ANGIOCARDIOGRAPHIC EVALUATION OF VENTRICULAR SEPTAL DEFECT

— Pre- and Post-operative Cardiac Volume Characteristics —

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The characteristics of the left and the right heart volume in isolated ventricular septal defect were investigated in 62 patients before surgery and in 17 after corrective surgery, which was undergone at ages ranging from 0.5 to 13. Postoperative cardiac catheterization was performed one to two months after surgery. Preoperatively, the right atrial maximal volume increased in accordance with the pulmonary to systemic pressure ratio, and the left ventricular end-diastolic volume, the left atrial maximal volume and the right ventricular end-diastolic volume increased in accordance with the degree of the left-to-right shunt. These volumes decreased considerably after surgery, although they still remained above normal. The left ventricular mass also increased in accordance with the degree of the left-to-right shunt preoperatively and did not decrease postoperatively. The left and the right ventricular ejection fractions were close to or within normal limits preoperatively and remained so after surgery. On the basis of our results and the findings previously published in the literature, factors which may influence the post-operative cardiac function in ventricular septal defects were discussed.

JARMAKANI and his associates^{1,2} have found persistent abnormalities in the left heart size and function in children following the closure of ventricular septal defect (VSD). Later, Cordell and his co-workers³ reported better results on these in patients who underwent surgical intervention earlier in life. They considered that advances in operating procedure may be a major factor for better results. As operative techniques have been improved considerably over

the past decade, postoperative cardiac performance in congenital heart disease should be re-evaluated. In the present study we determined cardiac volumes and functions in children with VSD who had undergone surgical repair during the last 3 years.

MATERIALS AND METHODS

Patient Population

Sixty-two children with isolated VSD ascertained by cardiac catheterization were the subjects of the present study. Forty-seven of these had infracristal defect, 13 supracristal defect, one atrioventricular canal type defect and one

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TABLE I PREOPERATIVE HEMODYNAMIC DATA

Patient No.	Age		LVP (mmHg)	RVP (mmHg)	Rp/Rs	Pp/Ps	Qp/Qs
1		7m	98/10	50/8		0.36	1.68
2		8m		96/8	0.28	1.00	3.55
3		6m	86/22	86/7	0.37	1.00	2.75
4	1y			40/7		0.40	1.68
5	1y		100/10	87/6	0.21	0.85	3.47
6	1y	3m	80/12	71/10	0.36	0.93	2.71
7		8m	73/6	20/3		0.21	1.08
8	1y			22/4		0.15	1.29
9	1y	1m	86/8	80/8	0.35	0.83	3.34
10	1y			32/3		0.29	2.15
11	1y	5m	96/9	80/6	0.19	0.87	3.69
12	1y	2m	94/11	87/8	0.71	1.00	1.51
13	2y		93/8	36/4		0.33	1.95
14	2y	1m	86/11	31/4		0.37	2.04
15	1y	11m	70/5	17/3		0.30	1.14
16	2y	3m	104/14	34/5		0.28	2.72
17	2y	2m	121/11	25/5		0.18	1.07
18	2y	4m	88/4	25/4		0.29	1.51
19	3y	5m	105/15	29/5		0.23	1.15
20	2y	6m	81/7	21/6		0.26	1.08
21	1y	11m	95/10	21/5		0.22	1.45
22	2y	10m	85/10	19/5		0.25	1.23
23	3y	10m	114/12	27/5		0.19	1.04
24	3y	1m	122/12	31/5		0.31	1.45
25	4y	10m	100/12	20/3		0.18	1.35
26	3y	4m	100/4	17/2		0.16	1.18
27	4y	7m	102/7	21/4		0.24	1.07
28	3y	6m	100/4	20/3		0.14	1.25
29	5y	1m	105/8	21/4		0.19	1.21
30	5y	9m	111/12	33/7		0.30	1.05
31	4y	8m	89/7	28/3		0.31	1.06
32	4y	11m	98/6	23/4		0.27	1.97
33	6y	4m	104/14	21/5		0.17	1.03
34	5y	6m	99/10	23/6		0.23	1.16
35	5y		120/8	32/4		0.27	1.22
36	5y	8m	107/10	32/5		0.24	1.15
37	5y	5m	99/5	21/3		0.19	1.03
38	8y	2m	97/10	17/3		0.21	1.18
39	6y	3m	104/11	28/7		0.15	1.01
40	7y	5m	90/7	90/7	1.49	1.00	0.63
41	8y	10m	109/7	16/4		0.16	1.09
42	8y	5m	109/7	15/4		0.14	1.11
43	10y	4m	121/12	28/3		0.22	1.07
44	9y	7m	123/15	25/7		0.24	1.40
45	12y		117/8	21/6		0.15	1.20
*46		5m	99/15	88/15	0.28	0.77	3.27
*47		6m	80/9	53/7	0.17	0.56	3.08
*48		9m	92/16	88/16	0.41	0.97	2.36
*49		8m		93/9	0.45	1.00	2.24
*50	1y	4m	76/10	60/7	0.31	0.82	2.14
*51	1y	4m		75/10	0.31	0.68	2.30
*52	1y	10m		77/12	0.29	0.62	2.70
*53	1y	6m	103/11	95/10	0.53	0.84	1.58
*54	2y	10m	105/5	44/5		0.27	1.48
*55	2y	3m	112/9	25/5		0.21	1.17
*56	3y	1m	107/14	34/4		0.32	1.91
*57	1y	10m	93/7	35/4		0.30	1.07
*58	2y	8m	89/9	86/7	0.54	0.94	1.82
*59	4y	1m	112/12	45/8		0.36	1.54
*60	4y	1m	100/9	20/4		0.23	1.12
*61	5y	6m	91/7	20/4		0.16	1.59
*62	13y	10m	108/12	25/5		0.17	1.16

