ORIGINAL ARTICLE

Patent Ductus Arteriosus Before and After Surgery

by

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Abstract

Twenty five patients with patent ductus arteriosus, who had undergone surgical closure were studied retrospectively. Girls were more affected than boys; the sex ratio was 4 : 1. Associated cardiac lesions were diagnosed in 3 patients, two with ventricular septal defect and one with congenital mitral stenosis.

Congestive heart failure was diagnosed in 5 patients before surgery. Typical continuous murmur was heard in most cases (76%), while in the rest only systolic murmur was detected. Electrocardiographic left atrial enlargement, left ventricular hypertrophy and right ventricular hypertrophy were found in 8%, 48% and 40%, respectively. Cardiomegaly with increased pulmonary vascular markings was found in 60% of cases, while ratio of left atrial to aortic root diameter greater than 1.2 was detected in 60% of patients. The PDA could be directly visualized by echocardiography in 15 cases. Cardiac catheterization was performed in 17 cases, 47% with hyperkinetic pulmonary hypertension, 41% with high pulmonary flow without pulmonary hypertension and 12% with mild increased pulmonary flow. The pulmonary-systemic flow ratio (Qp/Qs) was more correlated to pulmonary vascular markings rather than to cardio-thoracic ratio.

Division of the ductus was the procedure of choice, but in 16% of cases ductal ligation was performed because of technical reasons. Postoperative catch-up in both weight and height was observed more clearly in children operated at earlier age. Ejection systolic murmur was still detected in 2 patients, in whom hyperkinetic pulmonary hypertension existed prior to surgery. No cardiomegaly was found in patients followed-up 1 year or more after surgery. The mortality was nil.

Introduction

Failure of the ductus to close after birth results in the well-known condition of patent ductus arteriosus (PDA), which may lead to cardiac failure during early infancy and to the development of pulmonary vascular obstructive disease in later life (Rudolph, 1978).

Since definitive repair of an uncomplicated PDA is accompanied by minimal risk in any but the smallest preterm infants, closure should be recommended soon after the diagnosis is made (Nadas and Fyler, 1972; Heymann, 1983; Graham, 1984). The reasons for closure in asymptomatic patients are first to prevent the development of possible pulmonary vascular disease and secondly to diminish the risk of bacterial endocarditis (Shinebourne and Anderson, 1980). In the hand of an experienced surgeon, repair of this lesion is probably the simplest and safest of all cardiovascular operations. In large series the operative mortality rate is less than 1 - 2 per cent (Rowe, 1978; Behrman and Vaughan, 1987) or even zero when small infants and patients with pulmonary hypertension are excluded (Shinebourne and Anderson, 1980).

Patients with PDA may be retarded in growth. Although repair of PDA in infancy and chilhood is usually accompanied by a definite acceleration of both weight and height, an unexpectedly large proportion of the children remained permanently below normal (Suoninen, 1971).

The purpose of this article is to evaluate the physical growth as well as clinical, electrocardigraphic, radiographic, and echocardiographic findings of patients with PDA before and after surgery.

Materials and Methods

This retrospective study was conducted on patients with PDA, in whom surgical closure had been performed in Dr. Cipto Mangunkusumo Hospital, Jakarta from February, 1987 to Desember, 1988.

The patients have been under the observation of the Pediatric Cardiology Division, Department of Child Health, University of Indonesia; Dr. Cipto Mangunkusumo Hospital. They were followed-up 3 months to 2 years after operation.

Height and weight measurements were made by an experienced staff, using the same equipment. These are compared with control group of 25 normal children without cardiac anomalies from the same hospital.

Recurrent acute respiratory tract infection was estimated by comparing the number of instances in the child's past history with those of his siblings and playmates.

Thorough physical examination was done in every patients. At auscultation the intensity of heart murmurs was graded from I to VI. Congestive heart failure was diagnosed on the base of the usual criteria.

Complete electrocardiogram was reorded in all cases, i.e. standard leads, unipolar limb leads and chest leads V3R, V1-V6. All of the electrocardiograms were reviewed and assessed by the authors.

Heart size was evaluated roentgenographically by measuring the cardio-thoracic ratio, i.e. the ratio of the maximum width of the heart to the width of the bony thorax at the level of the right diaphragm in postero-anterior view.

