ECHOCARDIOGRAPHIC ASSESSMENT OF Qp/Qs IN CHILDREN WITH ATRIAL SEPTAL DEFECT OR PARTIAL ANOMALOUS PULMONARY VENOUS CONNECTION

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In 24 children with atrial septal defect of the secundum type and/or partial anomalous pulmonary venous connection, the pulmonary to systemic blood flow ratio (Qp/Qs) was estimated by echocardiography. Using M-mode echocardiography, right ventricular diameter (RVD), left ventricular diameter (LVD), total cardiac diameter (TCD) and aortic root (AOR) were measured, and the following 5 indices were obtained: RVD/LVD, RVD/TCD, RVD/AOR, RVD/BSA (body surface area) and TCD/BSA. The single linear correlation coefficients between these 5 indices and Qp/Qs, obtained by the Fick method during cardiac catheterization, were 0.88, 0.80, 0.74, 0.75 and 0.55, respectively. Thus, RVD/LVD ratio was the most sensitive echocardiographic index to assess Qp/Qs in these children. Clinically, however, the multiple linear regression equation derived from 3 indices (RVD/BSA, RVD/LVD and TCD/BSA) might be more useful ($r = 0.89$). Although the abnormal motion of the interventricular septum was analyzed, the quantification of this motion as an index of Qp/Qs was difficult.

THE role of echocardiography in the diagnosis of various congenital heart diseases has been well established, but its usefulness in the quantitative assessment of congenital heart disease leaves much to be desired.

The purpose of this study is to evaluate the shunt volume in children with atrial septal defect

of the secundum type or partial anomalous pulmonary venous connection by M-mode echocardiography.

MATERIALS AND METHODS

Twenty-four Japanese patients including 21 with isolated secundum atrial septal defect (ASD sec), one with isolated partial anomalous pulmonary venous connection (PAPVC) and 2 with ASD sec combined with PAPVC were studied. There were 8 boys and 16 girls, ranging in age from 3 years and 3 months to 10 years and

Key Words:

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TABLE I CLINICAL AND ECHOCARDIOGRAPHIC DATA

Case No.	Sex	Age	Diagnosis	Qp/Qs	CTR	RVD/BSA (mm/m ²)	TCD/BSA (mm/m ²)	RVD/LVD	RVD/TCD	RVD/AOR	IVS motion par.	int.	nor.
1	F	3Y 3M	ASD + PAPVC	4.13	0.62	52.5	110.8	1.39	0.47	1.83		Yes	
2	M	6Y 9M	ASD + PAPVC	3.55	0.55	44.2	70.4	1.31	0.48	1.63		Yes	
3	F	7Y 5M	ASD	3.36	0.50	37.0	82.6	1.30	0.45	1.53	Yes		
4	F	4Y 4M	ASD	2.83	0.54	48.9	109.5	1.28	0.45	1.73	Yes		
5	F	7Y 6M	ASD	2.74	0.51	38.9	92.2	0.94	0.42	1.39	Yes		
6	F	4Y 10M	ASD	2.59	0.55	40.3	93.7	0.95	0.43	1.41	Yes		
7	M	4Y 1M	ASD	2.54	0.56	45.7	104.9	1.07	0.44	1.65	Yes		
8	F	4Y 5M	ASD	2.48	0.59	50.3	115.9	1.22	0.43	1.83	Yes		
9	M	5Y 10M	ASD	2.35	0.56	38.9	95.3	1.00	0.41	1.36		Yes	
10	F	5Y 4M	ASD	2.31	0.60	40.3	92.2	1.00	0.44	1.49	Yes		
11	F	9Y 0M	ASD	2.26	0.57	28.8	68.7	1.10	0.43	1.65		Yes	
12	F	4Y 6M	ASD	2.26	0.62	47.3	108.5	1.14	0.44	1.73		Yes	
13	F	3Y 10M	ASD	2.20	0.54	24.2	108.9	1.00	0.41	1.42	Yes		
14	M	7Y 9M	ASD	2.14	0.55	31.6	81.9	0.77	0.39	1.14		Yes	
15	M	7Y 4M	ASD	1.91	0.50	24.6	77.5	0.61	0.32	1.20		Yes	
16	M	6Y 9M	ASD	1.88	0.51	26.6	78.8	0.75	0.34	0.94		Yes	
17	M	6Y 4M	ASD	1.87	0.51	27.1	77.2	0.74	0.35	1.18		Yes	
18	M	10Y 2M	ASD	1.86	0.51	23.4	65.0	0.74	0.36	1.23		Yes	
19	F	5Y 2M	ASD	1.83	0.55	29.9	88.1	0.77	0.23	1.12	Yes		
20	F	9Y 0M	ASD	1.77	0.48	18.4	66.4	0.61	0.28	0.90		Yes	
21	F	9Y 9M	ASD	1.66	0.55	24.7	69.5	0.75	0.33	1.04		Yes	
22	F	9Y 6M	PAPVC	1.63	0.56	19.2	71.4	0.59	0.27	0.95	Yes		
23	F	6Y 9M	ASD	1.60	0.56	30.9	89.4	0.74	0.24	1.33		Yes	
24	F	6Y 3M	ASD	1.42	0.56	23.1	78.0	0.63	0.30	1.03		Yes	

