Mild to Moderate Pulmonary Valvular Stenosis in Infant Sometimes Improves to the Condition Unnecessary to Do PTPV: Doppler Echocardiographic Observation

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TOMITA, H., IKEDA, K., IIDA, K. and CHIBA, S. Mild to Moderate Pulmonary Valvular Stenosis in Infant Sometimes Improves to the Condition Unnecessary to Do PTPV: Doppler Echocardiographic Observation. Tohoku J. Exp. Med., 1995, 176 (3), 155-162 —— The purpose of this study is to clarify the natural history of the valvular pulmonary stenosis (PS) from the standpoint of the indication for percutaneous transvenous pulmonary valvuloplasty (PTPV). We retrospectively analyzed age-dependent changes of the peak velocity in the pulmonary artery (peak V) using Doppler echocardiography (Doppler), and some other echocardiographic and clinical findings in 55 children with mild to moderate PS. Groups A, B, and C consisted of those who had peak V above 3.54 m/sec, between 3.54 and 2.74 m/sec, and less than 2.74 m/sec, respectively. Peak V of 42 patients who had the first Doppler study before 1 year of age decreased from 2.61 ± 0.66 to 2.27 ± 0.80 m/sec (p < 0.01). One infant in group A, that initially included 3 children, has improved to group B. Among the 15 patients in group B, one patient deteriorated to group A, and peak V of 10 infants reduced to less than 2.74 m/sec. In group C, peak V of 2 infants increased above 2.74 m/sec. Other than age at the first examination, we could not find specific indications that could predict the reduction of peak V. Mild to moderate PS younger than 1 year of age sometimes markedly improves; the invasive procedure of PTPV may not be necessary in non-critical infant patients with mild to moderate PS. —— pulmonary valvular stenosis; percutaneous transvenous pulmonary valvuloplasty; Doppler echocardiography

Percutaneous transvenous pulmonary valvuloplasty (PTPV) has been widely accepted as the first line treatment for pulmonary valvular stenosis (PS) (Rao et al. 1988; Stanger et al. 1990). Because of its effectiveness, technical simplicity and safety, it is favored over open heart surgery for milder cases of PS (Tinker et al. 1965; Nugent et al. 1977; Gersony et al. 1993). Several follow-up studies have revealed normal or near normal life expectancy and quality for most mild PS patients; in addition, spontaneous improvement of transvalvular pressure gradi-
ent has been reported in some of them (Leuker et al. 1970; Danilowicz et al. 1975).

In this study, we used a noninvasive method in an attempt to distinguish when best to do PTPV for mild to moderate cases of PS. We evaluated the natural history of transpulmonary valve pressure gradient in these patients using Doppler echocardiography from the standpoint of how well they provided indications for PTPV.

**SUBJECTS AND METHODS**

**Subjects**

Fifty-five patients (26 boys and 29 girls) with mild to moderate PS who had undergone 2 or more consecutive Doppler studies were examined in this study. Age at the first Doppler study ranged from 1 month to 10 years and 3 months old (average 1 year and 3 months old). The last examination was performed at from 3 months to 15 years and 9 months of age (average 4 years old). As a result, the follow up period ranged from 2 months to 7 years (average 2 years and 9 months).

These patients were divided into 3 groups, named A, B, and C, consisting of those who had a peak V above 3.54 m/sec, between 3.54 and 2.74 m/sec, and below 2.74 m/sec, respectively.

The diagnosis of PS was based on these signs during the observation period: auscultatory findings (heart murmur, pulmonary ejection click, wide splitting of S₂); peak velocity of pulmonary artery just above the pulmonary valve (Peak V) of 2.0 m/sec or faster; and two dimensional echocardiographic findings (domes formation of the pulmonary valve, poststenotic dilatation of the pulmonary artery).

**Methods**

Age-dependent serial changes of peak V recorded by continuous wave or pulsed Doppler echocardiography using a Toshiba SSH 160A (Toshiba Co., Tokyo) were retrospectively analyzed.

The frequency of spontaneous improvement and deterioration of peak V across 2.74 or 3.54 m/sec in the follow up period was studied. Based on the simplified Bernoulli’s equation, peak V of 2.74 or 3.54 m/sec correspond approximately to transpulmonary valve pressure gradients of 30 or 50 mmHg, respectively (Hatle and Angelsen 1982).

