Results of percutaneous balloon pulmonary valvuloplasty in pediatric valvular pulmonary stenosis

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Objective: To review the results of percutaneous balloon pulmonary valvuloplasty (PBPV) in pediatric patients with moderate or severe valvular pulmonary stenosis (PS).

Setting: Division of Pediatric Cardiology, Department of Pediatrics, Faculty of Medicine, Chulalongkorn University

Research design: Retrospective study

Patients and Method: Between June 1995 and September 1998, PBPV was performed successfully in 20 of 22 cases of moderate or severe PS. Of the 20 successful cases, there were 10 females and 10 males. The mean age was 6.5 ± 5.2 years (ranged from 10 months to 16 years). The mean weight was 21.2 ± 13.6 kg (ranged from 6.3 to 45 kg)

Results: Immediately after PBPV, there was significant regression of the systolic pressure gradient across the pulmonary valve from 89.15 ± 36.37 to 26.75 ± 14.79 mm Hg (p<0.001) and the right ventricula
systolic pressure from 110.50 ± 34.70 to 51.90 ± 13.12 mm Hg
(p<0.001). There was a major complication in one patient who
developed right hemiparesis from cerebral emboli after the procedure.

Conclusions : PBPV is effective in the relief of obstruction secondary to valvular
PS. It provides successful and good results in cases of typical
valvular PS with the use of an appropriate balloon catheter.

Key words : Percutaneous balloon pulmonary valvuloplasty, Valvular pulmonary
stenosis.

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ผลกระทบ เลือกฟันจริงใจ, ไพร เพราะได้รับการขาด, วิชัย แม่บ้านมารา, จุฬา มีนา บ้านยัน, วิจาร ศิลป์ม่วงcosa. ผลของการรักษาโรคส่วนหัวใจ pulmonary ด้วยการทำขยายตัวลูกโป่งในเด็ก. จุฬาลงกรณ์วิทยาคาร 2542 ภ.ป. 43(2): 89-97

วัตถุประสงค์:
เพื่อศึกษาผลของการรักษาโรคส่วนหัวใจ pulmonary ด้วยการทำขยายตัวลูกโป่งในเด็กที่เป็นโรคส่วนหัวใจ pulmonary ที่มีแนวโน้มกล่าวและซ้อน

สถานที่ที่ทำการศึกษา:
หน่วยโรคหัวใจเด็ก ภาควิชามะวรรธนศาสตร์ คณะแพทยศาสตร์ จุฬาลงกรณ์ มหาวิทยาลัย

วัสดุและวิธีการ:
ระหว่างเดือนมีนาคม พ.ศ. 2538 ถึงเดือนกันยายน พ.ศ. 2541 ได้ทำการรักษาผู้ป่วยโดยโรคส่วนหัวใจ pulmonary จำนวน 22 ราย โดยทำขยายตัวลูกโป่ง ผู้ป่วยจำนวน 20 ราย ได้รับการขยายตัวลูกโป่ง pulmonary ที่มีแนวโน้มกล่าวและซ้อนที่เป็นโรคส่วนหัวใจ pulmonary จำนวน 10 ราย และขยาย 10 ราย อายุตั้งแต่ 10 เดือน ถึง 16 ปี (เฉลี่ย 6.5 ± 5.2 ปี) น้ำหนักตั้งแต่ 6.3 ถึง 45 กิโลกรัม (เฉลี่ย 21.2 ± 13.6 กิโลกรัม)

ผลการศึกษา:
หลังจากการขยายตัว pulmonary ด้วยลูกโป่ง พบว่าการหายอย่างมีนัยสำคัญของความแตกต่างของแรงดัน systole ระหว่างวัณตรือสกิจว่ากับเส้นเลือด pulmonary จาก 89.15 ± 36.37 เหลือ 26.75 ± 14.79 มิลลิเมตร ปอด (p<0.001) และคำว่าแรงดัน systole ของเวียนรินเดชชาจาก 110.50 ± 34.70 เหลือ 51.90 ± 13.12 มิลลิเมตร ปอด (p<0.001) ผู้ป่วย 1 ราย มีผลแข้งข้นจากภาวะการรักษาคือ มีอาการอ่อนแรงซ้ายขวา (right hemiparesis) จาก cerebral emboli.