Qp = pulmonary blood flow; Qs = systemic blood flow; CTR = cardio-thoracic ratio; RVD = right ventricular diameter;
 LVD = left ventricular diameter; TCD = total cardiac diameter; AOR = aortic root; IVS = interventricular septum;
 par = paradoxical; int = intermediate; nor = normal; BSA = body surface area.

Fig.1. Echocardiogram of Case 8 with a Qp/Qs of 2.48. Measurements of RVD, LVD and TCD are shown. RVD/LVD is 1.22.

Fig.2. Echocardiogram of the same case as in Fig.1. Measurement of AOR is shown.

2 months (average, 6 years and 3 months) (Table I).

Biplane cineangiography and operative findings were used to confirm the diagnosis of ASD and/or PAPVC and to rule out the presence of other cardiac anomalies. Patients associated with pulmonic stenosis or pulmonary hypertension were excluded.

Echocardiograms were performed within 48 hours before cardiac catheterization, using a 5 MHz transducer ($\phi 5$ mm) and an E for M VR-12 recorder with the paper speeds of 50 mm/sec or 100 mm/sec.

The transducer was placed in the third or fourth intercostal space at the left sternal border where the mitral valve could be recorded. The ultrasonic beam was then angled inferiorly and laterally to record the inter-ventricular septum (IVS) and the left ventricular posterior wall (LVPW) clearly at the level of the chordae. The gain and the damping of the instrument were adjusted to record the clearest images from the right ventricular anterior wall (RVAW).

The RV diameter (RVD) was measured from the endocardial surface of the RVAW to the RV surface of the IVS. The LV diameter (LVD) was measured from the LV surface of the IVS to the endocardial surface of the LVPW. The total cardiac diameter (TCD) was measured from the epicardial surface of the RVAW to the epicardial surface of the LVPW (Figs. 1 and 3). The above three diameters, RVD, LVD and TCD, were measured over three consecutive cardiac cycles at

Fig.3. Echocardiogram of patient with ASD sec and Qp/Qs of 1.43. RVD/LVD is 0.56.

the onset of QRS (ECG Lead II) and the average diameters were derived. The aortic root (AOR) was measured as an outer/inner diameter in the end systolic phase when the left atrial diameter was maximal (Figs. 2 and 4). All these echocardiographic measurements were performed by one person.

The cardio-thoracic ratio (CTR) was derived from the plain chest film in the antero-posterior projection. During cardiac catheterization, pulmonary and systemic blood flows were measured using the Fick principle. Blood oxygen contents were determined by the Van Slyke method. The volume of the left to right shunt

Fig.4. Echocardiogram of the same patient as in Fig.3.

was expressed as the pulmonary to systemic flow ratio (Q_p/Q_s). A YHP System 45 was used to obtain single or multiple linear regression equations.

Thus, we derived 6 ratios, RVD/LVD, RVD/TCD, RVD/AOR, RVD/BSA, TCD/BSA and CTR. Each ratio was compared with Q_p/Q_s , and linear regression equations and r -values were calculated (Figs. 5-11).

We divided the patients into two groups according to the value of Q_p/Q_s : the first with a Q_p/Q_s greater than 2.0 and the second with a Q_p/Q_s less than 2.0. We classified IVS motions into three forms (paradoxical, intermediate and normal), and the differences in the IVS motions between the two groups were studied (Table II).