Correlation among changes of peak V, and clinical or two dimensional echocardiographic features (auscultatory findings, right ventricular hypertrophy on electrocardiogram, dome formation of the pulmonary valve, and poststenotic dilatation of the pulmonary artery) was investigated.

All values are expressed as mean value ± s.d. Paired or unpaired t-test was used to compare continuous variables in the presence of a normal distribution. In all analyses the chosen level of significance was $p < 0.05$. 
RESULTS

Peak V in all patients at the first examination ranged 1.36–4.66 (2.49±0.64) m/sec; it decreased to 0.89–4.58 (2.22±0.76) m/sec at the last study (Fig. 1, p<0.01). In the 42 patients who had the first Doppler study before 1 year of age, peak V significantly decreased from 1.36–4.66 (2.61±0.66) m/sec to 1.05–4.58 (2.27±0.80) m/sec (p<0.01). On the other hand, changes of peak V in the 13 who underwent the first examination after 1 year of age were from the initial of 1.65–2.80 (2.12±0.36) m/sec to 0.89–3.28 (2.02±0.58) m/sec; these were not statistically significant (Fig. 2).

Initially there were 3, 15, and 37 patients in groups A, B, and C, respectively. The age at the first examination in these groups ranged from 1 to 11 months (average 6 months), 1 month to 6 years and 10 months (average 8 months), and 1 month to 12 years and 3 months (average 1 year and 6 months), respectively. The follow up period of these groups was 3 months to 2 years and 3 months (11±14 months), 2 months to 6 years and 1 month (26±23 months), and 4 months to 7 years (37±24 months), respectively.

One patient in group A whose peak V was 3.58 m/sec at 11 months moved to group B 3 months later, with a peak V of 3.20 m/sec. In the other two, whose initial peak V were 4.66 and 3.95 m/sec, peak V remained faster than 3.54 m/sec throughout the observation period; final values were 3.80 and 4.21 m/sec, respectively. In group B, one patient whose peak V was 3.53 m/sec at 9 months increased to 4.58 m/sec in 4 months. On the other hand, peak V of 10 infants in group B decreased to below 2.74 m/sec, then improved to group C. Peak V of these patients ranged 2.83–3.53 (3.09±0.20) m/sec at the first study, which decreased to 1.05–2.66 (2.04±0.48) m/sec. The age of the first examination in these patients ranged from 1 month to 6 months old (average 3 months), and improve-
A peak V was documented between ages of 3 months and 6 years and 6 months (average 3 years). The other 4 patients remained in group B during the follow-up period. Peak V of these four ranged 2.74–2.98 (2.86 ± 0.11) m/sec at first, and 2.98–3.35 (3.21 ± 0.16) m/sec in the last study. The ages of these 4 ranged from 1 month to 5 years and 10 months old (average 1 year and 8 months) in the first study, and the last examination was done at 1 year to 6 years and 9 months of age (average 2 years and 9 months). In group C, peak V of 2 infants who had the first examination within 1 month of age rose from 2.63 to 3.13, and 1.93 to 3.20 m/sec, respectively, then they deteriorated to Group B at the last examination. Peak V of the other 35 patients remained less than 2.74 m/sec; it decreased from the levels of 1.36–2.67 (2.13 ± 0.31) m/sec originally to 0.89–2.68 (1.91 ± 0.46) m/sec in the end (p < 0.05). The age of the 35 patients ranged from 1 month to 10 years and 3 months old (average 1 year and 7 month) at first study, and the last examination was done at from 1 year to 15 years and 9 months of age (average 4 years and 9 months) (Fig. 3).

Although all patients whose peak V changed across 2.74 or 3.54 m/sec had the first Doppler study before 1 year of age, we could not find any other specific
clinical or two dimensional echocardiographic findings that predict spontaneous improvement or deterioration.

CASE PRESENTATION

This girl was brought to our department at 1 month of age. At the first examination, she had a grade 3 systolic ejection murmur on the upper left sternal border with wide splitting of S₂ and typical pulmonary ejection click. ECG showed right ventricular hypertrophy, and two dimensional echocardiography revealed a dome formation of the pulmonary valve and poststenotic dilatation of main pulmonary artery with a peak V of 3.53 m/sec. Although RVH on ECG was stable at 1 year, the peak V decreased gradually to 2.57 m/sec at 2 years, and 1.64 m/sec at 3 years. Although mild poststenotic dilatation remained at 3 years, dome formation had become unclear and RVH on ECG had improved (Fig. 4). Her heart murmur had decreased to grade 1, and ejection click was not audible.

