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Echocardiographic Estimation of the Left Atrial/ Aortic Root Ratio in Children with Ventricular Septal Defect and Atrial Septal Defect

(LAD/AoD/LA enlargement/left-to-right shunt)

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Thirty-seven patients with ventricular septal defect (VSD) and twenty-seven patients with atrial septal defect (ASD) were examined echocardiographically for changes in left atrial (LA) size in relation to the size of the left-to-right (L to R) shunt. The LA size was expressed as a ratio of the left atrial to aortic root dimension (LAD/AoD) and the size of the L to R shunt was expressed in terms of pulmonary-to-systemic flow ratios (Qp/Qs).

In VSD, LA size was enlarged when L to R shunt was more than 1.5. In ASD, the size was enlarged at end systole, exclusively in large L to R shunt (>2.0).

The correlation between LAD/AoD and Qp/Qs in VSD was relatively good (r = 0.74) but poor in ASD (r = 0.57) with much scatter.

The echo derived LAD/AoD is a useful method for detecting the LA enlargement and may be helpful in the evaluation of L to R shunt size in patients with VSD.

It has been considered of clinical importance to estimate changes of LA size in the L to R shunting congenital heart disease (CHD). There have been many echocardiographic reports concerning VSD and PDA, and these two lesions have shown LA enlargement due to increased shunt flow (1). It is, however, generally accepted that the LA is of normal size in ASD.

For confirmation, we used ultrasound in isolated VSD and ASD, and the regression equations were calculated with attention given to the correlation between the LA size expressed as LAD/AoD and the shunt size as Qp/Qs.

MATERIALS AND METHODS

Thirty-seven patients with isolated VSD and twenty-seven patients with isolated ASD who recently underwent both cardiac catheterization and echocardiography were studied. Sixteen hospitalized children with no evidence of cardiac disease served as controls. Table I shows the age distribution of these three groups.

During cardiac catheterization, three mililiters of blood from each patient was drawn from the usual sampling sites and the oxygen content was measured

TABLE I. *Groups and Ages of Patients*

	−11m	1−5y	6y−	Total
VSD	12	19	6	37
ASD	2	12	13	27
Normal	0	12	4	16
Total	14	43	23	80

using Van Slyke's method. Using the Fick principle, pulmonary and systemic blood flows were calculated and the size of the L to R shunt was expressed as Qp/Qs. Biplane serial angiocardiography was performed to confirm the diagnosis and to rule out any associated cardiac anomalies.

All echocardiograms were taken within twenty-four hours before or after the cardiac catheterization. Recordings were made on 35 mm photographs using Aloka SSD 90 W with a 0.5 cm diameter, 5 cm focused, and 5 MHz transducer. The transducer was placed mainly in the third intercostal space to record the aortic root (Ao) and the LA. M mode scan from the Ao and LA to the left ventricle (LV) and mitral valve leaflets was performed to confirm alignments of the aortic anterior wall to the interventricular septum and the posterior wall of LA to that of LV.

The LAD was taken from the anterior margin of the posterior Ao wall echo to the surface of the posterior LA echo at the end of ventricular systole. The AoD was taken from the anterior margin of the anterior Ao wall echo to that of the posterior Ao wall echo at the end of ventricular diastole (at the peak of R wave in ECG). Both dimensions were measured at the level of the aortic valve leaflets and at the sites where the posterior wall of LA moves little (Fig. 1).

The LAD and AoD were measured over several cardiac cycles and using the average value, LAD/AoD was calculated in each case.

These LAD/AoD were correlated with Qp/Qs calculated at cardiac catheterization by linear regression analysis in both ASD and VSD. Each was then separated into three groups according to the ranges of Qp/Qs, and mean

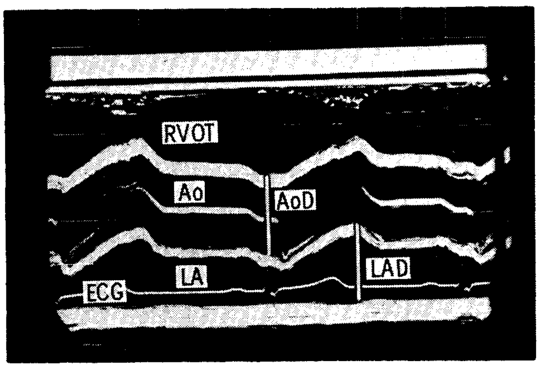

Fig. 1. Echogram taken in the plane of the right ventricular outflow tract (RVOT), the aortic root (Ao) with its valve, and the left atrium (LA). The sites used for the measurements of the aortic root dimension (AoD) and the left atrial dimension (LAD) are demonstrated.

