 7th-9th. More than 400 attendees from more than 30 countries around the world were able to follow over 20 live cases performed by Horst Sievert, Neil Wilson and Shak Qureshi, as well as a distinguished international faculty; attendees were able to interact directly with the operators. Additional live cases were transmitted from Great Ormond Street Hospital, London. A total of 110 didactic lectures were given during the congress, presenting emerging technologies and state of the art knowledge in various fields of congenital and structural heart disease.

This congress has a long tradition, and started as an ASD closure workshop in 1996. Over the years, the spectrum has become much broader, and now includes all kinds of congenital heart disease interventions in adults and children. Other main topics of equal importance are catheter interventions in structural heart and valve disease. Both pediatric and adult cardiology specialists are involved as faculty, live case operators and attendees. CSI is famous for its policy of "live transmissions," and discussions have priority. There was excellent interaction between the faculty and the attendees, stimulated by Neil Wilson, Shak Qureshi and Greg Robertson. Daily lunchtime and evening symposia were held by the most experienced specialists for different interventions. A unique feature following the congress has been the hands-on workshops (June 10th and 11th), where interventional cardiologists were able to perform procedures themselves under the professional guidance of Horst Sievert.

## June 7th

As a tradition of the CSI workshop, the outcome of last year's patients' was presented in the first lecture given by Corinna Heinisch from the CardioVascular Center, Frankfurt. The first session on this morning was on Atrial Septal Defects. There were several lectures about pathology of atrial septal defects, including very educational presentations of specimens, results of the multicenter trial with the Solysafe septal occluder, and an interesting talk on transcatheter patch closure of ASDs. During lunch, lectures about the Helex septal occluder, the use of large sheaths, closure of difficult VSDs and different echo techniques for the interventionalist were held. The first afternoon session was on Patent Foramen Ovale closure, and during the second afternoon session called, "LV and RV Outflow Tract," a very interesting talk was given by Yen Ho about the pathology of the left and right ventricular outflow tract.

Further talks about RV and LV outflow obstructions resulted in interesting discussion on these issues. Live cases on this day, performed by Neil Wilson, Nina Wunderlich and Horst Sievert, comprised several cases of ASD, PFO and ductus arteriosus closure. Thursday afternoon sessions were followed by a symposium on current, as well as future PFO closure techniques.

## June 8th

Various posters on congenital and structural heart disease were on display the entire day. Friday morning lectures were about coarctation, aortic aneurysm and ventricular septal defects. Lectures were supplemented by live case transmissions from the CardioVascular Center in Frankfurt. They included PFOs, difficult ASDs, a thoracic aortic aneurysm, and, as a world premiere, the first live case on the treatment of a left ventricular aneurysm using the Parachute® device. In the lunch symposia, tips and tricks for transseptal puncture and the treatment of Coarctation were presented. An e-valve symposium on "Edge-to-Edge Mitral Repair With a Clip," and an NMT symposium on "The Future of PFO Closure: Bioabsorbable Materials and PFO Morphology" were presented as well.

In the afternoon a special lecture. "A Global View on Interventions in Congenital Heart Disease: Who Does What and Where and How and Why?" was given by Mike Tynan. The next session was about transcatheter aortic valve implantations. The newest results of percutaneous aortic valve implantation with the Cribier-Edwards Valve and the CoreValve were given as well as new concepts, such as the Direct Flow Concept and the JenaValve, were presented. Transcatheter mitral valve repair was the subject of the second session held on Friday af-



ternoon. The session started with a presentation of mitral valve anatomy by Yen Ho. After a very interesting debate about transcatheter mitral valve repair between an interventionalist and a surgeon, an update of the status of edge-to-edge mitral valve repair and mitral annuloplasty was presented. Afterwards, the session focused on new concepts of transcatheter mitral valve repair, such as the Ample Medical "PS3 System, The RF Approach: Quantum Cor and Myocor iCoapsys." After a long day full of state-of-the-art lectures and various live case demonstrations, a social dinner was held at an old castle near Frankfurt.

