# Percutaneous Balloon Valvuloplasty with Inoue Balloon Catheter Technique for Pulmonary Valve Stenosis in Adolescents and Adults

**Dr Bhavesh Talaviya[1], Dr P. P. Deshmukh[2], Dr Mukund Deshpande[3], Dr Sunil Washimkar[4], Dr Mahendra Maske[5]**

[1, 2, 3, 4, 5]Department of Cardiology, Super Speciality Hospital & Medical College, Nagpur, Maharashtra, India

**Abstract:** *Background: Percutaneous balloon pulmonary valvuloplasty is the procedure of choice for uncomplicated severe or symptomatic pulmonary stenosis. The present study describes our experience in balloon pulmonary valvuloplasty using the Inouemiral valve dilatation balloon catheter in adolescent and adult patients. Aims: To assess the immediate and mid-term outcomes of percutaneous balloon valvuloplasty with Inouemiral valve dilatation balloon catheter in patients with age group between 18 to 25 years. Methods and results: Between august 2015 and May 2017, we performed percutaneous balloon pulmonary valvuloplasty with Inouemiral valve dilatation balloon catheter in 14 patients (50% females) aged 18 to 25 years. Following the procedure, the mean right ventricular systolic pressure and thePulmonary valvular peak-to-peak systolic gradient decreased from ( 200 to 60 mmHg, (p = 0.001) and ( 180 to 38 mmHg, p = 0.001), respectively. 8 patients which were available for follow-up for 1 year had a mean residual peak gradient of 10 mmHg on Doppler and mean infundibular gradient was 10 mmHg . There was no further increase in grade of pulmonary regurgitation or restenosis on mid-term follow-up. Conclusion: Percutaneous Inoue balloon technique is an attractive alternative with excellent mid-term results for adolescents and adults with isolated pulmonary valvularstenosis.*

## 1. Introduction

Pulmonary valve stenosis (PS) is relatively common disease, and may also be diagnosed in adults, with an incidence of 0.12 per 1000 adults.(1).The presentation may be mild (mostly asymptomatic), moderate (dyspnoea on exertion and fatigue), or severe (right ventricular failure and cyanosis). Since the first trans catheterballoon pulmonary valvuloplasty (BPV) by Kan et al(2).,it has become the procedure of choice for children and adults with uncomplicated severe or symptomatic PS. Most of centres use various fixed size balloon catheters using a single or a double balloon techniqueforBPV.But there are disadvantages of using double or triple balloons such as prolonged procedural time, stretch-induced injury to vessels, balloon slippage and more frequently injuring the pulmonary valve.(3).The Inoue balloon is a unique balloon designed specifically for dilation of the mitral valve.(4 ).It is manufactured with two layers of latex and a fine layer of nylon mesh sandwiched between them. Inoue balloons are available in multiple sizes from 20 to 30mm varying in 2mm increments. The inoueballoons have burst pressures from 4 atm for the 20mm diameter decreasing to2 atm for the 30mm diameter balloon. Each catheter can be safely inflated to a maximal diameter of 1–2mm above the nominal size because of the built-in safety margin. The use of the Inoue balloon wasfirst reported by Lau et al.(5) has advantages over the single-balloon technique. Unlike the cylindrical balloon catheter, with its stiff tip and long balloon, the Inoue balloon catheter is flexible and short, thus minimising the extent of injury to the RV outflow tract and the MPA.(5).Double balloon technique is more complex due to one balloon snagging on the other when both are positioned side by side across the annulus. Moreover,inoueboloon due to its short and self-positioning characters, it minimises possible injury to the right ventricular (RV) infundibulum or the main pulmonary artery (PA).(6).The adjustable inflation of the Inoue balloon makes stepwise dilation possible, reducing the risk of over-dilation of the pulmonary valve. This is not possible with the cylindrical balloon catheter as it wrinkles after inflation andloses its low profile shape. A further advantage of the Inoue balloon arises from its short inflation–deflation cycle of approximately five seconds. This takes care of haemodynamic compromise resulting from the complete obstruction of right ventricular outflow during inflation of the balloon. All these advantages of the Inoue balloon catheter make procedures simpler, safer, and faster.(5),(7).