M-mode and two-dimensional echocardiograms were made in all cases prior to, one week after operation and several month thereafter when indicated; Doppler technique was applied in some patients in whom ductal patency could not be visualized by real-time echocardiogram.

Cardiac catheterization was performed in patients who were suspected to have pulmonary hypertension or in those without classical continuous machinary murmur.

The surgical procedure used was division or ligation of the ductus arteriosus.

For statistical analysis Fisher's ideal index was used.

Results and Discussion

There were 25 patients with PDA operated in the study period, comprising 20 girls and 5 boys (table 1 and 2). The female to male ratio thus being 4 : 1, as is generally known to be the case (Anthony et al., 1979; Madiyono et al., 1981; Nadas and Fyler, 1972; Perloff, 1987).

Associated intra cardiac lesions were diagnosed in 3 out of 20 girls (15%), i.e. in 12 per cent of all PDA patients, consisted of 2 patients with ventricular septal defect and 1 patient with mild congenital mitral stenosis (table 3). No extracardiac congenital anomaly was found in this series. This was less than other similar clinical series (Suoninen, 1971).

All of the 25 patients with PDA were born with body weight of more than 2500 grams. The incidence of this type of PDA (PDA in full-term infants) is about 1 in 2000 live birth (Heymann, 1983). Unlike the ductus in premature infants in whom failure of closure is due to developmental retardation, the ductus arteriosus in full-term infants is abnormal and failure to constrict is probably related to a significant structural abnormality (Heymann, 1983).

In mature infants and older children the factors determining the clinical features are the same as in premature infants, namely: the size of the communication, the relation between pulmonary and systemic vascular resistance, and the ability of the myocardium to handle the extra volume load (Mikhail et al., 1982; Heymann, 1983).

Growth retardation occurred in a large proportion of children with congenital heart disease (Chan et al., 1987). In this series physical retardation was found in 3 out of 5 boys (60%) and in 14 out of 20 girls (70%) before surgery. Comparing the percentile distributions in this series with the control group of normal patients without cardiac anomalies (table 5, 6 and 7), it appears that the preoperative means of height and weight were significantly lower. Girls had lower weight than height values and were in general more retarded in growth than boys (table 1). This finding was in contrast to the previous series (Suoninen, 1971) in which retardation was predominant in boys. There was no correlation between the degree of growth retardation and the severity of the left to right shunt, the size of the communication, or the heart size. This finding is in agreement with the previous report (Suoninen, 1971). In tetralogy of Fallot and ventricular septal defect there was a good correlation between the degree of growth retardation and the severity of the lesions (Suoninen, 1971; Chan et al., 1987).

Table 1 : *Clinical findings and time of surgical closure of the 25 PDA patients*

No.	Name	Sex	Age (yrs)	Body weight kg	Body weight (P)	Body height cm	Body height (P)	ARI-HM-CHF			Surgery Tech.	Surgery Date
1.	F	M	2 2/12	13	(50)	90	(80)	—	Cont	—	D	2/04/87
2.	D	F	9	19	(25)	127	(05)	+	Cont	—	D	3/04/87
3.	R	F	6 9/12	11.5	(05)	93.5	(05)	+	Cont	—	D	3/16/87
4.	D	F	4 2/12	12.5	(40)	95	(50)	—	Cont	—	D	3/16/87
5.	M	F	10	21	(05)	117	(05)	—	Cont	—	D	4/01/87
6.	A	F	4/12	5.5	(40)	60	(50)	+	Syst	+	L	4/27/87
7.	Y	M	1 7/12	9.7	(50)	73	(25)	+	Cont	—	D	4/27/87
8.	A	F	2/12	3.9	(60)	53	(50)	+	Syst	+	L	9/25/87
9.	F	F	2 2/12	8	(20)	77	(25)	+	Syst	+	D	12/16/87
10.	S	F	2/12	3.2	(25)	50	(25)	+	Syst	+	L	12/16/87
11.	F	M	5 9/12	16	(05)	105	(05)	+	Cont	—	D	1/06/88
12.	L	F	2 5/12	12.5	(60)	83	(50)	+	Cont	—	D	3/09/88
13.	I	F	5 9/12	12.5	(05)	103	(05)	—	Cont	—	D	4/13/88
14.	S	F	1 2/12	5.5	(05)	65	(05)	+	Syst	+	L	7/04/88
15.	A	F	4 6/12	15	(60)	105	(70)	+	Cont	—	D	7/27/88
16.	L	F	8 2/12	20	(05)	126	(25)	—	Cont	—	D	8/10/88
17.	J	M	2 9/12	13	(60)	94	(75)	+	Cont	—	D	8/24/88
18.	M	F	4 5/12	12	(25)	102	(60)	—	Cont	—	D	9/07/88
19.	B	F	9	20	(05)	120	(05)	—	Cont	—	D	9/14/88
20.	I	M	3 6/12	13	(55)	91	(50)	+	Cont	—	D	9/26/88
21.	I	F	3 1/12	10	(25)	83	(25)	—	Cont	—	D	10/28/88
22.	Y	F	4 2/12	15	(60)	97	(50)	—	Cont	—	D	11/15/88
23.	A	F	3 7/12	12	(50)	86	(60)	+	Syst	—	D	11/23/88
24.	R	F	5 5/12	13	(25)	101	(40)	—	Cont	—	D	12/07/88
25.	H	F	4 10/12	14.5	(50)	105	(60)	+	Cont	—	D	12/21/88