Abbreviations: LVP = left ventricular pressure; RVP = right ventricular pressure; Rp/Rs = pulmonary to systemic resistance ratio; Pp/Ps = pulmonary to systemic pressure ratio; Qp/Qs = pulmonary to systemic flow ratio; y = year; m = month.

* Patients who underwent postoperative cardiac catheterization.

Fig.1. The left ventricular mass (LVM) as a function of the body surface area (BSA) in 30 "normal" children. The equation and solid line represent the best fit for this relationship.

TABLE II NORMAL VALUES AND RANGES OF CARDIAC VOLUME VARIABLES

	Normal values	Normal ranges
LVEDV	70.6 (BSA) ^{1.31}	80 – 120%
LVM	64.6 (BSA) ^{1.1}	75 – 125%
RVEDV	69.2 (BSA) ^{1.34}	80 – 120%
LAmx	41.6 (BSA) ^{1.18}	80 – 120%
RAmx	60.5 (BSA) ^{1.46}	75 – 125%
LVEF		0.55 – 0.75
RVEF		0.51 – 0.70

Abbreviations: LVEDV = left ventricular end-diastolic volume; LVM = left ventricular mass; RVEDV = right ventricular end-diastolic volume; LAmx = left atrial maximal volume; RAmax = right atrial maximal volume; LVEF = left ventricular ejection fraction; RVEF = right ventricular ejection fraction; BSA = body surface area

muscular defect. Preoperative catheterization data of these patients is shown in Table I.

Forty patients underwent surgical closure of VSD because they had a large left-to-right shunt and/or aortic cusp deformity due to a suprasternal defect. During surgery the hypothermic cardiopulmonary bypass technique was used, and myocardial protection was performed by releasing aortic cross-clamping intermittently or, recently, by the cold blood cardioplegia technique. In 17 of these patients, postoperative cardiac catheter-

ization study was done within 2 months after the operation. A residual shunt at the ventricular level was found in 3 patients: one (No.58), who remained with severe pulmonary hypertension (PH) and a moderate left-to-right shunt, underwent re-operation 2 months after the first surgery. The other 2 (Nos.52 and 56) had a small residual shunt without PH. The remaining 14 patients had neither a residual shunt nor PH after surgery. Four of the 17 had complete right bundle branch block following the operation.

Methods

Hemodynamic data was obtained by routine cardiac catheterization. The patients were sedated with pethidine (2 mg/kg) and promethazine (1 mg/kg, i.m.) given 30 min before catheterization. In patients over 12 months of age, additional doses of thiopental (2–3 mg/kg, i.v.) were occasionally required for sedation.

Left and right heart pressures were obtained using a NIH catheter or a Millar micro-tip transducer catheter. The oxygen saturation in the blood was determined using a reflectance oxymetry, and the pulmonary to systemic flow ratio (Qp/Qs) was calculated according to Fick's principle.

