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THE RELATIONSHIP BETWEEN THE "A" WAVE DEPTHS OF THE PULMONARY VALVE ECHOCARDIOGRAM AND THE HEMODYNAMIC VALUES OF PATIENTS WITH ISOLATED VALVULAR PULMONARY STENOSIS*

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Valvular pulmonary stenosis is the most frequently seen anomaly among obstructions of the right ventricular out-flow tract[1,2]. Although isolated valvular pulmonary stenosis can be diagnosed by clinical findings, electrocardiography, x-ray, and cardiac catheterization is performed to determine the severity of the disorder and as an indication for surgical therapy[1,3,4]. Cardiac catheterization is a method which is invasive, relatively expensive and requires a team study. A method which can be applied and repeated more easily is more valuable practically than cardiac catheterization. From this point of view, echocardiography has many advantages and permits definitive noninvasive diagnosis of several cardiac disorders. Since we knew these advantages, we used echocardiography, particularly the "a" wave depth of the pulmonary valve in patients with pulmonary valve stenosis to determine the severity of the stenosis and as an indication for surgical therapy.

Material and Methods

Sixty-six patients with isolated valvular pulmonary stenosis were selected for this study which was performed in the Pediatric Cardiology Unit of Hacettepe University Children's Hospital in Ankara. There were 34 boys and 32 girls and their ages ranged between 1-16 years (mean 9.6 years).

The control group consisted of 54 children without any cardiac pathology evidenced by a lack of clinical, roentgenologic and electrocardiographic findings. There were 28 boys and 26 girls and their ages ranged between 1-16 years (mean 9.6 years).

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Physical examination, medical history along with electrocardiographic and telecardiographic findings were evaluated. Subsequent echocardiographic, cardiac catheterization and angiocardiographic studies were obtained. All of the above procedures except for cardiac catheterization and angiocardiography were performed also on the control group.

Echocardiographic examinations were performed with an Ecoline 20 (Smith Kline Co.) diagnostic ultrasonoscope combined with an Ecoline 21 recorder. A 2.5 megahertz transducer was used. The method described by Gramiak et al[5] was used in recording the pulmonary valve echoes. Photographic recordings were made on Type 2295 Kodak linagraph paper.

Measurements: The depth of the motion directed backward ("a" wave) occurring in the diastolic part of the pulmonary valve echo which follows the electrocardiographic P wave was measured in millimeters. These measurements were taken in at least three cardiac cycles and the average values were obtained[6,7]. The values were then corrected according to the calibration factors. By dividing these measurements into the body surface and the length of the subject, "a" mm/m^2, "a" mm/m indices were obtained, respectively[8].

Results

The mean values of the "a" wave depths on the pulmonary valve echocardiograms of the control group (Group I) and of the patients with pulmonary stenosis are given in Table I. In addition, the hemodynamic values of the cases of pulmonary stenosis are indicated in this table. One of the echocardiocardiograms of the control group is shown in Fig. 1 and those of the patients with pulmonary stenosis in Fig. 2 (a, b).

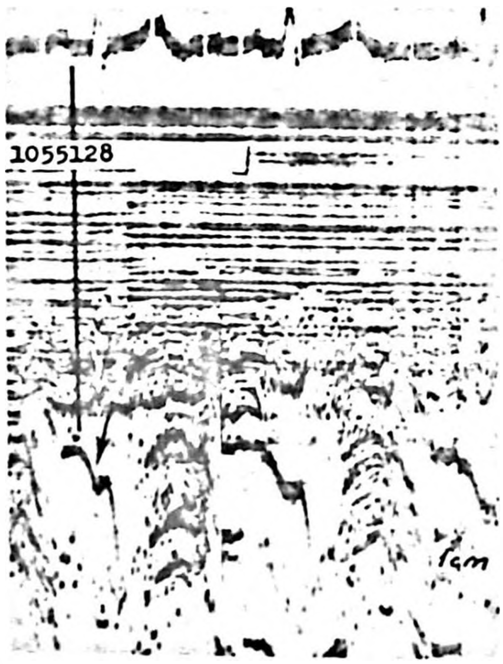

Fig. 1: A normal pulmonary valve echocardiogram. "A" wave (arrow) of the pulmonary valve beginning immediately after the P wave in the electrocardiogram.