Abbreviations :
ARI : Recurrent acute respiratory tract infection
Tech. : Technique of surgical closure
HM : Heart murmur
CHF : Congestive heart failure
P : Percentile
M : Male
F : Female
D : Division
L : Ligation
Cont : Continuous
Syst : Systolic

Table 2 : *Age and sex distribution of 25 PDA patients*

Age (yrs)	Male	Female	Total	%
0 -	0	3	3	12.0
1 -	4	10	14	56.0
5 -	1	7	8	32.0
Total	5	20	25	100.0

Recurrent acute respiratory tract infections occurred in 15 patients (60%). Classical continuous machinary murmur could be detected in 19 patients (76%), while in 6 patients (24%) where the diastolic pressure of the main pulmonary artery was equal to the diastolic pressure of the aorta due to high pulmonary vascular resistance, only systolic murmur could be heard (table 1). Congestive heart failure was manifested in 5 patients (20%).

The electrocardiogram is generally not helpful early in the neonatal period, but if a moderately large shunt persists for several weeks, left ventricular hypertrophy and left atrial enlargement may become evident (Heymann, 1983). In this series (tables 3 and 4) the electrocardiogram showed normal in 9 patients (36%). Left atrial enlargement was seen in 2 patients (8%). Left ventricular hypertrophy, manifested by deep Q wave and tall R wave in leads II, III, aVF and the left precordial leads V5 and V6 was found in 13 patients (52%). Right ventricular hypertrophy evident with right axis deviation, tall R wave in the right precordial leads and upright T wave in the right precordial leads was seen in 10 patients (40%), in whom pulmonary hypertension existed. Combined ventricular hypertrophy was found in 6 patients (24%), included 3 patients with associated cardiac anomalies.

In patients with small PDA, the chest X-ray was entirely normal, as found in 5 patients (20%). Moderately large left to right shunt without increased pulmonary vascular resistance may show cardiomegaly and increased vascular markings. It was detected in 15 patients (60%), most evident at the age of less than 5 years (tables 3 and 4).

The echocardiogram has become very useful in assessing the magnitude of shunting through the ductus. Left atrial to aortic root diameter ratio greater than 1.2 indicates left atrial enlargement, which in the abscence of left ventricular failure due to other causes, indicates a significant left to right shunt. In this series, the ratio greater than 1.2 was found in 15 patients (60%). Direct visualization of the ductus arteriosus could be demonstrated in 14 patients (56%) (tables 3 and 4). Doppler techniques have recently been applied to the evaluation of flow pattern in infants with PDA, which was performed in 5 patients to confirm the diagnosis. Flow from the aorta into the pulmonary artery could be detected, and velocity profiles of flow in the descending aorta have been characterized.