#### June 9th

Saturday was another busy congress day, starting with a session called "What Comes Next?" After a talk on a new concept of PFO closure using a sponge occluder with suture-based anchors, two

different devices (CardioMEMS and Remon) for pulmonary artery pressure monitoring in chronic congestive heart failure patients were presented. Another very interesting talk on catheter treatment of left ventricular aneurysms was given by Gregg Robertson. Uros Babic presented a concept of catheter-based implantation of chordae tendineae for mitral repair. This very interesting session ended with an overview called "Other New Stuff" given by J.P. Cheatham. During the second session on this day, "Other Structural and Congenital Heart Interventions," several talks, including unusual access to the heart, an update on left atrial appendage closure, interventional treatment of central venous occlusions, paravalvular leak closure and catheter closure of ruptured Sinus of Valsalva aneurysm were presented. During the lunchtime symposia, tips and tricks for closure of paravalvular leaks, closure of fistulae, and retrieval of embolised devices were given by several speakers. A large variety of complex live cases



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were performed in the catheterization laboratory of the CardioVascular Center Frankfurt on this day: left atrial appendage closure, treatment of a pseudoaneurysm of the ascending aorta, a complex ASD, a paravalvular mitral leak, and the treatment of a baffle stenosis of the inferior caval vein. The last session of the CSI workshop was about complications in the catheter laboratory, and how to avoid them.

#### June 10th and June 11th

In the unique hands-on workshop at the end of the CSI congress, more than 20 attendees improved their knowledge about ASD and PFO closure in the CardioVascular Center Frankfurt. Under the guidance of Horst Sievert, the participants were able to perform these procedures themselves using various devices. With many live cases, step-by-step procedures, and educational lectures, the "Congenital and Structural Interventions" is the most important interventional meeting in this field in Europe, and one of the largest in the world. It stresses the practical abilities and experience of interventional cardiologists. Next year's CSI congress will be

held in Frankfurt, Germany, from June 25-28, 2008.

For more detailed information and registration, please visit the CSI website: [www.csi-congress.org](http://www.csi-congress.org).

**CCT**



*Nicolas Majunke, MD  
CardioVascular Center  
Seckbacher Landstrasse 65  
60389 Frankfurt, Germany  
Tel: +49 69 4603 1358  
Fax: +49 69 4603 1343*

*[n.majunke@cvcfrankfurt.de](mailto:n.majunke@cvcfrankfurt.de)*

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#### Headquarters

9008 Copenhaver Dr. Ste. M  
Potomac, MD 20854 USA

#### Publishing Management

*Tony Carlson, Founder & Editor*

[TCarlsonmd@mac.com](mailto:TCarlsonmd@mac.com)

*Richard Koulbanis, Publisher & Editor-in-Chief*

[RichardK@CCT.bz](mailto:RichardK@CCT.bz)

*John W. Moore, MD, MPH, Medical Editor/  
Editorial Board*

[JMoore@RCHSD.org](mailto:JMoore@RCHSD.org)

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# PICS-AICS 08 **July 20-23, 2008** Bellagio, Las Vegas

PEDIATRIC AND ADULT INTERVENTIONAL CARDIAC SYMPOSIUM



Course Directors: Dr. Ziyad M. Hijazi, Dr. William E. Hellenbrand, Dr. John P. Cheatham, & Dr. Carlos Pedra

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- The popular session of **"MY NIGHTMARE CASE IN THE CATH LAB"**
- **LIVE CASE DEMONSTRATIONS** featuring approved and non-approved devices will be transmitted daily from many cardiac centers around the world. During these live cases, the attendees will have the opportunity to interact directly with the operators to discuss the management options for these cases.
- **BREAKOUT SESSIONS** for cardiovascular nurses and CV technicians.
- **MEET THE EXPERT SESSION**, held on Sunday, will give attendees the opportunity to discuss difficult cases with our renowned faculty.

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