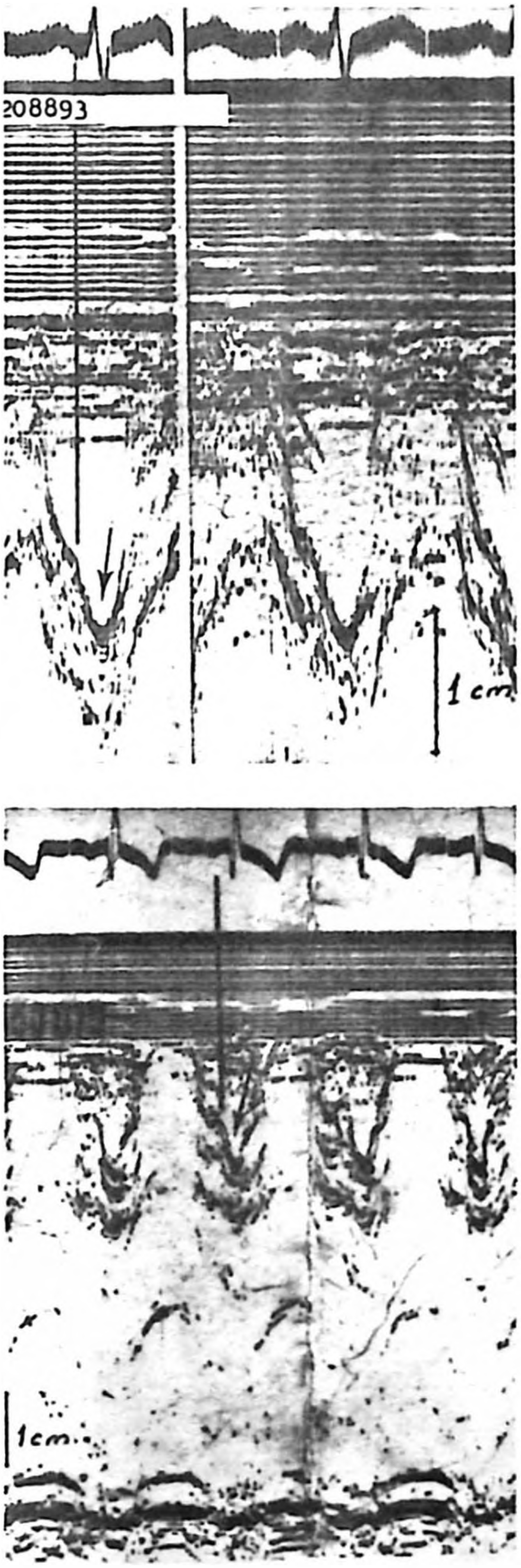

Fig. 2 : The echocardiograms of two cases with moderate (a) and severe (b) pulmonary stenosis are seen. The "a" wave depths in these cases are greater than normal.

TABLE I: Statistical Comparison of the Mean Values of "a" Wave Depths of the Patients with Isolated Valvular Pulmonary Stenosis and Those of the Control Group as Seen on the Pulmonary Valve Echocardiograms

	Mean values			Differences between the groups		
	Group I	Group II	Group III	Groups I-II	Groups I-III	Groups II-III
amm	2.74 ± 0.90	4.37 ± 1.56	8.01 ± 2.34	t: −6.32 p 0.001	t: −14.61 p 0.001	t: −7.56 p 0.001
amm / m	2.17 ± 0.57	3.56 ± 1.03	6.69 ± 1.15	t: −8.17 p 0.001	t: −23.66 p 0.001	t: −11.57 p 0.001
amm / m^2	2.91 ± 0.77	4.81 ± 1.37	9.06 ± 1.25	t: −8.47 p 0.001	t: −27 p 0.001	t: −12.88 p 0.001

Group I : Control group.
Group II : RVSP/LVSP less than 1.
Group III : RVSP/LVSP greater than 1.
amm : The depth of the "a" wave (mm).
amm / m : The depth of the "a" wave corrected according to the length of the patient.
amm / m^2: The depth of the "a" wave corrected according to the body surface of the patient.