There is scant Indian data on Inoue balloon catheter technique for PS. The present report describes our experience in BPV using the Inoue balloon catheter and its immediate and mid-term results in adolescent and adult patients.

## 2. Methods

### 2.1. Study patients

From august 2015 to May 2017, 14consecutive adolescent or adult patients underwent BPV with an Inoue balloon catheter. Patient selection was based on symptoms and/or signs and investigations supporting significant isolated valvularPS. All patients had an electrocardiogram (ECG), chest radiograph, and transthoracic echocardiography (TTE) studies done prior to the procedure. Balloon valvotomy was planned in asymptomatic patients with echocardiographic evidence of doming of the pulmonary valve and maximum instantaneous gradient across the pulmonary valve greater than 60mmHg or mean gradient greater than 40 mmHg,and in symptomatic patients with instantaneous gradient greater than 50mmHg and mean gradient greater than 30 mmHg.Patients with grade III or more Pulmonary regurgitation were excluded from this study.

The degree of severity of the pulmonary valve stenosis as well as the pulmonary subvalvular obstruction was assessed and quantified with continuous wave Doppler. The presence and intensity of pulmonary regurgitation were assessed

Paper ID: ART20174911

through colour flow mapping. There were total 14 patients, 7 men and 7female .There were no ASD as well as no VSD or PDA in any patients. There were no cases of any complex congenital heart disease associated.

## 2.2. Procedure

All patients were taken for BPV with prior informed consent. After 6F right femoral vein sheath insertion , intravenous heparin was given at a total dose of 100U/kg. A 5F right femoral arterial access was taken for pressure monitoring. A diagnostic right heart catheterisation to include RV and PA pressure was performed. Right ventriculography in the left lateral view was done using an NIH catheter of appropriate size. From thiscineangiogram assessment of the pulmonary annulus was done and the presence of systolic doming was confirmed. The pulmonary annulus diameter was measured during systole. Over a 0.032 "double length angled tip guide wire a 5F Judkins Right (JR) catheter was delivered into the right heart and placed distal to the stenotic pulmonary valve. The JR catheter was exchanged over the wire with an 8F Mullins dilator. A 270 cm, 0.025mm floppy-tipped stainless steel guide wire was anchored distally in the dilated PA over the Mullins dilator, then dilator was removed. Then14F dilator was used to dilate the venous groin access for easy passage of the balloon catheter. A 12F air free Inoue balloon catheter was prepared, stretched and slenderised by insertion of 18G silver metal tube. The catheter was inserted over the guide wire into the right femoral vein and advanced into the right atrium and then into the RV. On reaching the level of RVOT, de-slenderised. The catheter balloon was then manoeuvred across the stenotic valve with slight clockwise torque to facilitate easy crossing. It was placed in the main

pulmonary artery with the guide-wire firmly held in place. The distal half of the balloon was inflated with diluted contrast agent with normal saline (dilution, 1:4). Initial inflation was performed with a balloon size 1−2mm less than its maximal capacity. Then catheter was pulled back until the middle portion of the balloon was positioned just across the pulmonic valve. The balloon was fully inflated within 4-5 s and then quickly deflated.Repeat inflations with increased balloon diameters (0.5 ml increments) were performed until the waist was abolished. The deflated balloonwas then removed. Then over guidewire , a Multi-Track Angio (Bonhoeffer) catheter advanced into the distal pulmonary artery for pull-back pressure measurement. After successful dilatation, angiography revealed an increase in the systolic excursion with relief in doming of the leaflets, and an increase in the width of the jet across the valve. Following BPV, allcatheters were removed and hemostasis was achieved. After the procedure, all patients were transferred to therecovery facility and given aspirin 3 mg/kg per day forsix months. Transthoracic echocardiography (TTE) and electrocardiography were performed prior to discharge and patients were routinely assessed at one month after the procedure and yearly thereafter.