Table 3 : *Noninvasive and invasive findings of the 25 PDA patients*

No.	Age (yrs)	Sex	Ass	ECG			CXR		ECHO		CATH	
				LAE	LVH	RVH	CTR	PVM	LAE	PDA	FR	PH
1.	2 2/12	M	-	-	-	-	N	↗	-	-	H	-
2.	9	F	-	+	+	-	>	↗	+	+	H	-
3.	6 9/12	F	-	-	-	-	>	↗	+	-	H	+
4.	4 2/12	F	-	-	-	-	>	↗	-	-	H	-
5.	10	F	-	-	-	-	N	N	-	-	L	-
6.	4/12	F	-	-	+	+	>	↗	+	+	H	+
7.	1 7/12	M	-	-	-	+	>	↗	+	-	H	+
8.	2/12	F	-	-	-	+	>	↗	+	+	H	-
9.	2 2/12	F	VSD	-	+	+	>	↗	+	+	H	+
10.	2/12	F	-	-	-	+	>	↗	+	-	H	-
11.	5 9/12	M	-	-	+	-	N	↗	-	-	H	-
12.	2 5/12	F	MS	-	+	+	>	↗	+	-	H	+
13.	5 9/12	F	-	-	-	-	N	N	+	+	L	-
14.	1 2/12	F	-	-	+	+	>	↗	+	+	H	+
15.	4 6/12	F	-	-	+	-	>	↗	+	+		
16.	8 2/12	F	-	-	+	-	N	N	-	-		
17.	2 9/12	M	-	-	-	+	N	↗	-	+	H	-
18.	4 5/12	M	-	-	+	-	N	N	+	-		
19.	9	F	-	-	+	-	N	N	-	+		
20.	3 6/12	M	-	-	+	+	>	↗	-	+		
21.	3 1/12	F	-	-	-	-	N	↗	-	+		
22.	4 2/12	F	-	-	-	-	>	↗	+	+		
23.	3 7/12	F	VSD	+	+	+	>	↗	+	+	H	+
24.	5 5/12	F	-	-	-	-	N	N	-	-		
25.	4 9/12	F	-	-	+	-	>	↗	+	+	H	+

Abbreviations :

Ass : Associated cardiac anomaly
VSD : Ventricular septal defect
MS : Mitral stenosis
CXR : Chest X-ray
CTR : Cardio-thoracic ratio
PVM : Pulmonary vascular markings
Echo : Echocardiogram + Dopller
PDA : Visualized PDA

ECG : Electrocarddiogram
LAE : Left atrial enlargement
LVH : Left ventricular hypertrophy
RVH : Right ventricular hypertrophy
Cath : Cardiac catheterization
FR : Flow ratio
H : Flow ratio > 2.0
L : Flow ratio < 2.0
PH : Pulmonary hypertension

Table 4 : *Age distribution and laboratory findings of 25 PDA patients*

Age (yrs)	ECG						CXR				Echo				Cath			
	LAE		LVH		RVH		CTR		PVM		LAE		PDA		FR		PH	
	+	-	+	-	+	-		N	/	N	+	-	+	-	H	L	+	-
0-	0	3	1	2	3	0	3	0	3	0	3	0	2	1	3	0	1	2
1 -	1	13	7	7	7	7	10	4	13	1	9	5	9	5	9	0	6	3
5 -	1	7	4	4	0	8	2	6	3	5	3	5	3	5	3	2	1	4
Total	2	23	12	13	10	15	15	10	19	6	15	10	14	11	15	2	8	9

Cardiac catheterization was performed in 17 patients (68%), 15 out of them (88,2%) showed high pulmonary-systemic flow ratio (Qp/Qs > 2.0), and 8 patients (47,1%) had hyperkinetic pulmonary hypertension (table 3 and 4). All of the high pulmonary flow cases showed increased pulmonary markings on chest X-ray, but only 12 out of 15 patients (80%) had cardiomegaly. It means that the pulmonary-systemic flow ratio (Qp/Qs) has a good positive correlation with the vascular markings rather than with the cardio-thoracic ratio. Six out of 8 patients (75%) with hyperkinetic pulmonary hypertension had right ventricular hypertrophy on ECG examination, 5 out of them had combined ventricular hypertrophy (table 3).