No findings of heart failure that would effect the "a" wave depth were observed in the cases being studied, and during the time of investigation all the patients had normal sinus rhythms and P-R intervals on their electocardiograms.

The patients were grouped according to the criteria of the hemodynamic surgical indications used in various centers and also in ours [2]. The patients whose ratio of right ventricular systolic pressure to left ventricular systolic pressure (RVSP/LVSP) was less than one were the group in whom surgery was not necessary[2] (Group II). The others whose ratio was greater than one formed the group of patients in whom surgery was indicated (Group III). As shown in Table I, the comparision of the mean values of the "a" wave depths of these two groups were found statistically to be significant ($p < 0.001$).

Statistical analysis of the data obtained in our study indicated that there was a significant relationship between the "a" wave depth and the RVSP/LVSP ratio, with the r value being 0.67 (Fig. 3).

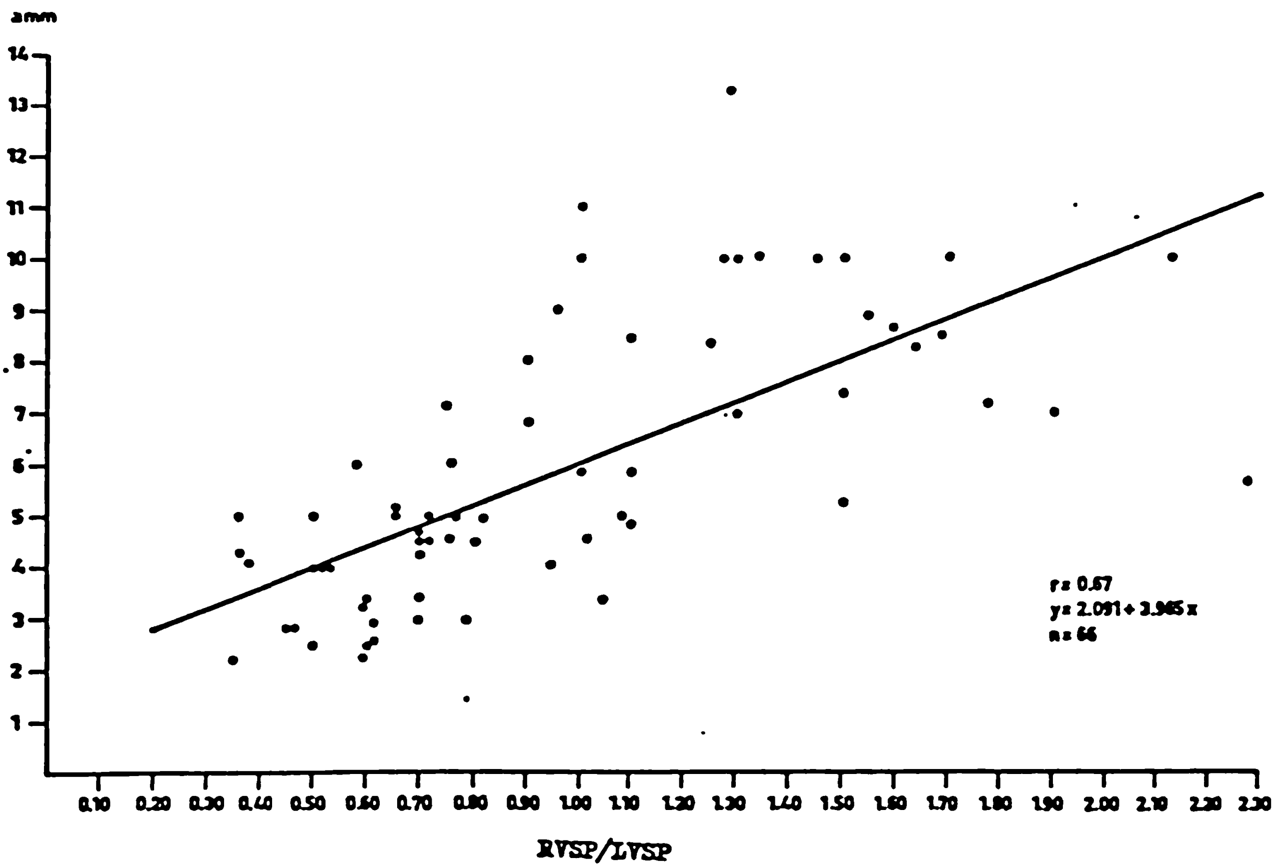

Fig. 3 : The relationship between the "a" wave depths on the pulmonary valve echocardiograms of the patients and the ratio of right to left ventricular systolic pressure.