The sequential changes of RVD/LVD after operation were studied in 17 patients (Fig. 13).

RESULTS

The clinical and echocardiographic data in the 24 patients with ASD sec or PAPVC are summarized in Table I. No patients were receiving digitalis or diuretics. In end-diastole, RVD was greater than LVD in the patients with large left to right shunt and smaller in those with small shunt flows. Thus, the RVD/LVD ratio was more than 1.0 in the former patients and less in the latter ones (Figs. 1 and 3).

The relations of Q_p/Q_s to RVD/LVD, RVD/TCD, RVD/AOR, RVD/BSA and TCD/BSA are shown in Figs. 5 to 9. The single linear correlation coefficients of these echocardiographic

TABLE II IVS MOTION IN THE TWO GROUPS

		IVS motion		
		par	int	nor
Q_p/Q_s	$I \geq 2.0$	8	6	0
	$II < 2.0$	2	7	1

IVS = interventricular septum;

nor = normal;

int = intermediate;

par = paradoxical;

I = first group with Q_p/Q_s more than 2.0;

II = second group with Q_p/Q_s less than 2.0.

Fig.5. RVD/LVD is plotted against Q_p/Q_s . The linear regression equation (Y), the correlation coefficient (r) and the number of patient (n) are shown. The r -value was 0.88 ($p < 0.001$).

Fig.6. RVD/TCD is plotted against Q_p/Q_s . The r -value is 0.80 ($p < 0.001$).

indices to Q_p/Q_s were 0.88 for RVD/LVD, 0.80 for RVD/TCD, 0.74 for RVD/AOR, 0.75 for RVD/BSA and 0.55 for TCD/BSA. Among the

Fig. 7. RVD/AOR is plotted against Qp/Qs. The r-value is 0.74 ($p < 0.001$).

Fig. 8. RVD/BSA (RVD index) is plotted against Qp/Qs. The r-value is 0.75 ($p < 0.001$).

Fig. 9. TCD/BSA (TCD index) is plotted against Qp/Qs. The r-value is 0.55 ($p < 0.025$).

14 patients having Qp/Qs higher than 2.0, 13 revealed an RVD/LVD larger than 0.9, 14 an RVD/TCD larger than 0.38, 13 an RVD/AOR larger than 1.3, 11 an RVD/BSA larger than 35 and 11 a TCD/BSA larger than 90. On the other hand, all of the 10 patients having Qp/Qs less than 2.0, except one patients for RVD/AOR,

revealed an RVD/LVD less than 0.9, an RVD/TCD less than 0.38, an RVD/AOR less than 1.3, an RVD/BSA less than 35 and a TCD/BSA less than 90.

In Fig. 10, the estimated Qp/Qs calculated from the three parameters (RVD index, RVD/LVD, TCD index) is compared with actual Qp/Qs. The multiple linear regression equation was $Y = 0.051X_1 + 1.6X_2 - 0.028X_3 + 1.4$ and the r-value was 0.89. All patients with an estimated Qp/Qs greater than 2.3 had a Qp/Qs over 2.2. All but one patient with an estimated Qp/Qs less than 2.1 had a Qp/Qs below 2.0.

In Fig. 11, the cardio-thoracic ratio (CTR) is compared with Qp/Qs. All patients with a CTR greater than 0.57 had a Qp/Qs above 2.0. Ten of the 19 patients with a CTR less than 0.56 had a Qp/Qs below 2.0, but 9 patients had a Qp/Qs above 2.0.

In Table II, IVS motions in the two groups are shown. Eight patients in group I had paradoxical IVS motion and 6 had intermediate motion. One patient in group II had normal IVS motion, 7 had intermediate motion, and 2 had paradoxical motion.

In Fig. 12, a postoperative echocardiogram of Case 8 (6 months after corrective surgery) is shown. Compared to her preoperative echocardiogram in Fig. 1, the RVD/LVD ratio decreased from 1.22 to 0.42 and IVS motion changed from paradoxical to normal. The sequential changes of RVD/LVD after corrective surgery in each patient are given in Fig. 13. The most prominent decrease in this ratio took place within the first month after operation. From the second to twelfth month, changes of the ratio were slight. The decrease of the mean value of RVD/LVD from 0.95 ± 0.24 (SD) before operation to 0.43 ± 0.04 12 months after operation was highly significant ($P < 0.001$).

