Ventricular diastolic filling indices in pulmonary stenosis

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Children with valvar pulmonary stenosis have right ventricular diastolic filling abnormalities that may be due to either right ventricular hypertrophy or right ventricular outflow obstruction.

In order to investigate the reason for this abnormality, 23 consecutive cases with pulmonary stenosis (mean age 7.94 ± 3.33 years) undergoing transluminal pulmonary balloon valvuloplasty without significant tricuspid or pulmonary valvar regurgitation were studied prospectively. Right ventricular diastolic filling indices and pulmonary valvar systolic gradients were measured in these children one day before and after pulmonary balloon valvuloplasty and were re-examined six months later. Right ventricular diastolic indices based on rapid early diastolic filling peak velocity (peak E), peak velocity during atrial contraction (peak A), and ratio of E/A were determined by pulsed Doppler echocardiography.

In conclusion, right ventricular diastolic filling indices in patients with pulmonary stenosis did not improve after pulmonary balloon valvuloplasty in the first day but when re-examined by the sixth month there was a significant improvement. These data suggest that diastolic filling abnormalities are more likely a result of right ventricular hypertrophy than of right ventricular outflow obstruction.

Key words: pulmonary stenosis, balloon valvuloplasty, Doppler echocardiography, diastolic functions, children.

Left ventricular filling indices obtained from the transmitral flow velocities by echocardiography have been used in patients with a variety of cardiac diseases including systemic hypertension[1], left ventricular outflow tract obstruction[2], hypertrophic cardiomyopathy[3], coronary artery disease[4], dilated cardiomyopathy[5,6], constrictive pericarditis[7] and valvular heart disease[8]. Use of transtricuspid flow velocities as determined by Doppler echocardiography has been established as a valid method for assessing right ventricular filling[9]. Right ventricular diastolic function has been less extensively studied than diastolic function of the left ventricle[10]. Tricuspid valve Doppler indices were studied for normal values in children with a normal heart[9] and in children with valvular pulmonary stenosis. It is shown that right ventricle (RV) diastolic filling abnormalities in patients with pulmonary stenosis (PS) do not change immediately after successful relief of RV outflow tract obstruction[11].

The purpose of the present study was to determine whether there is any improvement via pulmonary balloon valvuloplasty (PBV), in the early and late phases, on diastolic filling of the RV, and to determine the mechanisms underlying RV diastolic filling abnormalities.

Material and Methods

Patients: The study investigated ventricular diastolic filling indices in patients with pulmonary stenosis and in 17 age-matched normal control subjects (1 females, 10 males). The patient group comprised 23 children (11 females, 12 males) who were randomly selected from all children with pulmonary stenosis undergoing cardiac catheterization in Hacettepe University İhsan Doğramacı Children's Hospital between April 1991 and May 1994. The patient group was 3.5 to 16.5 years old (mean 7.94±3.33 years) and the control group was 3.5 to 14 years old (mean 9.0±3.1 years).

Selection Criteria Included: a) Presence of PS severe enough to warrant treatment with balloon valvuloplasty, b) Absence of additional congenital defects such as tricuspid stenosis or left to right shunts that might alter the tricuspid valve Doppler recording, and c) Absence of significant tricuspid or pulmonary regurgitation by Doppler examination before and after valvuloplasty.

Cardiac Catheterization: The patient group underwent right-and left-sided cardiac catheterization after being sedated with a combination of morphine sulfate, diphenhydramine and diazepam. Peak to peak pressure gradient across the obstruction was measured before and after balloon dilatation.

Echocardiographic Examination: All study participants underwent a range-gated pulsed Doppler eşamination one day before and after pulmonary balloon valvuloplasty and were re-examined six months later. Tricuspid valve Doppler examination was from the apical four chamber view using Toshiba Sonolayer S-SSH 60-A. The sample volume was positioned so as to record the maximum velocities through the valve. Velocities through the tricuspid valve vary significantly throughout the respiratory cycle, with maximal velocities occurring at peak inspiration[5,10]. Therefore, to obtain all Doppler measurements at a standard time in the respiratory cycle, only those beats recorded at peak inspiration were used.

From the Doppler spectral recordings, the peak velocities during rapid ventricular filling (peak E) and during atrial contraction (peak A) were measured and the ratio of peak E to peak A velocities (E/A) was calculated.