When the RVSP/LVSP ratio is equal to or more than one, and the "a" wave depth 6.5mm, these findings are taken as criteria for surgical treatment, However, in seven of our cases, although the RVSP/LVSP ratio was greater than one, the "a" wave depth was less than 6.5mm, and in four cases in which this ratio was less than one, the "a" wave depth registered more than 6.5mm. These findings indicate a 84 percent correlation between the "a" wave depths and the RVSP/LVSP ratios.

When the relationship between the "a" wave depths, which were corrected according to the length and body surface of the patient, and the RVSP/LVSP were investigated, the r values were found to be 0.81 and 0.86, respectively (Figs. 4, 5). This indicated that the relationship between the hemodynamic values and the corrected "a" wave depths was much more significant (Table II).

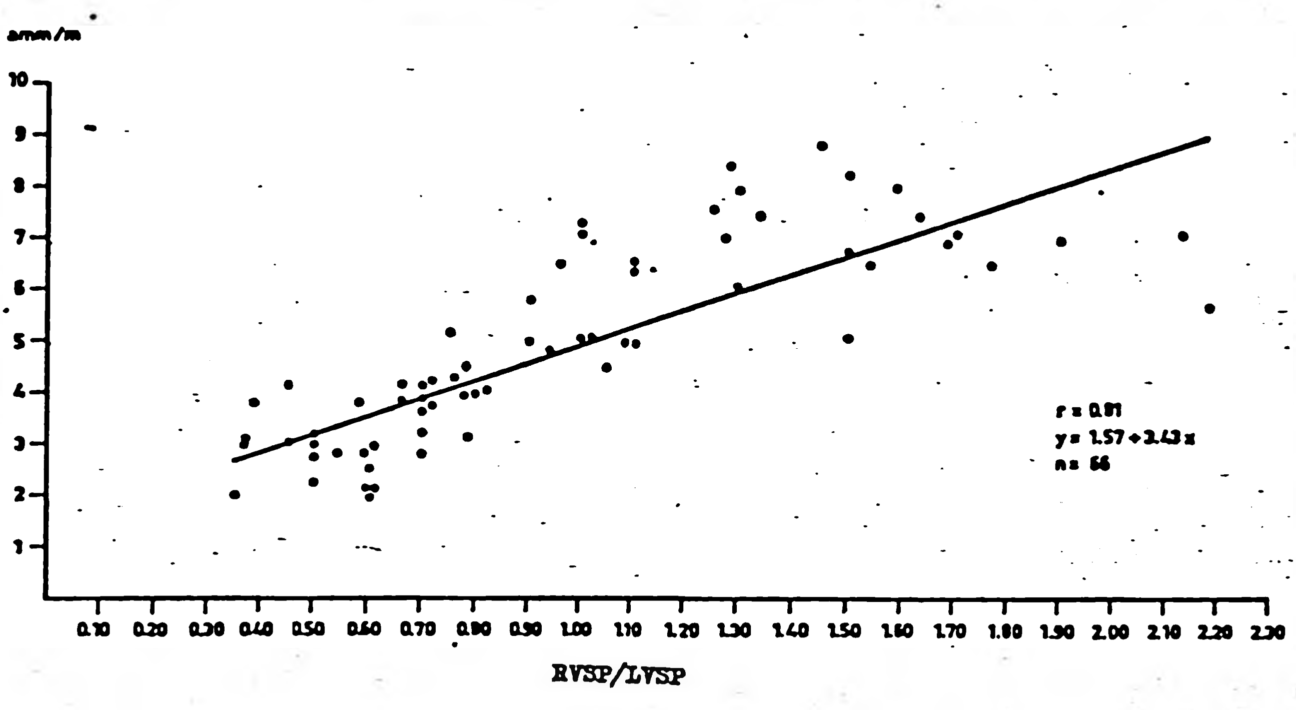

Fig. 4 : The relationship between the "a" wave depths corrected according to the length of the patient and the ratio of right to left ventricular systolic pressure.