Cardiac volumes were measured from biplane cineangiocardigrams taken at 70 frames/sec: the left and the right atrial volume, and the left ventricular volume were calculated using the area-length method, and the right ventricular volume was obtained using Simpson's rule method. These values were expressed as a percent of the normal values, which was determined previously.⁴ The right atrial maximal volume was not determined after surgery, because the right atrium had decreased in its volume as a result of caval cannulation. The left ventricular mass (LVM) was obtained using the method of Rackley et al⁵ in patients in whom the free lateral wall of the left ventricle could be well visualized. It was also expressed as a percent of the normal. The normal value of the LVM in each patient was derived from the body surface area using the following equation based on data from 30 "normal" children (Fig. 1): $LVM = 64.6 (BSA)^{1.1}$ ($r = 0.96$). The normal values and ranges of these cardiac volume variables in our institute are summarized in Table II.

RESULTS

The cardiac volumes before and after surgery

TABLE III PREOPERATIVE CARDIAC VOLUMES

Patient No.	BSA	LVEDV		LVEF	LVM		RVEDV		RVEF	LAmax		RAmax	
		ml	%N		g	%N	ml	%N		ml	%N	ml	%N
1	0.27	22	173	0.65	na		20	167	0.63	17	196	16	181
2	0.31	41	272	0.63	na		24	167	0.46	32	303	21	188
3	0.32	43	269	0.58	30	162	na		na	31	278	na	
4	0.36	36	194	0.60	na		30	173	0.58	29	233	na	
5	0.36	54	294	0.62	44	210	30	173	0.57	33	264	31	230
6	0.36	51	273	0.58	35	165	na		na	28	222	na	
7	0.38	20	99	0.65	24	107	21	112	0.55	17	128	19	125
8	0.41	29	134	0.71	30	124	24	116	0.70	24	165	20	125
9	0.41	76	352	0.60	na		45	218	0.59	57	396	33	205
10	0.41	41	186	0.63	40	166	38	183	0.56	38	262	32	197
11	0.42	63	278	0.63	na		37	170	na	67	451	39	229
12	0.43	62	262	0.49	48	187	na		na	31	201	na	
13	0.46	47	184	0.70	39	141	26	108	0.56	32	193	24	125
14	0.47	42	163	0.72	35	126	35	140	0.58	36	212	28	140
15	0.48	32	117	0.66	31	108	28	106	0.65	23	132	26	122
16	0.52	113	382	0.51	56	180	na		na	58	308	48	209
17	0.53	31	102	0.69	32	109	29	100	0.59	24	122	28	117
18	0.55	54	165	0.69	40	120	43	137	0.57	44	214	41	161
19	0.56	41	126	0.63	32	93	36	114	0.53	30	144	25	97
20	0.56	36	107	0.68	29	86	31	98	0.54	20	96	31	117
21	0.57	60	175	0.60	48	138	42	129	0.52	34	157	32	118
22	0.60	54	148	0.67	na		51	145	0.65	41	179	41	140
23	0.61	39	107	0.69	38	101	31	87	0.60	32	138	29	101
24	0.61	57	155	0.68	48	127	40	111	0.56	35	151	43	145
25	0.63	69	179	0.56	60	154	na		na	42	173	30	98
26	0.63	55	142	0.72	44	113	na		na	39	161	na	
27	0.64	52	133	0.67	43	111	46	121	0.60	25	102	32	101
28	0.66	46	114	0.65	43	106	46	117	0.59	27	107	49	150
29	0.66	53	130	0.69	43	105	44	111	0.64	37	148	36	111
30	0.69	48	112	0.69	43	101	46	111	0.63	28	103	25	70
31	0.71	50	110	0.61	49	111	45	104	0.57	28	103	36	99
32	0.73	93	198	0.62	67	146	67	148	0.56	53	185	50	131
33	0.73	48	102	0.66	40	87	49	108	0.67	32	114	40	104
34	0.77	58	117	0.67	61	126	53	110	0.54	35	117	47	114
35	0.77	73	145	0.64	60	123	54	110	0.53	43	141	39	94
36	0.78	83	161	0.62	77	157	58	117	0.55	46	148	49	110
37	0.80	57	109	0.63	45	90	63	124	0.54	37	117	40	92
38	0.81	77	144	0.57	68	133	53	102	0.54	43	133	50	112
39	0.84	71	126	0.62	50	95	63	115	0.55	41	121	40	86
40	0.86	66	115	0.62	58	107	64	114	0.60	31	91	59	123
41	0.89	70	117	0.55	60	107	66	111	0.59	41	112	na	
42	0.90	88	143	0.67	66	116	98	165	0.53	42	114	53	103
43	0.90	69	112	0.69	58	101	69	116	0.60	39	108	47	91
44	0.99	94	136	0.66	71	112	78	115	0.55	56	138	53	89
45	1.24	92	99	0.55	81	98	na		na	67	124	na	
46	0.27	32	255	0.73	28	183	na		na	25	282	na	
47	0.31	40	260	0.65	39	219	27	186	0.67	31	297	20	184
48	0.31	40	260	0.62	39	218	29	200	0.59	22	206	na	
49	0.33	42	254	0.72	32	166	na		na	31	275	na	
50	0.39	37	181	0.68	39	170	na		na	na		na	
51	0.41	65	295	0.64	na		58	275	0.53	49	339	29	173
52	0.42	70	306	0.62	na		28	129	0.53	66	435	33	194
53	0.46	51	203	0.64	na		38	156	0.54	38	232	na	
54	0.50	52	181	0.67	29	94	32	117	0.65	38	204	na	
55	0.51	41	140	0.71	43	142	27	98	0.63	32	172	na	
56	0.52	54	184	0.58	na		51	179	0.55	41	217	34	146