Table 5 : *Characteristics of control group of 25 normal patients without cardiac anomalies*

No.	Name	Sex	Age (yrs)	BW		BH		CTR	ECG	Echo
				kg	(P)	cm	(P)			
1.	S	F	2 7/12	11	(50)	88	(60)	0.48	N	N
2.	L	F	5	14.5	(50)	105	(60)	0.49	N	N
3.	U	M	5	17	(60)	108	(70)	0.45	N	N
4.	N	F	2	11	(60)	90	(80)	0.46	N	N
5.	A	M	4 6/12	17.5	(75)	109	(80)	0.49	N	N
6.	H	M	5	17	(60)	104	(60)	0.52	N	N
7.	A	M	3 6/12	14	(60)	100	(75)	0.51	N	N
8.	D	F	1 6/12	10	(60)	80	(70)	0.50	N	N
9.	D	F	5	17	(60)	104	(60)	0.53	N	N
10.	E	F	3	11.5	(50)	86	(40)	0.49	N	N
11.	A	M	2	11.5	(65)	82	(50)	0.44	N	N
12.	R	M	2 10/12	15	(75)	95	(75)	0.47	N	N
13.	R	F	1 6/12	9.5	(50)	77	(50)	0.43	N	N
14.	K	F	1 6/12	11.5	(75)	85	(80)	0.49	N	N
15.	D	M	1 6/12	10	(60)	76	(50)	0.50	N	N
16.	I	M	3	13	(60)	89	(60)	0.48	N	N
17.	A	M	3 6/12	14.5	(65)	97.5	(70)	0.51	N	N
18.	S	M	3 6/12	15	(70)	103	(80)	0.52	N	N
19.	R	M	4	15	(60)	100	(70)	0.50	N	N
20.	I	M	1	8.5	(50)	70	(50)	0.48	N	N
21.	B	F	3 6/12	15.5	(75)	98	(75)	0.52	N	N
22.	P	M	4	16	(70)	104	(75)	0.49	N	N
23.	A	M	4	17	(80)	112	(95)	0.52	N	N
24.	F	F	4 3/12	17	(75)	105	(75)	0.52	N	N
25.	H	M	2	10.5	(50)	82	(50)	0.47	N	N

Table 6 : *Percentile of body weight in PDA patients and control group*

	Body weight (percentile)															
	P80	P75	P70	P65	P60	P55	P50	P45	P40	P35	P30	P25	P20	P15	P10	P05
PDA	–	–	–	–	5	1	4	–	2	–	–	5	1	–	–	7
Control	1	5	2	2	9	–	6	–	–	–	–	–	–	–	–	–

$p < 0.01$

Table 7 : *Percentile of body height in PDA patients and control group*

	Body height (percentile)															
	P80	P75	P70	P65	P60	P55	P50	P45	P40	P35	P30	P25	P20	P15	P10	P05
PDA	1	1	1	–	3	–	6	–	1	–	–	5	–	–	1	6
Control	5	5	4	–	5	–	5	–	1	–	–	–	–	–	–	–

$p < 0.01$

Division of the ductus was performed on most of the PDA patients (84%), but because of some technical reasons the ductus was only ligated in 4 patients (16%). Ligation of the ductus should be avoided to prevent recanalization or incomplete occlusion of the ligated ductus (Jones, 1965; Rachmad, 1985). The age at operation varied from 2 months to 10 years (table 1). The mortality rate was 0 per cent; this was predicted before, because all were uncomplicated cases (Shinebourne and Anderson, 1980).

Table 8 : *Clinical and laboratory findings of 25 patients after surgery*

No.	Follow-up (months)	Sex	Age (yrs)	Body weight (kg)	Body weight (P)	Body height (cm)	Body height (P)	HM	ECG	CTR	ECHO
1.	7	M	2 9/12	14.5	(60)	92	(80)	-	N	N	N
2.	22	F	10 1/12	30	(40)	132.5	(10)	-	N	N	N
3.	21	F	8 6/12	15.9	(05)	105	(05)	syst	N	N	N
4.	19	F	5 9/12	14	(40)	104	(50)	-	N	N	N
5.	21	F	11 9/12	32	(40)	132.5	(05)	-	N	N	N
6.	20	F	2	11.5	(60)	86	(75)	-	N	N	N
7.	21	M	3 4/12	15	(75)	115	(75)	-	N	N	N
8.	12	F	1 2/12	9	(60)	83	(75)	-	N	N	N
9.	13	F	2 3/12	9	(25)	90	(75)	syst	N	N	VSD
10.	13	F	1 3/12	9.3	(60)	71	(40)	-	N	N	N
11.	1	M	5 10/12	16	(05)	105	(05)	-	N	N	N
12	4	F	2 9/12	15	(75)	87	(60)	dias	N	N	MS
13.	1	F	5 10/12	12.5	(05)	103	(05)	-	N	N	N
14.	3	F	1 5/12	7	(25)	69	(05)	syst	N	N	N
15	4	M	3 1/12	16	(80)	107	(95)	-	N	N	N
16.	5	F	8 7/12	21	(05)	126	(25)	-	N	N	N
17.	5	M	3 5/12	12.5	(55)	97.5	(75)	-	N	N	N
18.	4	F	4 9/12	13	(40)	100	(50)	-	N	N	N
19.	3	F	9 3/12	21	(05)	124	(05)	-	N	N	N
20.	3	M	3 10/12	14.5	(60)	93	(50)	-	N	N	N
21.	2	F	3 3/12	11.5	(40)	87	(40)	-	N	N	N
22.	2	F	4 4/12	16	(70)	102	(60)	-	N	N	N
23.	2	F	3 9/12	12.5	(50)	86	(60)	syst	CVH		VSD
24.	1	F	5 6/12	13	(25)	101	(40)	-	N	N	N
25.	1	F	4 11/12	14.5	(50)	105	(60)	-	N	N	N

