Earpiece Dye-dilution Technics for Estimation of the Left-to-right Shunt in Infants and Children

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A single earpiece dye-dilution technics was found to be applicable satisfactorily for the estimation of the shunt magnitudes in infants and children with the left-to-right shunt, when some correction of the build-up time was made.

The present study was undertaken to introduce the single earpiece dye-dilution technique reported by Nakamura *et al.*¹ into pediatric practice for the estimation of the shunt magnitudes in infants and children with the left-to-right shunt.

MATERIALS AND METHODS

The infants and children subjected to this study consisted of 21 cases with ventricular septal defect, 9 cases with atrial septal defect, 3 cases with patent ductus arteriosus, one case with partial anomalous pulmonary venous return and 3 cases with the innocent murmurs (cf. Tables 1 and 2).

The right-heart catheterization was performed in all the cases according to the conventional Fick procedure,² under the generalized anesthesia with sodium thiopental and the premedication with atropine sulfate and pethidin hydrochloride.

Indocyanine green (Diagnogreen®: Daiichi Seiyaku Co. Ltd.) was used as an indicator. By using a cardiac catheter, 2-5 mg of the indicator were injected into the pulmonary artery (49 curves), right ventricle (12 curves), right atrium (15 curves), left atrium (7 curves) or inferior vena cava (3 curves). Immediately after the injection of the indicator, 5-10 ml of 5% glucose solution were infused rapidly through the same catheter. Eighteen curves were obtained after the peripheral injection of the indicator in such a way that 5-10 mg of the indicator were given into basilic, cephalic or dorsal metacarpal veins, immediately followed by a rapid infusion of 15-20 ml of 5% glucose solution.

The dye-dilution curves were recorded by means of the Earpiece Dye-Densitograph (Erma: DDGEN 6).

RESULTS AND DISCUSSION

1) *Comparison of the left-to-right shunt magnitudes obtained by Fick's method² with those calculated from the dye-dilution curves according to the original method of Nakamura et al.¹ (cf. Table 1)*

The correlation between the left-to-right shunt in infants obtained by Fick's method and that calculated from the dye-dilution curves according to Nakamura

TABLE 1. *Infants subjected to the estimation of the shunt magnitudes by Fick's method and by the dye-dilution technics with a modification of ours*

No. of cases	Age and sex	Diagnosis	Location of catheter inserted*	Type of the dye-dilution curves	Left-to-right shunt (%)		
					Calculated from dye-dilution curves		Calculated by Fick's method
					Without correction of tap	With correction of tap	
1	7 m F	VSD	RA	3	26	36	45
2	11 m F	VSD	PA	3	43	71	73
3	5 m M	VSD	RV	3	39	79	77
			RV	3	27	69	
4	6 m F	VSD	PA	1	48		50
			PA	1	52		
5	5 m F	VSD	RV	2	38		48
			RV	2	43		
6	11 m F	VSD	PA	2	39		39
7	3 m F	PDA	PA	3	47	68	70
			PA	3	59	69	
8	2 m F	VSD	PA	2	51		59
			RA	2	45		
			IVC	2	50		
9	3 m M	VSD	RA	3	28	72	60
			RA	3	33	78	
			RA	3	30	75	
			RA	3	24	81	
10	3 m M	VSD	RV	3	47	77	57
			RV	3	36	61	
11	9 m M	PAPVR†	PA	3	33	51	44
			RV	2	42		
12	7 m M	VSD	PA	3	46	66	20‡
13	3 m M	VSD	IVC	3	46	49	23‡
14	3 m M	VSD	PA	3	50	63	Not performed
			PA	3	38	88	

*RA: Right atrium. PA: Pulmonary artery. RV: Right ventricle.

IVC: Inferior vena cava.

†PAPVR: Partial anomalous pulmonary venous return.