± S. D. calculated for each. These mean values were compared with values in the controls to determine the statistical significance (t-test).

RESULTS

Relationship between Qp/Qs and LAD/AoD in patients with VSD is shown in Fig. 2. The infants (below 11 months of age) were plotted as open circles

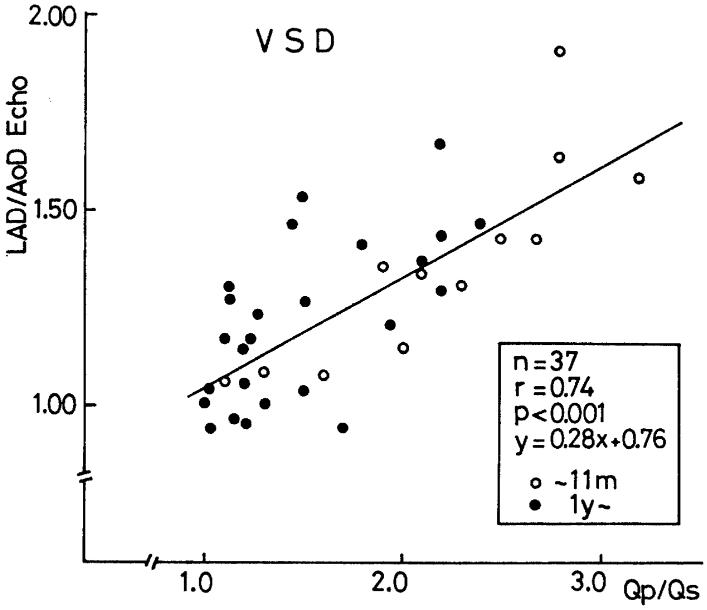

Fig. 2. Relationship between Qp/Qs and LAD/AoD determined on the echogram in patients with VSD. The patients having Qp/Qs below 3.5 are analysed here.

and patients above one year of age as closed circles. The correlation as a whole was relatively good ($r = 0.74$), and the regression equation was expressed as: LAD/AoD = 0.28 (Qp/Qs) + 0.76. or Qp/Qs = 3.6 (LAD/AoD) − 2.7. When only the infants are considered, the correlation improves ($r = 0.85$). A small number of patients with Qp/Qs exceeding 3.5 were not involved here because their LAD/AoD were not so large as expected and showed wide distribution (ranges 1.25 to 1.85). A linearity with Qp/Qs was apparently not maintained.

The results of ASD group are shown in Fig. 3. Patients with a normal pulmonary arterial pressure are indicated by closed circles and those with pulmonary hypertension (pulmonary-to-systemic pressure ratio $\geqq 0.4$) as open circles. The correlation was poor ($r = 0.57$) with a wide distribution although LAD/AoD was somewhat larger according to Qp/Qs.

The populations were separated into three groups according to Qp/Qs (Fig. 4). In VSD, the mean values of LAD/AoD were 1.11 ± 0.15 S. D., 1.22 ± 0.20 S. D., and 1.52 ± 0.28 S. D. for the Qp/Qs ranges of <1.5, 1.5−2.0, and 2.0−3.5, respectively, and the latter two were statistically significant ($p<0.005$ and $p<0.001$) compared to that of the controls (1.04 ± 0.08 S. D.). The mean value of the second group did not differ significantly from that of the first group, but that of the third group differed significantly from