สรุป:
การรักษาลูกโป่ง pulmonary ด้วยการทำขยายตัวลูกโป่งสามารถลดการสิ่งของโรคส่วนหัวใจที่โหนตอนการได้ปัจจัยที่ทำให้โรคส่วนหัวใจมีลักษณะโรคส่วนหัวใจ pulmonary ที่มีแนวโน้มการขยายตัวที่เสียหาย
Pulmonary valvular stenosis (PS) occurs in 8 to 10% of patients with congenital heart diseases.\(^{(1)}\) Mild PS has a benign course and does not require treatment.\(^{(2,3)}\) Relief of obstruction is recommended in moderate to severe PS with systolic pressure gradients across the pulmonary valve (PS gradient) greater than 50 mm Hg.\(^{(2)}\) In the past, surgical valvotomy had been the only available treatment for PS. After Kan’s first report of successful percutaneous balloon pulmonary valvuloplasty (PBPV) in 1982,\(^{(3)}\) there have been other reports of successful treatment of PS using the PBPV technique.\(^{(4-10)}\) This report describes the results in our 22 cases of PS who were admitted for PBPV to the department of Pediatrics, Chulalongkorn University after April 1995, the time of opening of the new Cardiac Catheterization Laboratory in the Cardiac Center of the H.M. Queen Sirikit Building, King Chulalongkorn Memorial Hospital.

**Patients and Methods**

Between June 1995 and September 1998, PBPV was attempted in 22 patients who were diagnosed to have moderate or severe PS. The procedure could not be successfully performed in 2 male patients with severe PS (aged 5 days and 8 months; weights of, 3 kg and 6 kg, respectively) because of an inability to advance the balloon dilation catheter across the pulmonary valve. Both of these patients had successful surgical valvulotomy within 1 week after the failed PBPV. The remaining 20 patients comprised 10 females and 10 males. Patients’ age at the time of the PBPV ranged from 10 months to 16 years with a mean age of 6.5 ± 5.2 years. Patients’ weights ranged from 6.3 to 45 kg, with a mean weight of 21.2 ± 13.6 kg.

Prior to PBPV, two-dimensional echocardiography was performed to diagnose PS and other associated cardiac lesions and to evaluate the pulmonary valve anatomy. Doppler echocardiography was performed to estimate the PS gradient before PBPV for assessing the severity of the PS and after PBPV for evaluating the results. The doppler estimation of PS gradient was calculated by applying a modified Bernoulli equation to the maximum systolic peak flow velocity (Vmax) recording from the right ventricular (RV) outflow tract proximal to the pulmonary valve using continuous wave Doppler.\(^{(11)}\) The equation is stated as: \( \text{PS gradient} = 4 \times (V_{\text{max}})^2 \).

**Technique of PBPV:** After initial hemodynamic assessment, a right ventriculogram was performed. The pulmonary valve annulus was measured at the hinge points of the valve from the lateral right ventriculogram. The balloon catheter was advanced over an exchange guide-wire that had previously been positioned in the distal left or right pulmonary artery. An oversized balloon with a balloon diameter ratio of 1 to 1.5 to the pulmonary annulus was used.\(^{(7)}\) Once the balloon had been centered across the pulmonary valve, it was inflated rapidly by hand until the waist on the balloon disappeared (figure 1), and then deflated. If the pulmonary annulus was more than 20 mm, two balloon catheters were used simultaneously.\(^{(8)}\) Yeager’s formula was used to calculate the effective combined diameter of the two balloons.\(^{(12)}\) Repeated inflation was performed until no waist appeared during balloon inflation. PS gradient and RV systolic pressure were measured immediately after PBPV to evaluate the result.

Our last three cases were small infants (weights of 7.3, 6.3 and 8.4 kg, respectively) who had
severe PS. Two of the 3 cases had cyanosis at rest in room air. We performed successful PBPV in all 3 cases by means of using small balloon catheters (3 mm in balloon diameter) for the initial dilation, followed by oversized balloon catheters for subsequent dilations.

**Statistical analysis:** The continuous data are presented as mean ± SD. The PS gradient and RV systolic pressures before and after PBPV are compared by using the Student t-test for paired samples. P values less than 0.05 were considered significant.

**Results**

Of the 20 patients, who underwent successful PBPV, there were 12 cases of severe PS (PS gradients greater than 80 mm Hg) and 8 cases of moderate PS (PS gradients greater than 35 but less than 80 mm Hg). Among the 12 severe PS cases, there were 3 cases who had cyanosis at rest in room air (percutaneous oxygen saturation around 70%) due to right to left shunt via patent foramen ovale.

The mean PS gradient before PBPV, measured by Doppler echocardiography, was 94.55 ± 24.20 mm Hg (ranged from 60 to 164 mm Hg) and that measured in cardiac catheterization before PBPV was 89.15 ± 36.37 mm Hg (ranged from 53 to 198 mm Hg). There was no significant difference in PS gradients before PBPV measured by both methods (p = 0.12).