## 2.4. Statistical Analysis

All data is presented as meanstandard deviation for continuous variables and as proportions for categorical variables. ] SPSS version 20.0 (SPSS.Inc.)was used to perform statistical analysis. Continuous variables were analysed using student t test. All p values were two sided and $p<0.05$ was considered assignificant.
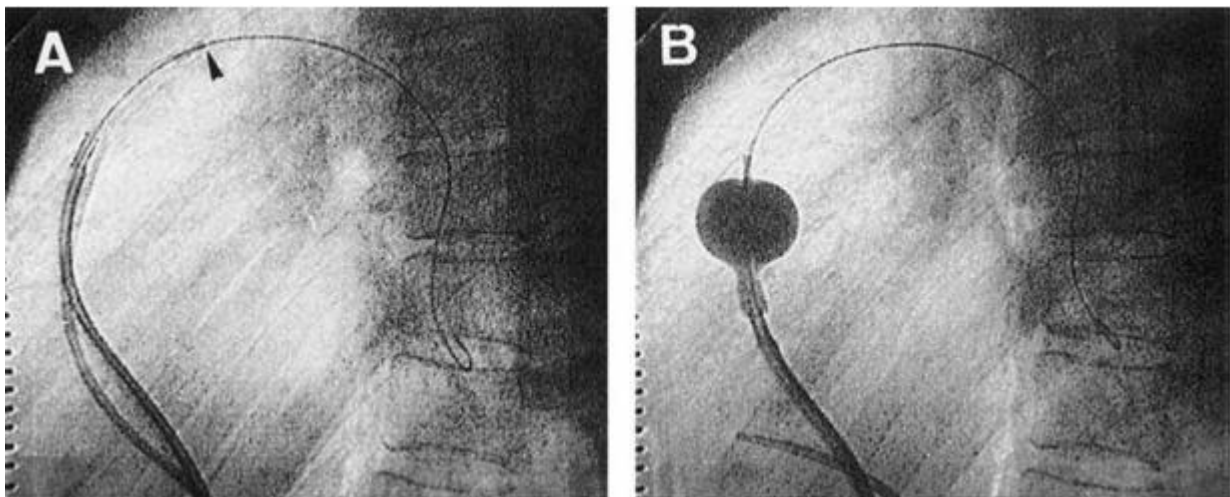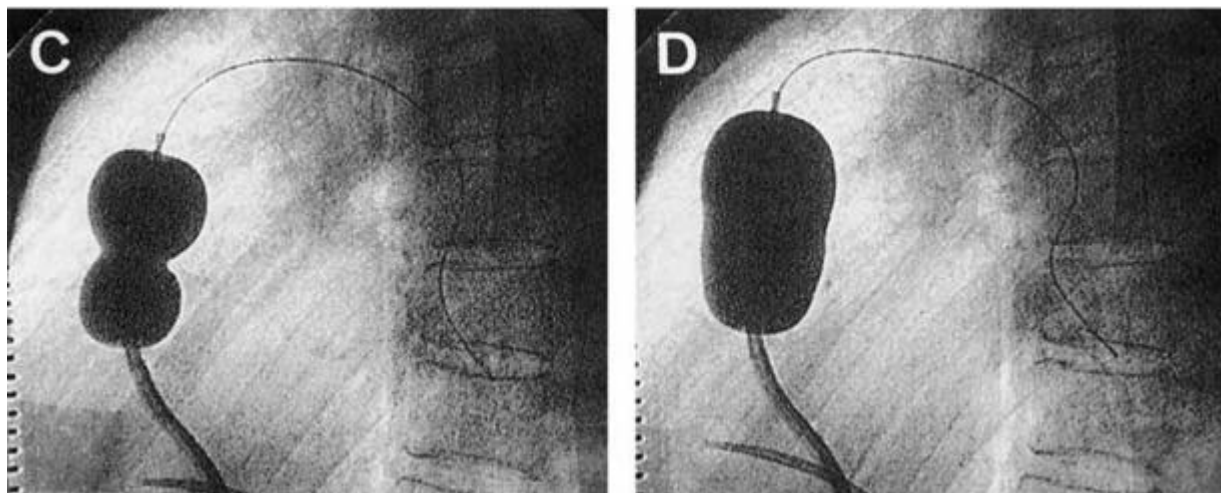
**Figure 1:** Sequence of pulmonary valvuloplasty using an lnoue balloon catheter in the lateral view. A: The catheter balloon (arrowhead)is placed in the main pulmonary artery over a guide wire positioned in the distal left pulmonary artery. B: After the more compliant distal balloon is inflated, the catheter is pulledback to anchor the balloon at the pulmonary valve. C: As the proximal balloon is inflated, a waist is created by the stenosed valve. D: At full inflation, the waist disappears as the valve is dilated. A Berman catheter is also seen in all frames

## 3. Results

### 3.1 Patient characteristics

14 patients aged 18–25years underwent BPV, including 7 male and 7 female patients. The baseline characteristics of patients are summarised in table given below.In our study, most patients were symptomatic with complaintsof effort intolerance or shortness of breath (78.13%). Two patients had syncopal episodes while three had symptoms of right heart failure with pedal oedema. Two patients presented with re-stenosis after prior BPV.