57	0.56	33	99	0.68	33	97	na	na	27	129	na		
58	0.59	60	170	0.57		na	na	na	41	183	na		
59	0.63	74	190	0.64	64	164	na	na	48	197	na		
60	0.64	53	133	0.69		na	na	na	43	176	na		
61	0.77	77	155	0.64	64	133	55	113	0.53	45	147	45	109
62	1.61	141	107	0.60		na	148	113	0.52	96	132	na	

Abbreviations: BSA = body surface area; LVEDV = left ventricular end-diastolic volume; LVEF = left ventricular ejection fraction; LVM = left ventricular mass; RVEDV = right ventricular end-diastolic volume; RVEF = right ventricular ejection fraction; LAmx = left atrial maximal volume; RAmx = right atrial maximal volume; %N = percentage of the estimated normal values; na = not analyzed

TABLE IV POSTOPERATIVE CARDIAC VOLUMES

Patient	BSA	LVEDV		LVEF	LVM		RVEDV		RVEF	LAmx	
		ml	%N		g	%N	ml	%N		ml	%N
46	0.33	22	138	0.61	28	149	18	119	0.60	18	161
47	0.37	29	154	0.57	39	183	24	135	0.54	21	165
48	0.45	33	134	0.63	39	145	32	135	0.51	18	112
49	0.36	24	131	0.61	33	157	na	na	na	16	130
50	0.45	27	108	0.68	34	127	na	na	na	16	99
51	0.44	34	137	0.60	32	120	29	126	0.57	23	143
52	0.44	47	194	0.56	47	179	na	na	na	41	263
53	0.48	30	110	0.56	40	139	na	na	na	na	na
54	0.56	48	146	0.66	42	124	35	111	0.63	28	133
55	0.53	35	112	0.66	48	148	26	89	0.61	25	126
56	0.53	58	189	0.58	46	145	42	145	0.48	30	155
57	0.55	36	109	0.61	37	109	na	na	na	25	122
58	0.60	46	128	0.37	44	119	na	na	na	na	na
59	0.65	46	115	0.56	66	163	na	na	na	29	117
60	0.66	49	120	0.71	58	142	46	117	0.65	38	151
61	0.82	71	130	0.61	72	140	58	109	0.53	42	127
62	1.61	126	96	0.65	na	na	na	na	na	81	112

Abbreviations are the same as in Table III.

are shown in Tables III and IV.

Preoperation

As expected, the left ventricular end-diastolic volume (LVEDV), the LVM and the left atrial maximal volume (LAmx) were increased significantly in patients with a large left-to-right shunt as compared with normal children. There was a linear relationship between these values and Qp/Qs (Figs. 2–4).

The right ventricular end-diastolic volume (RVEDV) was also increased in accordance with the increase of the left-to-right shunt (Fig. 5). However, the increment of the RVEDV was smaller than that of the corresponding LVEDV in each patient with a moderate to large shunt.