DISCUSSION

Indications of operative repair for the asymptomatic child with ASD sec or PAPVC without pulmonary hypertension or pulmonic stenosis are determined by the Qp/Qs obtained from the results of cardiac catheterization.

According to the survey by Moss et al., most cardiologists (70%) recommend operation if the Qp/Qs is 1.5 or greater.¹

Our policy is to withhold operation for a small ASD sec or PAPVC with a Qp/Qs of less than 1.5. Hence, noninvasive and serial assess-

Fig.10. The estimated Qp/Qs calculated from the three parameters is plotted against Qp/Qs.

The r-value is 0.89 ($p < 0.005$).

X_1 : RVD/BSA

X_2 : RVD/LVD

X_3 : TCD/BSA

Fig.11. The cardio-thoracic ratio (CTR) is plotted against Qp/Qs.

The r-value is 0.26 ($p < 0.40$).

ments of the shunt flow in these children are necessary to determine the appropriate time for cardiac catheterization and surgical repair.

Zaver et al. reported that clinical findings are poorly related to severity². Our patients, even those with a Qp/Qs above 3.0, had no symptoms at all.

The electrocardiogram and the thoracic roentgenogram are not accurate for determining the size of the shunt flow, the latter especially being less predictive. In the present study, the correlation coefficient of CTR with Qp/Qs was very low (Fig. 11).

Therefore, we introduced several echocardiographic parameters to evaluate the Qp/Qs in children with ASD sec or PAPVC without pulmonary hypertension or pulmonic stenosis.

Several investigators have described the echo-

Fig.12. Postoperative echocardiogram of Case 8. (6 months after corrective surgery). RVD/LVD is 0.42.

Fig.13. Pre- and postoperative values of RVD/LVD. The sequential changes after corrective surgery in each patient is given.

cardiographic pattern of right ventricular volume overload,³⁻⁷ but the quantitative assessment of the left-to-right shunt at the atrial level has not yet been developed enough for clinical use.

Diamond et al. plotted the RVD index against Qp/Qs in patients with ASD sec and normal pulmonary vascular resistance, and obtained a correlation coefficient of 0.64⁸. In the present study, the correlation coefficient of the RVD index and Qp/Qs was 0.75 (Fig. 8). Our patients ranged in age from 3 years and 3 months to 10 years and 2 months, while their patients were older, ranging from 15 to 59 years old.

In the present study, RVD/LVD and RVD/

TCD had a higher correlation coefficient with Qp/Qs ($r = 0.88, 0.80$, respectively) than did the RVD index. The RVD/LVD ratio had the best single linear correlation coefficient among the five echocardiographic parameters, but for clinical purposes the multiple linear regression equation derived from the three parameters (RVD/BSA, RVD/LVD and TCD/BSA) was more useful (Fig. 10), because when the measurement of one parameter was not appropriate, the other two parameters could compensate for it. For example, the predicted Qp/Qs of Case 8 (Fig. 1) was 2.94 according to the RVD/LVD ratio, but 2.67 according to the three parameters (the actual Qp/Qs from cardiac catheterization results was 2.48).

Abnormal septal motion in patients with ASD sec was reported by Diamond et al.⁸ McCann et al. noted 3 cases with isolated PAPVC and reversed septal motion (type A).⁷ Our 14 patients with a Qp/Qs greater than 2.0 had abnormal septal motion, paradoxical (type A) or intermediate (type B). Nine of the 10 patients with a Qp/Qs below 2.0 also had abnormal septal motion (Tables I and II).

Normal septal motion would be related to smaller left-to-right shunt in patients with ASD sec or PAPVC, unless they had such complications as pulmonary hypertension, pulmonic stenosis, or mitral regurgitation. However, reverse septal motion has been reported in a patient with a Qp/Qs of 1.1.⁸

Kerber et al. demonstrated abnormal septal motion in animal models by changing the shunt

flow at the atrial level, but there was no relation between the types of IVS movement and the shunt volume.³

Thus, it would be impossible to quantitate the shunt volume in asymptomatic patients with ASD sec or PAPVC by the patterns of IVS motion.

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