### 3.2 Haemodynamic results

The Inoue balloon catheter could be advanced with ease acrossthe RVOT and dilatation at the orifice was achieved in all patients.All patients had typically a "dome-shaped" pulmonary valve, post-stenoticdilatation of the main pulmonary artery and markedtrabeculation of RV on right ventricular angiography. The meanannular size and final balloon-to-annulus ratio was 30 mm and 0.87respectively. The RV systolic pressure decreased by 50 % from $102 \pm 41$ to $52 \pm 19$ mmHg immediately post BPV ( p = 0.001).The pulmonary valvularpeak to peak gradient was reduced by 91 % from $81 \pm 40$ to $7\pm7$ mmHg (p = 0.0002) with 11 patients experiencing almost total abolition of valvular gradient of less than 10 mmHg . immediately after BPV the infundibular peak to peak systolic gradient developed in 13 patients and increased in remaining patients from 20 to 64 mmHg , the gradient ranged from 8 to 70 mmHg (mean 29). Right atrial and pulmonary arterial pressure remains unchanged .There was , however a trend towards a lower right ventricular diastolic pressure after BPV from $9 \pm 6$ to $8 \pm 5$ mmHg (p= 0.09). Of the 9 patients who received BPV at least 12 months earlier , 8 underwent repeat hemodynamic study at 6 and 12 months. After treatment all had sustained hemodynamic improvement with no e/o valvular restenosis ( Table 1). The mean right ventricular systolic pressure and the mean infundibular peak to peak systolic gradient were reduced compared to immediate post BPV results ( 54 to 40 mmHg , p = 0.03 , and 28 to 10 mmHg , p= 0.03 respectively).

**Echocardiographic and electrocardiographic results:**
Colour Doppler echocardiography after BPV revealed no significant pulmonary regurgitation. In 8 patients unchanged mild regurgitation in two patients and new mild regurgitation in one patients. Electrocardiographic evidence of right ventricular hypertrophy in 8 of 9 patients who had been followed up for more than 6 months , so complete regression in 4 ( patients no 1 ,2 , 6 , 9) and partial regression in other 4 ( patients no 3 ,4 ,5 , 7). Majority of regression occur in first three months.

### 3.3 Complications

Apart from infrequent ventricular premature beats, none of thepatient experienced significant arrhythmic events. There was noepisode of dizziness or syncope, stroke and hypotension duringinflation. Trauma to the RV outflow tract or other cardiac structuresdid not occur in any patient. Post procedure, one patient developeddeep venous thrombosis (DVT) extending to the common iliac vein.Shewas administered anticoagulation therapy and responded well with no evidence of DVT on last follow-up. All other patients weredischarged the following day.