The right atrial maximal volume (RAmx) was clearly above normal in 14 out of 43 patients studied, and showed a significant correlation with the pulmonary to systemic pressure ratio

(Pp/Ps) (Fig. 6).

The left ventricular ejection fraction (LVEF) was within normal limits in all but 2 patients, including 20 with congestive heart failure. These 2 patients (Nos.12 and 16) had a LVEF of 0.49 and 0.51, respectively. One of these had a high pulmonary to systemic resistance ratio (Rp/Rs of 0.71) and another had a extremely increased LVEDV (382% of normal) (Table III).

The right ventricular ejection fraction (RVEF) was close to or within normal limits in all but one patient in whom the RVEF was below normal (0.46) (Table III).

Postoperation

Changes in the LVEDV are given in Fig. 7. Although the LVEDV decreased considerably from $198 \pm 63\%$ (mean $\pm$ SD) to 132 ± 27 ($p < 0.01$) following the surgery, it remained significantly at a high level. In one patient (No.56),

Fig.2. Relation between the left ventricular end-diastolic volume (LVEDV) and the pulmonary to systemic flow ratio (Qp/Qs).

Fig.4. Relation between the left atrial maximal volume (LAMax) and the pulmonary to systemic flow ratio (Qp/Qs).

Fig.3. Relation between the left ventricular mass (LVM) and the pulmonary to systemic flow ratio (Qp/Qs).

Fig.5. Relation between the right ventricular end-diastolic volume (RVEDV) and the pulmonary to systemic flow ratio (Qp/Qs).

the LVEDV did not decrease at all. In this case, the persistence of the left and the right ventricular dilatation has been found echocardiographically during a long period after surgery, and the presence of the myocardial damage was suspected.

The LVM remained clearly above normal in 11 patients (Fig. 8). On the whole, the post-operative values were not significantly different from the preoperative ones, although in 4 patients it decreased after surgery.

The LAMax decreased considerably in all

patients (from 226 ± 82 to $141 \pm 39\%$, $p < 0.01$) following surgery (Fig. 9), but it still remained above normal.

The RVEDV also decreased considerably after surgery in patients who had shown a considerably high preoperative value, although it still remained above normal (Fig. 10).

The LVEF decreased mildly but significantly as compared with preoperative values ($p < 0.01$), but remained within normal limits in all except one patient with residual VSD and PH (No.58) (Fig. 11).

Fig.6. Relation between the right atrial maximal volume (RAMax) and the pulmonary to systemic pressure ratio (Pp/Ps).

Fig.8. Changes in the left ventricular mass (LVM) expressed as a percentage of the normal value. The shaded area indicates the normal range.

Fig.7. Changes in the left ventricular end-diastolic volume (LVEDV) after surgery. Values are expressed as a percentage of the normal value. The shaded area indicates the normal range.

Fig.9. Changes in the left atrial maximal volume (LAMax) expressed as a percentage of the normal value. The shaded area indicates the normal range.

Fig. 10. Changes in the right ventricular end-diastolic volume (RVEDV) expressed as a percentage of the normal value. The shaded area indicates the normal range.

The RVEF was also within normal limits post-operatively in all but one patient in whom the RVEF was mildly depressed to 0.48 after surgery (Fig. 12).

DISCUSSION

Preoperation

Patients with isolated VSD have been shown to have an increase in the left atrial and the left ventricular volume, the left ventricular mass⁶ and the right ventricular volume,⁷ which correlated well with the degree of the left-to-right shunt.

The right atrial response in isolated VSD, however, has not been well documented. We found that the right atrium also dilates considerably in isolated large VSD and that the degree of dilatation is related to the Pp/Ps. Nakano et al⁸ have noted a right atrial enlargement in patients with VSD and PH, and based on observations of right ventricular filling characteristics obtained by an analysis of the phasic tricuspid flow velocity, they suggested that the right atrial enlargement in cases with right ventricular pressure overload is caused by a reduction of the right ventricular compliance.⁹ This idea may be supported by Graham et al^{10,11} who found a right atrial enlargement in patients with pulmonary stenosis and with tetralogy of Fallot.

Fig. 11. Changes in the left ventricular ejection fraction (LVEF). The shaded area indicates the normal range.

Fig. 12. Changes in the right ventricular ejection fraction (RVEF). The shaded area indicates the normal range.