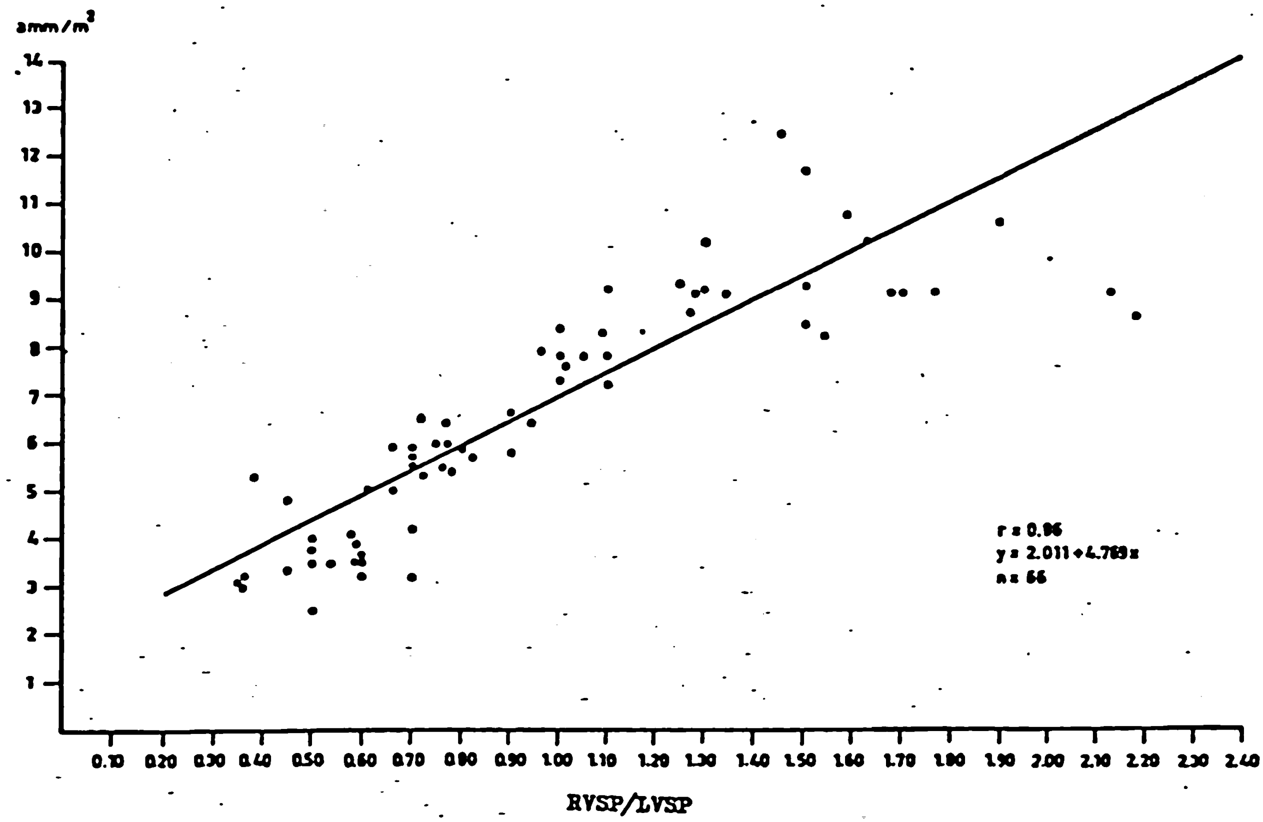

Fig. 5 : The relationship between the "a" wave depths corrected according to the body surface of the patient and the ratio of right to left ventricular systolic pressure.