**Table 1:** Hemodynamic Data and Balloon-Related Data

| Patient | Age (years) | sex | RVSP (mm Hg) B | A | F/U | PVG (mm Hg) B | A | F/U | IG (mm Hg) B | A | F/U | F/U (months) | BL (mm) | AN (mm) | BL/AN Ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 25 | M | 65 | 35 | 36 | 38 | 10 | | 0 | 10 | 0 | 30 | 28 | 30 | 0.93 |
| 2 | 19 | F | 62 | 44 | 48 | 48 | 12 | 14 | 0 | 10 | 22 | 28 | 24 | 26 | 0.92 |
| 3 | 18 | M | 110 | 54 | 22 | 88 | 20 | 10 | 0 | 12 | 0 | 12 | 25 | 28 | 0.89 |
| 4 | 24 | M | 200 | 52 | 36 | 182 | 2 | 2 | 0 | 36 | 16 | 12 | 26 | 32 | 0.81 |
| 5 | 20 | F | 134 | 50 | 34 | 115 | 0 | 3 | 0 | 40 | 12 | 14 | 24 | 28 | 0.89 |
| 6 | 21 | M | 110 | 38 | 38 | 88 | 14 | 4 | 0 | 10 | 0 | 14 | 26 | 34 | 0.80 |
| 7 | 21 | M | 138 | 70 | 48 | 115 | 10 | 12 | 0 | 44 | 0 | 14 | 26 | 30 | 0.86 |
| 8 | 19 | F | 65 | 42 | 66 | 46 | 8 | 23 | 0 | 10 | 30 | 12 | 28 | 30 | 0.93 |
| 9 | 17 | F | 90 | 90 | | 52 | 10 | 12 | 20 | 64 | | | 24 | 28 | 0.85 |
| 10 | 25 | M | 64 | 38 | | 50 | 0 | | 0 | 30 | | | 26 | 28 | 0.92 |
| 11 | 25 | F | 62 | 40 | | 50 | 0 | | 0 | 34 | | | 26 | 30 | 0.86 |
| 12 | 25 | F | 80 | 30 | | 60 | 0 | | 0 | 10 | | | 24 | 28 | 0.86 |
| 13 | 17 | F | 122 | 88 | | 94 | 0 | | 0 | 66 | | | 22 | 26 | 0.84 |
| 14 | 23 | M | 130 | 60 | | 110 | 12 | | 0 | 34 | | | 26 | 32 | 0.90 |
| Mean | 22 | | 102 | 52* | 41 | 81** | 7* | 10*** | 2 | 29* | 10** | 17 | 24 | 30 | 0.80 |
| SD | 10 | | 41 | 19 | 13 | 40 | 7 | 8 | 6 | 21 | 12 | 8 | 1 | 2 | 0.03 |

A = post-valvuloplasty; AN = annulus size; B = pre-valvuloplasty; BL = final balloon size; BL/AN ratio = balloon-to-annulus ratio; F = female;

F/U = follow-up; IG = infundibular peak-to-peak systolic gradient; M = male; PVG = pulmonary valvular peak-to-peak systolic gradient; RVSP =

right ventricular systolic pressure.

*$P < 0.05$ when compared with pre-valvuloplasty value; **$P < 0.05$ when compared to post-valvuloplasty value; ***not significant when comparedto post-valvuloplasty value.

## 4. Discussion

Pulmonary valve Stenosis is one of the more common forms of congenital heart disease. It needs adequate treatment. The percutaneous dilation of the pulmonary valve with a balloon is considered the therapeutic modality of choice for the treatment of pulmonary valve stenosis in all group and with any valvular morphology. There is scantyliterature which describes the experience with Inoue balloon catheter technique for BPV. It is one of the attractive alternatives to fixed size balloon techniques. Our study confirmed excellent outcomes with Inoue balloon technique in adult and adolescents patients of valvular PS. The procedure was succesful in all patients. The appropriate BAR helped to alleviate complications like pulmonary regurgitation.

### 4.1 Safety, efficacy, and mid-term results

In this study, Inoue size-adjustable balloon catheter was found to be feasible, safe, and efficacious. And also, the beneficial effects of BPV were well maintained during follow-up, for as long as 1year after the procedure. BPV of asymptomatic patients with isolated PS was has been controversial. In developing countries like India, the chances of inadequate or late follow-up are not insignificant hence it seems prudent to perform the procedure even in asymptomatic patients with significant trans-valvular gradients. Advantage of BPV includes not only the relief of symptoms but also prevention of secondary changes in the RV and progression to more severe degrees of stenosis. Due to a regression in the infundibularobstruction, considered a dynamic process that ebbs after a variable period of time the efficacy of pulmonary balloon valvuloplasty is underestimatedwhen only the immediate results are considered. It is not clear whether infundibular stenosis is due to subvalvularmuscular hypertrophy that subsequently resolves after successful treatment of the valvular stenosis or to infundibularspasm. Some studies recommend the use of beta-blockers for patients after valvuloplasty. We prescribed oral Propranolol routinely for threemonths to all patients after BPV with residual gradients deemedsecondary to infundibular hypertrophy secondary to PS.