Postoperation

Jarmakani and his associates¹ have reported persistent abnormalities of the left ventricular size and the pump function in children who underwent surgical closure of VSD at ages ranging from 1 to 12.¹ They investigated subsequently the pressure velocity indices of the left ventricular contractile state and noted a decrease of the left ventricular contractility in postoperative patients with VSD who had a large left-to-right shunt and left ventricular hypertrophy, which was determined by ventriculography, before

TABLE V POSTOPERATIVE LEFT HEART SIZE AND FUNCTION IN THE LITERATURE

Reporters	Operation age (years)	Period after surgery	Method	LVEDV	LVM	LA	LV function
Jarmakani et al. ² (1972)	2.0–15.0 (mean = 7.1)	0.7–1.4 years	ACG	↑	↑	↑	↓
Cordell et al. ³ (1976)	0.1–1.7 (mean = 1.1)	0.9–2.5 years	ACG	→	→	↑	→
Ahmad et al. ¹² (1979)	one: under 2; the other: 4–16	3 to 6 weeks	UCG	↑	↑	↑	→
Authors (1982)	0.5–13.9 (mean = 2.8)	within 2 months	ACG	↑	↑	↑	→

Abbreviations: LVEDV = left ventricular end-diastolic volume; LVM = left ventricular mass; LA = left atrial size; ↑ = above normal; ↓ = below normal; → = within normal limits; ACG = angiocardiography; UCG = ultrasonic cardiography

surgery²

Cordell and his co-workers³ have studied 13 patients, in whom VSD was closed within their first 2 years of life. They found that the LVEDV, the left ventricular systolic output and the LVM returned to normal, and that there was no impairment of the left ventricular pump function evaluated from the ejection fraction.

Ahmad and Hallidie-Smith¹² have studied pre- and post-operative echocardiograms in 7 patients with VSD, 6 of whom underwent surgery at ages from 4 to 16. They found that the left ventricular function evaluated from the ejection phase indices appeared to be unimpaired even 3 to 6 weeks after the operation, although the left atrial size and the LVM remained at high levels.

We found substantial reductions in the LVEDV, the LAmx and the RVEDV postoperatively, although these measurements still remained above normal. The LVM did not decrease either in its absolute value or in its relative one (% of the normal value). The left and the right ventricular functions evaluated from the ejection fraction decreased postoperatively as compared with preoperative values, but remained within normal limits in all but one patients who underwent a second operation for residual VSD and PH.

There are several differences between our postoperative study and those previously reported, as summarized in Table V.

Our assessment was done in the earlier post-operative stage, which may explain why the LVEDV, the LAmx, the RVEDV and the LVM remained above normal after surgery. Time may be required for the values to return to normal after relief of the long-standing volume overload.

In the present patients surgical treatment was

performed earlier in life. Krymsky¹³ has reported the presence of diffuse cardiac sclerosis in various congenital heart diseases, including VSD. He found sclerotic areas in young people, even in infants, but concluded as follows: "The older a patient is, i.e., the longer the duration of disease, the larger is the degree of cardiac sclerosis." Thus, a better functional status may be related to a shorter period during which the heart has been subjected to an abnormal work requirement.

The patients in Jarmakani's study underwent closure of VSD in the early and mid-1960s. The operating procedure has been improved considerably over the past decade. In our patients, the defects were closed using the hypothermic cardiopulmonary bypass technique and the myocardium was protected by intermittently releasing aortic cross-clamping or by intermittently infusing cold blood cardioplegia into the aortic root. It is possible that the procedures used in our patients may have served to protect heart to a greater degree as compared with Jarmakani's patients, resulting in a better cardiac function.

To the best of our knowledge, there are no published data on right ventricular volume characteristics following the repair of VSD. Because the right ventricle is subjected to both pressure and volume overloads in large VSD with PH, which may affect the postoperative right ventricular performance, it is considered important to determine postoperative volumes of the right ventricle as well as the left ventricle in evaluating these patients after a long period. The maintenance of the normal RVEF in our patients after surgery is indeed a most encouraging sign for a good prognosis.

Thus, in patients with VSD, the postoperative

left and right ventricular functions evaluated from the ejection fraction were unimpaired even during the early postoperative period when there may remain myocardial damage due to intra-operative manipulation.

Determination of the ejection fraction at rest gives only limited information on the contractile behavior of the myocardium; further assessment of the ejection phase and the diastolic phase indices during exercise must be done in order to simulate more closely the strained status of daily life in growing children.

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