Statistical Analysis: Using paired t tests, statistical comparisons were made between control and patient groups before and after PBV. A two tailed p value of <0.01 was used to indicate a significant intergroup difference. All values are presented as mean ± standard deviation.

Results

Patients: There were no significant differences in age, heart rate (93.4±13.3 beats/min versus 87±11 beats/min) or systolic blood pressure (112.78±13.2 mm/Hg versus 109±9.3 mm/Hg) between the pulmonary stenosis group and the control group, respectively. Clinical data of the patient group is illustrated in Table I.

Table I. Clinical Data of the Patients

Patient	Sex	Age (year)	Weight (kg)	Heart Rate (beat/minute)	Systolic Blood Pressure (mmHg)
1	F	16.5	52.6	82	146
2	M	4.5	17.4	122	110
3	F	6.3	22.7	106	120
4	F	14.7	36.3	80	134
5	M	7.6	18.3	95	108
6	M	9	22.8	90	120
7	F	6.5	17.1	110	110
8	M	5.1	14.6	100	85
9	F	10.8	33	80	115
10	M	4.5	13.9	98	100
11	F	11.2	37.5	85	110
12	F	6.7	18.1	74	105
13	F	7.4	24.8	78	105
14	M	5.7	15.5	102	95
15	M	3.6	9.2	90	115
16	F	4.4	13.9	106	96
17	M	5.3	14.7	94	120
18	F	6.6	16.5	110	115
19	M	7	17.1	83	120
20	M	9.7	28.9	92	115
21	M	10.3	24.3	110	130
22	F	11.4	24.6	72	105
23	M	7.9	22.7	90	115
Mean		7.94±3.3	22.45±9.86	93.43±13.28	112.78±13.21

Pulmonary balloon valvuloplasty (PBV) was carried out successfully in all patients without any complication. At cardiac catheterization, all of the patients had sufficient relief of pulmonary stenosis by balloon valvuloplasty. The peak to peak systolic pressure gradient before balloon valvuloplasty (87.3±33.0) was significantly higher than that after valvuloplasty (19.5±5.9) ($p<0.0001$) (Table II).

Table II. Mean Values for the Doppler Measurements of Patients Before and After Pulmonary Balloon Valvuloplasty

	Pre-PBV	Post-PBV (1st day)	p value	Post-PBV (6th month)	p value†
PS-gradient (mmHg)	87.3±33.0 (catheter)	19.5±5.9 (catheter)	0.0001*	23.1±7.5 (echo)	0.0001*
	91.4±22 (echo)	23.2±3.6 (echo)			
E wave (m/sec)	0.48±0.10	0.47±0.7	N.S.	0.51±0.10	N.S.
A wave (m/sec)	0.55±0.10	0.49±0.9	0.0136	0.41±0.09	0.0001*
E/A ratio	0.89±0.21	0.99±0.22	N.S.	1.3±0.2	0.0001*

* Statistically different between groups using paired t test at the 1% level.
† Comparison between pre-PBV and post-PBV (6th month).

PS : pulmonary stenosis.
E : velocity during rapid filling (m/s).
A : velocity at atrial contraction (m/s).
Pre-PBV : before pulmonary balloon valvuloplasty.
Post-PBV : after pulmonary balloon valvuloplasty.

Echocardiographic comparisons of patients with pulmonary stenosis prior to and after PBV: Although less significant differences were observed in Doppler velocities one day before and one day after PBV, A wave values in pre-PBV were much higher than those after six months ($p<0.0001$). E/A velocity ratios were not significantly different one day before and after PBV; however, there was a statistically significant difference in the values six months later, when compared with the one day before and after PBV values ($p<0.0001$) (Table II).

Echocardiographic comparisons of normal subjects and patients with pulmonary stenosis: Mean values of the Doppler measurements of the control group and those of the PS group one day before and six months after PBV are listed in Table III. The patient group had a much higher peak A velocity than the control group ($p<0.0003$) and a much lower peak E velocity than the control group ($p<0.0001$). Therefore, the ratio of peak E to peak A velocities was significantly lower in the patient group ($p<0.0001$). When we compared the results of the control group with results of PBV patients at the sixth month, we detected that there was no significant difference in A wave or E/A ratio (Fig. 1).