### 4.2. Comparison with the fixed-size balloon technique

Awidevariety of balloon catheters are available in market and can be usedto successfully treat pulmonary valve stenosis. The success of BPVdepends on the ability of the selected balloon to achieve stable andcomplete inflation.(19).Rao et al. have suggested to choose a lowprofile balloon capable of advancing through the smallest possiblevascular access in smaller patients whereas a balloon with higherrated burst pressure in adults.TheTyshak series of balloons (NuMed, Hopkintown, NY) likeTyshak, Tyshak II and Tyshakmini have been designed for balloon valvuloplasty and ongoing modifications have been made in order to reduce the profile of the balloon catheter, while maintaining theresistance to balloon rupture. In adult patients where smallervascular access size is less critical, there are a wide array ofballoons with higher-rated burst pressure that have beendeveloped, including the Z-med balloon series (NuMed), Diamond,Ultrathin, and XXL balloons (Boston Scientific, Natick, MA), Maxi-LD, Opta Pro, and Powerflex (Cordis Endovascular, Warren, NJ), and Marshal balloons (Meditech,Water town, MA). The Nucleus balloon(NuMed) is designed to inflate to a "barbell" shape similar to anInoue balloon. However, there are currently no published reports of the use of this balloon for pulmonary valve dilation.(19).Double balloon technique is used in case of larger annular size with non availability of appropriate single balloon. It decreases therisk of hypotension during

inflation due to a continuous flowbetween the balloons during inflation. On the other side it mayprolong the procedure time and requires extra venous access.Studies have suggested an equal efficacy when comparing doubleballoon technique to single balloon at similar balloon/annulusratio.(3),(20).Liu et al.(21).have shown that adults can be treated with BPV usingthe Inoue balloon with encouraging immediate and long-termfollow-up results that are similar to those in children using thesingle balloon.The Inoue balloon catheter technique is being used by us bothfor the ease of its use and easy availability of the balloon in oursetup, whereas the fixed balloon technique used in 15 subjectsduring the study period so far in our institute has shown the known complications of Melon seeding , balloon rupture in two cases,and prolonged procedural time due to multiple exchangesin-between serial inflation. In three patients, the procedure wasswitched from fixed single balloon to Inoue balloon technique asthe previous method was ineffective with significant slippagedistally into pulmonary artery without abolition of waist ('pingpong'or'melon-seeding' effect).The Inoue balloon catheter can be advanced freely in a relativelysimpler RV inflow and outflow anatomy. However, in patients with "difficult-to-track" RV anatomy (severe tricuspid regurgitationwith right atrial enlargement), the Inoue technique is limited by the rigidity of the metal stylet and also by inadequate support ofthe 0.025 "guide wire for tracking the Inoue catheter across thepulmonary valve. In two such cases the Inoue catheter (without the metal stylet) was slenderised over a 0.032" Amplatz super stiff guide wire (Cook Medical, Bloomington, IN), and tracked across the pulmonary valve.

### 4.3. Balloon sizing and pressure

Using an appropriate ratio of balloon to pulmonary valve hingepoint diameter (BAR) is shown to optimise the chance of long-termsuccess. The currently recommended ratio is 1.2−1.25.(19).Such sizing of  balloon is  likely to result in good relief of pulmonaryvalve obstruction while at the same time may help to preventsignificant pulmonary insufficiency at late follow-up. In thepresent study, we chose the appropriate balloon size on the basis of echo-cardiographic and angiographic measurements of the valveannulus The appropriate BAR was central in optimising the resultand preventing the occurrence of pulmonary regurgitation in the study population. In our study, the disappearance of the "waisting" of the balloon was noted even at 2 atm of pressure (mean 2.6_0.4 atm) with resultant successful valvuloplasty. Rao et al.(17).have suggested toperform valvuloplasty sequentially at 3, 4, and 5 atm of pressureinflation. Yeager et al.(22).observed that pressures much higher thanthose required to abolish waisting of the balloon offer noadvantage as the balloons maintain a relatively uniform diametereven at high pressures. High intra-balloon pressure may increasethe chance of balloon rupture with the consequent problems.