A single-balloon valvuloplasty procedure was performed in 15 cases and a double-balloon procedure in 5 cases. The ratio of the balloon diameter to the pulmonary valve annulus was 1.24 ± 0.12, ranging from 1 to 1.5. The PS gradient reduced immediately after PBPV from 89.15 ± 36.37 mm Hg (ranges of from 53 to 198 mm Hg) to 26.75 ± 14.79 mm Hg (ranges of from 0 to 66 mm Hg) (p<0.001) as shown in figure 2. Similarly, the RV systolic pressure reduced from
Figure 2. PS gradient measured during cardiac catheterization before (pre-balloon) and immediately after (post-balloon) PBPV.

110.50 ± 34.70 mm Hg (ranges of from 70 to 218 mm Hg) to 51.90 ± 13.12 mm Hg (ranges of from 31 to 80 mm Hg) (p<0.001) as shown in figure 3.

There were 4 patients who still had PS gradients greater than 36 mm Hg, measured by both cardiac catheterization immediately after PBPV and Doppler echocardiography within 24 hours after PBPV. However, the PS gradient measured by Doppler echocardiography declined to less than 36 mm Hg within 12-month follow-up in all 4 cases. For the 3 patients, the PS gradient continued to decline to less than 36 mm Hg after 12 months.

Figure 3. RV systolic pressure measured during cardiac catheterization before (pre-balloon) and immediately after (post-balloon) PBPV.
cases who had cyanosis before PBPV, the oxygen saturation increased to low 90% in 2 cases within 3 days after PBPV and in all 3 cases within 3 months after treatment.

One patient (a one year old girl) had major complications after the procedure. She developed a high fever with convulsions two hours after PBPV. A neurological examination revealed right hemiparesis. A CT scan performed six hours after PBPV suggested embolic cerebral infarction of the left middle cerebral artery. The other patients had no significant complications.

Discussion

Patients with mild PS usually continue to have mild PS (PS gradient less than 35 mm Hg), and usually without progression, although occasionally the stenosis has been known to progress. In patients with moderate to severe PS, the obstruction has a tendency to progress. Patients who have PS gradients greater than 50 mm Hg are candidates for either surgical or balloon pulmonary valvuloplasty. Nowadays, PBPV remains the treatment of choice for typical valvular PS. Several reports have shown that PBPV is effective in reducing the degree of right ventricular outflow obstruction.

The results of PBPV are as effective as surgical valvulotomy but with less valvular pulmonary insufficiency and less late ventricular ectopic activity.

Because the patient who had mild PS (PS gradient less than 35 mm Hg) need no further intervention, we use a cut-point of residual PS gradient less than 36 mm Hg or the Doppler peak systolic flow across the pulmonary valve of less than 3 m/sec to be the criterion for successful result. All of the 20 patients who underwent PBPV had a significant reduction of RV systolic pressures and PS gradients after the procedure. We had 16 of the 20 cases (75%) who had PS gradients less than 36 mm Hg immediately after PBPV, comparable to 74% from the results of the Valvuloplasty and Angioplasty of Congenital Anomalies Registry. Our 4 cases who had residual PS greater than 36 mm Hg may be explained by the development of subvalvular or infundibular obstruction immediately after the procedure, same as that mentioned in the previous reports. However there was a regression of the PS gradient to less than 36 mm Hg in those 4 cases within a one year follow-up as measured by Doppler echocardiography. This decrease reflected resolution of the infundibular component to outflow obstruction.

Regarding the two failed cases where the balloon catheter could not be passed across the valve orifice, the reasons for the failure may be due to 1) tiny valve orifice in both cases, or 2) lack of low profile and smaller balloon catheter. The last three cases who were small infants (weights of 6.3-8.4 kg) with severe PS, had successful outcomes by means of using small balloon catheters for the initial dilation, followed by oversized balloon catheters for subsequent dilations.

The factors that provide successful and good results in our cases are 1) we used oversized balloons, with the mean balloon diameter to the pulmonary valve annulus ratio of 1.24 ± 0.12 (ranged from 1.0 to 1.5), 2) there was no dysplastic valvular PS in our cases. 3) we used low profile and small balloon catheter for the initial dilation followed by oversized balloon in subsequent dilation, in case of severe PS with tiny valve orifice, and 4) we used double-balloon technique to provide adequate balloon size in case of pulmonary annulus larger than 20 mm.
Major complications (cerebral emboli) occurred in one patient. The patient had severe PS without cyanosis. Only a right heart catheterization was performed in this case. How the patient had cerebral emboli could not be clearly explained. This patient was lost to follow-up after discharge. But telephone contact (two years after the procedure), with her parents indicated that she was doing well but had a neurological sequel of mild weakness of the right upper extremity.

Conclusions

PBPV is effective for the relief of obstruction secondary to valvular PS. It provides successful and good results in cases of typical valvular PS with the use of appropriate balloon catheter

References


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