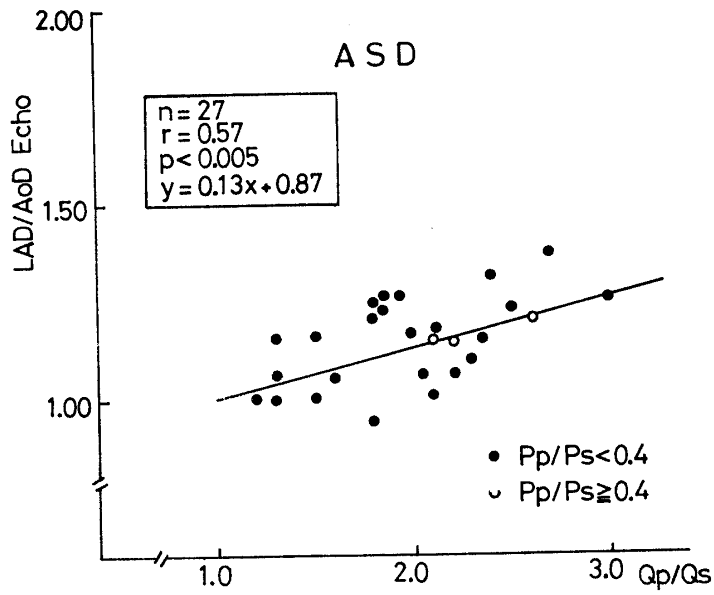

Fig. 3. Relationship between Qp/Qs and LAD/AoD determined on the echogram in patients with ASD. Pp/Ps = pulmonary-to-systemic pressure ratio.

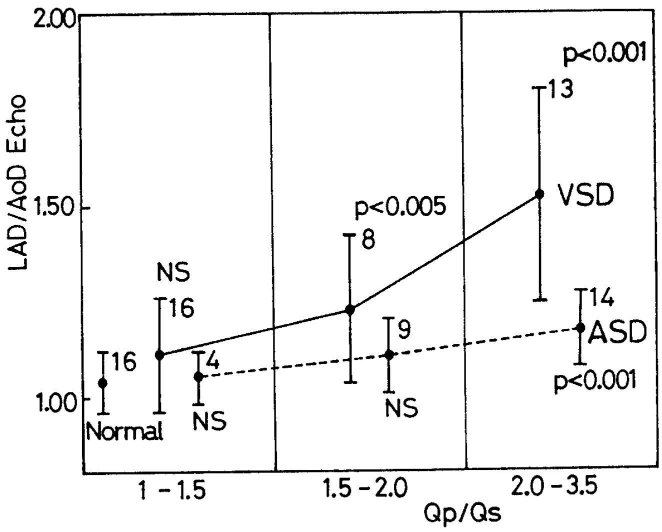

Fig. 4. LA enlargement of VSD and ASD. Each was separated into three groups according to Qp/Qs and means ± S. D. of LAD/AoD are shown.

that of the second group ($p<0.005$). The mean value in patients with Qp/Qs exceeding 3.5 was 1.50 ± 0.26 S. D., and was fairly equal compared to that of the third group.

In ASD, the mean values were 1.05 ± 0.08 S. D., 1.11 ± 0.10 S. D., and 1.17 ± 0.10 S. D. for the same Qp/Qs ranges as in VSD, and only that of the third group was statistically significant ($p<0.001$) compared to that of the controls, but not statistically significant compared to that of the second group.

DISCUSSION

In 1969, Hirata *et al.* reported an excellent method for detecting LA enlargement, using ultrasound (2). Since then, many studies have been performed showing that the LAD determined on the echocardiogram is a better reflection of the LA size than is any other non-invasive method and correlates well with angiographically determined LAD, LA area, and LA volume (2–5).

One of the applications of this clinically useful method for the CHDs in pediatrics is to estimate the degree of LA enlargement and then to quantitate the shunt size (6–8). It has already been shown in neonates with PDA that estimation of LA size was quite useful for the diagnosis, the evaluation of severity and the serial observations of the postoperative states (6, 9).

To compare the degree of LA enlargement in pediatric patients with different body sizes, some adjustment will be required. There have been two methods using body surface area and AoD. Considering that the AoD and LAD are about the same size through the pediatric age in normals, and that the former is a relatively non-distensible fibrous structure in various cardiac disorders, LAD/AoD may be better for detection of LA enlargement (5, 10, 11, 12).