### 4.4. Complications

We did not encounter any sustained arrhythmia, or haemodynamiccompromise during the procedure. The incidence of residualpulmonary regurgitation (PR) after

BPV in the most publishedseries ranged from 40 to 90%.(10),(23−25).Residual PR is usually of smallmagnitude after successful percutaneous dilation.(26).Its occurrenceafter the procedure may be explained by the fact that themechanism of valvular opening through the use of ballooncatheters consists of commissural separation, rupture, or even avulsion of the leaflets.(27).The VACA study,(10)incriminated the BAR greater than 1.4, andcomplex valvular morphology due to a previous surgical valvotomyor the presence of valvular dysplasia for moderate pulmonary insufficiency. Rupture of the right ventricular outflow tract hasbeen observed to be the major fatal complication of BPV occurringmostly in neonates or infants with critical pulmonary stenosis and hypoplastic pulmonary valve.(10).However, this complication seems to be extremely rare in adults.(7),(28).Previous experiences have shown that once successfuldilatation is achieved, the chances of restenosis are verysmall.(11),(29),(30).In the present study, no patient had a pulmonaryvalve restenosis during the mid-term follow-up period of 1yr.

## 5. Conclusions

BPV is currently considered the therapeutic modality of choicefor the treatment of PS. But limited information is available on theselection of balloon techniques in adolescent and adults, particularlywith regard to follow-up results. The present study confirmedexcellent safety and favourable early and mid-term outcomes forBPV for isolated PS, in adolescents and adults using the Inoueballoon catheter. Thus Percutaneous Inoue balloon technique is an attractive alternative for adolescents and adults with isolated PS and large annuli when performed by operators experienced with the Inoue balloon catheter.

## 6. Financial Statement

## 7. Conflicts of Interest

The authors have none to declare.

## References

[1] Marelli AJ, Mackie AS, Ionescu-Ittu R, Rahme E, Pilote L. Congenital heart disease in the general population: changing prevalence and age distribution. Circulation. 2007;115:163−172.
[2] Kan JS, White Jr. RIJr., Mitchell SE, Anderson JH, Gardner TJ. Percutaneous balloon valvuloplasty: a new method for treating congenital pulmonary-valve stenosis. N Engl J Med. 1982;307:540−542.
[3] Rao PS. Balloon pulmonary valvuloplasty: a review. Clin Cardiol. 1989;12 (2):55−74.
[4] Inoue K, Owaki T, Nakamura T, Kitamura F, Miyamoto N. Clinical application of transvenous mitral com-missurotomy by a new balloon catheter. J Thorac Cardiovasc Surg. 1984;87:394−402.

[5] Lau KW, Hung JS, Wu JJ, Chem MS, Yeh KH, Fu M. Pulmonary valvuloplasty in adults using the lnoue balloon catheter. CardiovascDiagn. 1993;29:99−104.

[6] Bahl VK, Chandra S, Wasir HS. Pulmonary valvuloplasty using Inoue balloon catheter. Int J Cardiol. 1994;45(2):141−143.

[7] Chen CR, Cheng TO, Huang T, et al. Percutaneous balloon valvuloplasty for pulmonic stenosis in adolescents and adults. N Engl J Med. 1996;335:21−25.

[8] Warnes CA, Williams RG, Bashore TM, et al. ACC/AHA 2008 guidelines for the management of adults with congenital heart disease: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (writing committee to develop guidelines on the management of adults with congenital heart disease). Circulation. 2008;118:e714−e833.

[9] Cooper JW, Nanda NC, Philipot EF. Evaluation of valvular regurgitation by color Doppler. J Am SocEchocardiogr. 1989;2:56−66.

[10] McCrindle BW. Independent predictors of long-term results after balloon pulmonary valvuloplasty. Circulation. 1994;89:1751−1759 (25).

[11] Rao PS. Long term follow up results after balloon dilatation of pulmonic stenosis, aortic stenosis, and coarctation of the aorta: a review. ProgCardiovasc Dis. 1999;42:59−74.

[12] Rao PS. Indications for balloon pulmonary valvuloplasty. Am Heart J. 1988;116 (6 Pt 1):1661−1662.

[13] Nadas AS. Pulmonic stenosis − indications for surgery in children and adults.N Engl J Med. 1972;287(23):1196−1197.