Discussion

The indices of right ventricular diastolic relaxation are related with many factors such as age, heart rate, and right ventricular preload (wall stress)[12-15]. Peak A velocity is higher then peak E velocity in the fetus and the newborn infant, but after this period, it returns to normal values and does not change during childhood[12,16-18]. The changes in preload and after load can affect the tricuspid valve diastolic filling indices. So in cases with pulmonary and tricuspid regurgitation, an increase in preload can change diastolic function of the tricuspid valve[5,19]. For these reasons we excluded the patients with pulmonary or tricuspid valve regurgitation. Normally, the peak E velocity of tricuspid valve diastolic indices increases up to 26 percent from expiration toward inspiration, but peak E velocity increases up to 18 percent and the E/A ratio is stable during respiration[12]. Therefore, measurements of the right ventricular diastolic filling flow velocities should be made in a standard time during respiration. We studied diastolic valve flows during peak inspiration.

Evaluation of the diastolic function of the left and right ventricle in congenital heart disease has been increasingly used in recent years[3,11].

Table III. Tricuspid Valve Doppler Measurements in Control Subjects and Patients with Pulmonary Stenosis Before and After PBV

	Controls	Pre-PBV	p value	Post-PBV (6th month)	p value
E wave (m/sec)	0.61±0.12	0.48±0.10	0.0001	0.51±0.10	0.0075
A wave (m/sec)	0.43±0.09	0.55±0.10	0.0003	0.41±0.09	0.5
E/A ratio	1.43±0.27	0.89±0.21	0.0001	1.3±0.20	0.296

* Statistically different between groups using paired t test at the 1% level.
PBV: pulmonary balloon valvuloplasty. E: velocity during rapid filling. A: velocity at atrial contraction.

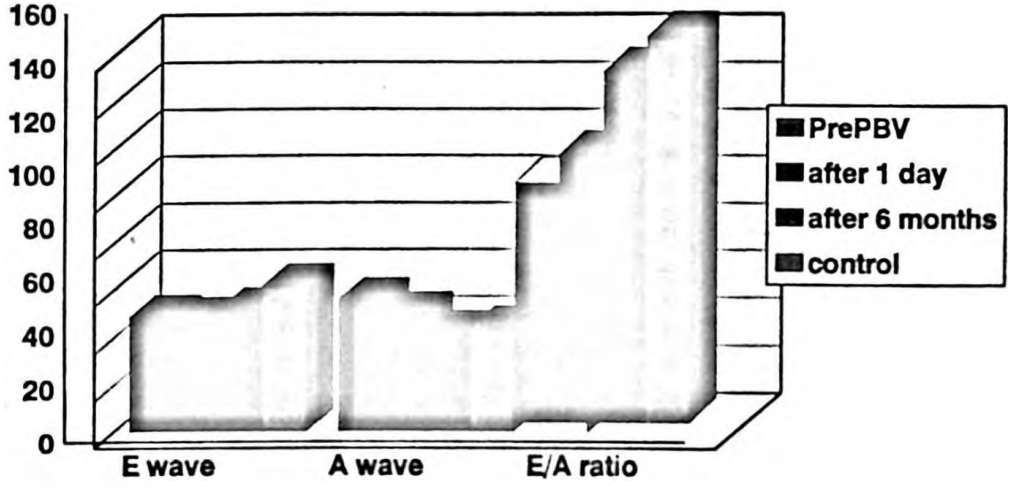

Fig. 1. Outcome of patients with pulmonary stenosis treated by balloon valvuloplasty. Doppler peak velocities before PBV, after 1 day and after 6 months.

It has been shown that diastolic functions worsened in children with right and left ventricular outflow tract obstruction and that they did not improve in the early stages after relief of the obstruction[11,20]. We detected that diastolic filling changes in patients with valvar PS do not improve after PBV, as shown in Table II. Six months after PBV, there was no significant difference in the pulmonary valve peak to peak systolic gradient, but the improvement in tricuspid diastolic indices was statistically significant. Diastolic filling abnormalities seen in patients with pulmonary stenosis did not improve immediately after PBV, as shown by Vermilion et al[11]. In this study, in patients having RV hypertrophy diagnosed by electrocardiographic criteria and echocardiographic findings, tricuspid valve diastolic functions partially improved six months after relief of obstruction.

Conclusion

The abnormalities of RV diastolic filling in patients with PS are not related with right ventricular outflow tract obstruction but are mainly due to right ventricular hypertrophy. As a result of our study, we recommend long-term echocardiographical follow-up for all patients with balloon valvuloplasty in order to evaluate future improvement of ventricular diastolic functions.

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