Some studies have been performed in VSD. However, the true relationship between the echo LAD and the shunt size is poorly understood. In our study, LAD/AoD versus Qp/Qs maintained an apparent linearity below 3.5 of Qp/Qs and the correlation between the two in this range was relatively good ($r = 0.74$ on the whole, and 0.85 for the infants). There were six who had a theoretically large Qp/Qs exceeding 3.5, but the LAD/AoD did not appear to enlarge more (1.50 ± 0.26 S. D.) with a wide distribution including unexpectedly small ones with large Qp/Qs. These cases were separated from the linear regression analysis considering that the linearity might not be maintained in this range of large Qp/Qs on calculation.

The correlation between LAD/ AoD and Qp/Qs is debatable. Lewis and Takahashi showed that there was an excellent correlation between LAD/AoD and Qp/Qs including huge Qp Qs range (11), but the number of patients was small and the reproducibility should be confirmed. On the contrary, Lester *et al.* showed that there was not a good correlation ($r = 0.64$) but showed a wide distribution (13). They also showed that there was not a statistically significant difference between the mean values of LAD/AoD of the two groups: Qp/Qs 1.5–2.5, and >2.5. The correlation between the angio LAD/AoD and Qp/Qs was also poor. The LA enlargement from increasing volume overload may not consistently be reflected in the echo A-P diameter as LA geometry changes. This was also considered in PDA (14).

There are many factors influencing the relation between the echo LAD/AoD and Qp/Qs: the reliability of the Fick method to calculate a wide range of Qp/Qs; the relation among the LA volume overload, LA geometry and spatial position of LA itself (Fig. 5); and the relation among the LA volume, angio LAD and echo LAD. More study is required. At present, we consider

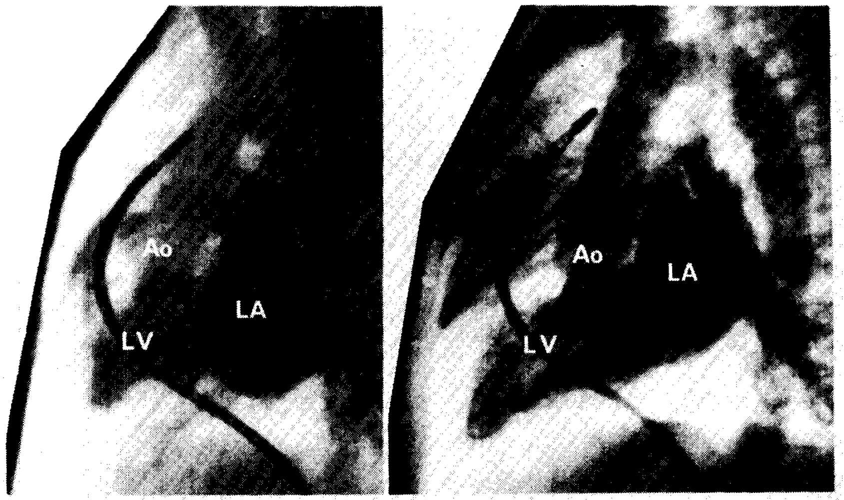

Fig. 5. Lateral angiograms at end systole from the two patients with VSD. One example of LA with changed spatial position relative to Ao is shown (left-hand panel) in comparison with its usual position (right-hand panel). The exact echo A-P dimension of LA may be difficult to obtain in the former.

that there may be a relatively good correlation between the echo LAD/AoD and Qp/Qs if patients with good recordings of LA posterior wall and without an excessive shunt flow ($Qp/Qs < 3.5$) are considered. Echo LAD/AoD may be a semi-quantitative method to estimate the size of Qp/Qs.

In ASD which has interatrial communication, the enlargement of LAD/AoD was to a lesser degree and showed a poor correlation with Qp/Qs and wide distribution. However, it can be seen that LAD/AoD showed a tendency toward enlargement, according to Qp/Qs. This indicates that, even in ASD, the LA receives some degree of volume overload, at least during the atrio-diastolic phase before much of the volume escapes into the right side of the heart through the ventricular late-systolic to diastolic phase.

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