[14] Parent JJ, Hoyer MH. Delayed success of balloon dilation for coexisting pulmonary valve stenosis and sinotubular narrowing. Congenit Heart Dis. 2014;9:216−220 Epub 2013 June 27.

[15] Earing MG, Connolly HM, Dearani JA, Ammash NM, Grogan M, Warnes CA. Long-term follow-up of patients after surgical treatment for isolated pulmonary valve stenosis. Mayo Clin Proc. 2005;80:871−876.

[16] Lee ML, Peng JW, Tu GJ, Chen SY, Lee JY, Chang SL. Major determinants and long-term outcomes of successful balloon dilatation for the pediatric patients with isolated native valvular pulmonary stenosis: a 10-year institutional experience. Yonsei Med J. 2008;49:416−421.

[17] Khambatta HJ, Velado M, Gaffney JW, Schechter WS, Casta A. Management of right ventricular outflow tract reactivity following pulmonary valve dilatation under general anesthesia: experience of a medical mission. PaediatrAnaesth. 2006;16:1087−1089.

[18] Rao PS. Percutaneous balloon pulmonary valvuloplasty: state of the art. Catheter CardiovascInterv. 2007;69:747−763.

[19] Rao PS, Fawzy ME. Double balloon technique for percutaneous balloon pulmonary valvuloplasty: comparison with single balloon technique. J Interv Cardiol. 1988;1:257−262.

[20] Liu S, Xu X, Liu G, Ding X, Zhao X, Qin Y. Comparison of immediate and longterm results between the single balloon and Inoue balloon techniques for percutaneous pulmonary valvuloplasty. Heart Lung Circ. 2015;24(January (1)):40−4510.1016/j.hlc.2014.05.020.

[21] Yeager SB. Occlusion time and inflation pressure in pulmonary valvuloplasty (letter). Am J Cardiol. 1985;55:619.

[22] Berman Jr. WJr., Fripp RR, Raiser BD, Yabek SM. Significant pulmonary valve incompetence following oversize balloon pulmonary valvuloplasty in small infants: a long-term follow-up study. Catheter CardiovascInterv. 1999;48:61− 65.

[23] Abu Haweleh A, Hakim F. Balloon pulmonary valvuloplasty in children: Jordanian experience.J Saudi Heart J. 2003;15:31−34.

[24] Garty Y, Veldtman G, Lee K, Benson L. Late outcomes after pulmonary valve balloon dilatation in neonates, infants and children. J Invasive Cardiol. 2005;17:318−322.

[25] Rao PS, Fawzy ME, Solymar L, Mardini MK. Long-term results of balloon pulmonary valvuloplasty of valvar pulmonic stenosis. Am Heart J. 1988;115:1291−1296.

[26] Walls JT, Lababidi Z, Curtis JJ. Morphologic effects of percutaneous balloon pulmonary valvuloplasty. South Med J. 1987;80:475−478. 180 C. Lanjewar et al. / Indian Heart Journal 69 (2017) 176−181

[27] Karagoz T, Asoh K, Hickey E, et al. Balloon dilation of pulmonary valve stenosis in infants less than 3 kg: a 20-year experience. Catheter CardiovascInterv. 2009;74:753−761.

[28] Rao PS, Galal O, Patnana M, Buck SH, Wilson AD. Results of three to 10 year follow-up of balloon dilatation of the pulmonary valve. Heart. 1998;80:591−595.

[29] Qian X, Qian Y, Zhou Y, Yang X. Percutaneous pulmonary balloon valvuloplasty provides good long-term outcomes in adults with pulmonary valve stenosis. J Invasive Cardiol.2015; Epub ahead of print.

[30] Gielen H, Daniëls O, van Lier H. Natural history of congenital pulmonary valvar stenosis: an echo and Doppler cardiographic study. Cardiol Young. 1999;9:129−135.

[31] Rowland DG, HammillWW, Allen HD, Gutgesell UP. Natural course of isolated pulmonary valve stenosis in infants and children utilizing Doppler echocardiography. Am J Cardiol. 1997;79:344−349.

[32] Vermilion RP, Snider R, Bengur AR, Meliones JN. Long-term assessment of right ventricular diastolic filing in patients with pulmonic valve stenosis successfully treated in childhood. Am J Cardiol. 1991;68:648−652.