TABLE II: Statistical Comparison of the "a" Wave Depth with the Ratio of Right to Left Ventricular Systolic Pressure in each Patient

	r	Sr	t	p
"a" mm	0.67	0.091	7.412	< 0.001
"a" mm / m	0.81	0.032	11.371	< 0.001
"a" mm / m^2	0.86	0.062	13.799	< 0.001

When the correction was made according to the length of the patient with the RVSP/LVSP ratio equal to or greater than one and the "a" wave depth 5mm, these were the criteria used as an indication for surgical treatment. However in four cases, the RVSP/LVSP ratios were 0.75, 0.90, 0.90, and 0.96 and the "a" wave depths were found to be 5.1, 5.0, 5.8 and 6.5 mm respectively. Our cases show a 92.5% correlation with regard to the said criteria.

- When the correction was made according to the body surface of the patient and the RVSP/LVSP ratio was equal to or greater than one and the "a" wave depth was taken as 7mm, these findings were used as indication for surgical treatment. However in one of our cases, the RVSP/LVSP ratio was 0.97 and the "a" wave depth was 7.9mm. These results show a 98.5% correlation in our patients.

Discussion

The "a" wave of the pulmonary valve which starts just after the P wave in the electrocardiogram shows the effect of pressure change on the pulmonary valve formed by atrial contraction in the right ventricle. Depending on the increase of the blood volume returning to the right ventricle in inspiration, an increase in tha "a" wave depth occurs in normal individuals. For this reason, researchers refer to the "a" wave depth recorded in the inspiratory phase of quiet respiration as " A maximum" or "A max" and have suggested that the "a" wave should be measured during inspiration[7,9]. Since normally the end diastolic pressure gradient between the pulmonary artery and the right ventricle is small, a mild increase formed by the atrial contraction in the end diastolic right ventricular pressure reflects to the pulmonary valve, and causes the pulmonary valve to bulge toward the pulmonary artery[10]. Thus any factor changing the normal relationship between the pulmonary artery and the right ventricle and diastolic pressures causes a difference in the depth of the shape of the pulmonary valve motion[10,11].

In a study conducted on adult subjects with pulmonary stenosis, Weyman and co-workers[6,7] emphasized that the "a" wave of the pulmonary valve echo can be used in the diagnosis and determination of the severity of the pulmonary stenosis. However they suggested the necessity for further studies, particularly in children.

1. The "a" wave depths of the pulmonary valve echocardiograms in normal subjects.

The "a" wave depths of pulmonary valve echocardiograms in normal subjects in our study and in the literature are shown in Table III.

TABLE III: The "a" Wave Depths of the Pulmonary Valve Echocardiograms of the Normal Population in our Study and in the Literature

	Özkutlu, Saraçlar (children)	Weyman et al[7] (adults)	Nanda et al[11] (adults)	Rey, LaBlanche[12] (children)	Leblanc, Paquet[13] (children)
Range	(1.6 – 6.0) mm	(2 – 7) mm	(1 – 12) mm	upper limit 6 mm	(0 – 12) mm
Mean	2.74 ± 0.90	3.7 ± 1.2	4.4	–	4.8 ± 0.4

With respect to the upper and lower depths, our values are similar to the reports of Weyman[7], and Rey and LaBlanche[12]. Since we know that the pulmonary artery and its valves are smaller in children than in adults, the "a" wave depth values of our control group were corrected according to the body surface and the length of the patient.

The "a" wave depths are illustrated in Table IV after correction according to the body surface and the length of the patient. After the correction, the difference between the upper and lower limits decreased.

TABLE IV: The Values of the "a" Wave Depths after Correction according to the Body Surface and the Length of the Patient

	According to the length of the patient	According to the body surface of the patient
Range value	(1.1 – 3.8) mm	(1.3 – 4.5) mm
Mean value	2.17 ± 0.57	2.91 ± 0.77

2. The "a" wave depths of patients with pulmonary stenosis.

Weyman et al[6,7] have found the upper and lower limits of the "a" wave depth to be between 2 and 10 mm and the average to be 6 mm in 14 cases whose pressure gradient between right ventricle and pulmonary artery was less than 50 mm Hg. They reported that the upper and lower limits of the "a" wave depth were between 6 and 18 mm and the mean value 9.9 mm in 17 cases with moderate or severe pulmonary stenosis, whose pressure gradient was more than 50 mm Hg ($p < 0.001$).