DISCUSSION

PTPV is generally indicated if the peak systolic pressure gradient across a nondysplastic pulmonary valve is 40–50 mmHg or more (Keane and Lock 1987), and the optimum age for PTPV in asymptomatic patients is considered to be 2–4 years of age. Because of its safety and simplicity, this procedure has sometimes been performed in milder cases of PS whose peak systolic pressure gradient was 30–40 mmHg (Sullivan et al. 1985; Tynan et al. 1985; Rao et al. 1988; Stanger et al. 1990). However, unnecessary invasive procedures may be obviated when the transpulmonary valve pressure gradient spontaneously improves, as often occurs in cases of mild to moderate PS.
Fig. 4. Serial Peak V and ECG findings in the patient whose initial peak V at 1 month, that was 3.53 m/sec, decreased to 2.57 m/sec in 2 years, and to 1.64 m/sec in 3 years. Right ventricular hypertrophy on 12 leads ECG also improved in 3 years.
The transpulmonary valve pressure gradient can be estimated from the peak $V$ measured by Doppler echocardiography using a simplified Bernoulli's equation, which is, at present, regarded as the most reliable noninvasive methodology to evaluate the severity of PS (Hatle and Angelsen 1982; Lima et al. 1983; Johnson et al. 1984; Goldberg 1989). Although some studies on serial catheter data showed spontaneous improvement of the transpulmonary valve gradient in mild to moderate patients of PS (Leuker et al. 1970; Danilowicz et al. 1975), there are few noninvasive studies on the natural history of PS. In this study, to clarify the optimal age to perform not only invasive examination but also PTPV for patients with mild to moderate PS, we retrospectively surveyed the changes in peak $V$ measured by serial Doppler echocardiography. In addition, we examined the frequency and the clinical findings of patients who showed increase or decrease of peak $V$ across 2.74 or 3.54 m/sec, which correspond to a transpulmonary valve pressure gradient of 30 or 50 mmHg according to the simplified Bernoulli's equation. These values were chosen because, as mentioned above, the transpulmonary valve gradient of 50 mmHg is generally accepted as the indication for PTPV, and that of 30 mmHg is, so far reported, taken as the lowest limit.

In this study, only one infant of group B deteriorated to Group A, and two of group C fell to group B. On the other hand, peak $V$ before 1 year of age tended to decrease with age regardless of its initial level. Especially notable was the amelioration in one patient of group A; at this writing he is 1 year and 6 months and has not yet been scheduled for PTPV. Several infants in group B sometimes improved to where it was clearly no longer necessary to undergo PTPV. Other than age at the first examination, we could not find indications that could predict the improvement of peak $V$ at the initial examination. Leuker et al. (Leuker et al. 1970) reported that the valve in such patients often grows in diameter faster than the rate of body growth, so that it 'catches up' with body size. Although we did not measure the valve area, the decrease of peak $V$ in this study supports their data. In addition, the significant improvement of peak $V$ in 11 patients of group A and B may reflect the rapid body growth in early infancy.

There are several limitations in this study. Most of the patients in this study were not examined with cardiac catheterization. Although the pressure gradient estimated by simplified Bernoulli's equation was reported to be highly reliable, there are still some potential sources of error (Lima et al. 1983; Johnson et al. 1984; Goldberg 1989). Peak $V$ can change easily through alterations of cardiac output by crying, motion, or the respiratory condition; thus, as the precise conditions under which this value was taken were not specified by the original observes, there is some doubt about the integrity of the data. Because of the retrospective feature of this study, there is a wide range in the follow up period, and we could not find specific findings that can predict the improvement of peak $V$ at the initial study. A further prospective study is mandatory to identify specific characteristics of patients who will improve and when it will occur.
In conclusion, taking these limitations into account, some infants with mild to moderate PS, which has been regarded as an indication for PTPV judging from the peak V, were not clearly indicated so in later examinations. On the basis of these data, we now consider that non-critically ill, mild to moderate cases of PS should wait to undergo PTPV at least until 1 year old.

References