Table 9 : *Change of body weight percentiles after surgery based on age group*

Age group (yrs)	Change of the body weight percentile: Increased	Change of the body weight percentile: Unchanged	Total
⩽ 5	12	5	17
> 5	2	6	8
Total	14	11	25

$p < 0.05$

Table 10 : *Change of body height percentiles after surgery based on age group*

Age group (yrs)	Change of the body height percentile: Increased	Change of the body height percentile: Unchanged	Total
⩽ 5	9	8	17
> 5	1	7	8
Total	10	15	25

$p < 0.05$

Repair of a PDA in children who has no pulmonary vascular obstructive disease or left ventricular myocardial insufficiency is probably the only operation that can be expected to provide completely normal cardiac structure. However, such patients may have a residual cardiac defect, sequelae of the defect itself, or of the operation that was performed, or a complication that must be checked on intermittently or further treated (McNamara and Latson, 1983; Sastroasmoro et al., 1985).

In present study the increase of the body weight and body height percentiles after surgery was significantly greater in PDA patients operated upon under 5 years of age (tables 8, 9 and 10). It means that postoperative catch-up in both height and weight occurred in children who had undergone operation at an earlier age. This conforms well with the earlier studies in which the best improvement was seen in children operated on generally at an earlier age (Suoninen, 1971).

After surgery (table 8) continuous murmur disappeared, but pansystolic murmur was still found in two patients with VSD, diastolic murmur was heard at the apex in one patient with mild congenital mitral stenosis and faint ejection systolic murmur was still detected on upper left sternal border in 2 patients, in whom hyperkinetic pulmonary hypertension existed before.

Left atrial enlargement and left ventri-

cular hypertrophy regressed promptly in all cases after repair of the ductus as reported previously (McNamara and Latson, 1983). Combined ventricular hypertrophy persisted on ECG examination in one patient, in whom VSD still existed.

In most cases, there is a measurable decrease in heart size on chest roentgenogram within days or weeks after surgical closure (McNamara and Latson, 1983). In our series all patients followed up for one year or more did not show cardiomegaly.

In all cases evidence of left atrial and left ventricular enlargements on echocardiographic examination decreased within weeks after surgical closure and became normal within 1 year. This finding similar to the previous report (McNamara and Latson, in 1983).

Conclusion

1. During 1987–1988, 25 patients of PDA were operated upon, with the mortality rate of 0 per cent.
2. PDA was more common in girl, the sex ratio was 4 : 1.
3. The mean height and weight of PDA before surgery was significantly below normal.
4. Post operative catch-up in both weight and height was observed more prominently in children operated at earlier age.
5. Classical continuous machinary murmur could be detected in most patients (76%) before surgery. Faint ejection systolic murmur was still detected in 2 patients after surgery, in whom hyperkinetic pulmonary hypertension existed prior to surgery.
6. Evidence of left ventricular hypertrophy on the electrocardiogram generally regressed promptly after repair of PDA.
7. Marked enlargement of the heart on chest X-ray preoperatively may require a full year to subside.
8. In all cases evidence of left atrial and left ventricular enlargements on echocardigram decreased within weeks after surgical closure and became normal after one year follow-up.
9. The pulmonary-systemic flow ratio (Qp/Qs) was more correlated to pulmonary vascular markings rather than to cardio-thoracic ratio.

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