In this study, although the "a" wave depth of the patients with mild pulmonary stenosis was significantly different from the control subjects, due to the several overlapping cases between these two groups, a complete separation of the cases with pulmonary stenosis from normal subjects was not possible. There was a significant increase in the "a" wave depth in the patients with moderate pulmonary stenosis. In these patients, the "a" wave depths were found to be significantly different so as to separate them from the normal cases. One patient in this group was a three-year-old child whose "a" wave depth was less than 8mm. This value is near the lowest limit of this group. The researchers explained that the "a" wave depth value was low in this patient because of the fact that the pulmonary valve and pulmonary artery is smaller in children than in adults. Thus, they suggested that the correction of the "a" wave depth values according to the body size of the patients would be useful but that further studies were neccessary on this subject.

Rey and LaBlanche[12] have studied 16 cases of pulmonary stenosis whose ages ranged between 6 to 15 years. Two of them had mild (systolic pressure gradient between right ventricle and pulmonary artery was 15 mm Hg), thirteen moderate (systolic pressure gradient between right ventricle and pulmonary artery ranged between 40 to 90 mm Hg) and one severe (systolic pressure gradient was 200 mm Hg) pulmonary stenosis. The mean "a" wave depths were 3.5 mm (3 and 4 mm) in the mild cases, 10 mm in the moderate cases (range between 4 to 15 mm) and 7 mm in the severe cases. They were unable to find a correlation between the "a" wave depth and systolic pressure gradient. Their cases were not sufficient in number to make a statistical evaluation.

In 1981, Leblanc and Paquet[13] evaluated the "a" wave depths of 38 cases of pulmonary stenosis whose ages ranged from 2 to 33 years. In this study, the cases consisted of children and adults, and no separation was made according to the ages of the patients. Moreover the patients were not classified hemodynamically according to the systolic pressure gradient between right ventricle and pulmonary artery, but according to the systolic pressure of the right ventricle.

Weyman et al[6,7] studied a group of patients consisting of adults with only one exception. In their study, the hemodynamic classification of the patients was also different from our classification. They did not evaluate the direct correlation between the pressure gradient and the "a" wave values for each patient separately.

To our knowledge, there have been no echocardiographic studies conducted of cases with valvular pulmonary stenosis in which the right and left systolic pressure ratio was used to determine the severity of the stenosis and as an indication for surgical treatment.

When we corrected the "a" wave values according to the body surface and the length of the patient, we found a significant statistical difference between the mean values of the groups ($p < 0.001$; Table I). According to this, a separation of the groups can be made. However Weyman et al[6,7], and Rey and Lablanche[12] did not use the correction method for the "a" wave.

After the correction of the "a" wave, the difference between the highest and the lowest limits decreased (Table V). Thus, depending on the "a" wave depths, the number of cases decreased measureably in which surgical indication was made when not necessary and also in those cases in which surgery was not performed, although it was needed.

TABLE V: The Minimum and Maximum Values of the "a" Wave Depths on the Pulmonary Valve Echocardiograms of the Patients with Pulmonary Stenosis that Are Divided into Two Groups According to the Ratio of Right to Left Ventricular Systolic Pressure

	Right / Left Ventricular Systolic Pressure	
	< 1	≥ 1
amm	2.2 – 9.0	3.4 – 13.3
amm / m	2.0 – 6.5	4.5 – 8.8
amm / m^2	2.5 – 7.9	7.3 – 12.5

As a result, we can say that the corrected "a" wave values are much more useful than the uncorrected "a" wave values. It is more significant when the correction is made according to the body surface than when it is determined according to the length of the patient.

Summary

This study was carried out on 66 children with pure pulmonary stenosis. Fifty-four healthy children comprised the control group. Hemodynamic and echocardiographic studies were performed on the patients.

The relationship between the hemodynamic findings and the "a" wave depths determined by the pulmonary echocardiograms was investigated in all the patients, and the "a" wave depths were measured in all the control subjects.

A significant relationship between the ratio of right to left ventricular systolic pressure and the echocardiografhic pulmonary "a" wave depth was demonstrated. This finding was more significant when the "a" wave depth was adjusted in accordance with the patient's body surface or length.

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