‡In these two cases, the cardiac catheter could not be advanced into the pulmonary artery and therefore exact values of the shunt were not obtained by Fick's method.

et al.'s method was given in Fig. 1, showing that the shunt magnitudes calculated from the dye-dilution curves were found to be smaller than those obtained by Fick's method, this tendency being more exaggerated in cases with larger defects. This finding revealed that the shunt magnitudes in infants with the left-to-right shunt could not be estimated exactly when the original method of Nakamura *et al.* was adopted as dye-dilution technics.

2) Correction of the build-up time to be introduced for calculation of the shunt magnitudes from the dye-dilution curves of type 3 in infants

In 14 infants with the left-to-right shunt, the earpiece dye-dilution curves recorded after the central injection of the indicator were examined and it was found

TABLE 2. *Children subjected to the estimation of the shunt magnitudes by Fick's method and by the dye-dilution technics with a modification of ours*

No. of cases	Age and sex	Diagnosis	Location of catheter inserted*	Left-to-right shunt (%)	
				Calculated from dye-dilution curves	Calculated by Fick's method
15	1 y 9 m F	PDA	PA	84	87
16	5 y 5 m M	ASD	PA	94	52
			PA	47	
17	6 y 10 m F	ASD	RA	59	59
			PA	64	
18	6 y 2 m F	VSD	PA	71	65
			PA	47	
19	8 y M	VSD	IVC	42	37
20	9 y 3 m F	VSD	PA	32	11
			PA	34	
21	10 y F	ASD	PA	34	50
22	14 y F	PDA	PA	21	9
			PA	25	
			RV	29	
			RV	19	
			PV	14	
23	4 y 4 m M	ASD	PA	51	70
			PA	50	
			LA	53	
			PV	37	
24	8 y 2 m F	ASD	PA	56	59
			PA	55	
			LA	58	
			PV	39	
			PV	31	
25	7 y 2 m M	ASD	PA	54	51
			LA	43	
			LA	43	
			PV	42	
26	6 y 1 m M	VSD	PA	26	19
			PA	32	
			PA	19	
27	5 y 6 m F	VSD	PA	39	40
			PA	27	
			PA	51	
			RV	31	
			RA	31	
			PV	18	
			PV	39	
28	6 y 8 m M	VSD	PA	51	39
			PA	54	
			RA	43	
			PV	30	
			PV	37	
			PV	39	
29	5 y 5 m F	ASD	PA	51	41
			PA	32	
			PA	34	
			RA	67	
			LA	35	

TABLE 2. *Continued*

No. of cases	Age and sex	Diagnosis	Location of catheter inserted*	Left-to-right shunt (%)	
				Calculated from dye-dilution curves	Calculated by Fick's method
30	11 y 11 m F	ASD	PV	33	39
			PV	51	
			PV	49	
			PV	49	
			RV	54	
31	4 y 5 m M	VSD	PA	18	13
			RA	12	
			RA	18	
			PV	7	
			PA	59	
32	2 y 9 m M	VSD	PA	63	43
			PA	60	
			RV	47	
			PV	44	
			PV	41	
33	3 y M	VSD	PA	56	48
			PA	56	
			RA	48	
			LA	38	
			LA	39	
34	6 y 1 m F	VSD	PA	18	6
			PA	26	
35	5 y 10 m M	Innocent murmurs	PA	0	0
			PA	0	
36	6 y 9 m F	"	RA	8	0
			PV	0	
37	11 y 8 m F	"	RA	0	0
			RA	9	
			PV	0	

* Cf. footnotes in Table 1. PV: Peripheral veins; LA: Left atrium

that there were three types in the pattern of the dye-dilution curves (Types 1, 2 and 3).

The first type, shown in Fig. 2, exhibited a characteristic distortion on the disappearance phase and no prolongation of the build-up time. In this type, the shunt values calculated from the dye-dilution curves showed a good agreement with those obtained by Fick's method. The first type of the curves was found in 2 out of 26 cases examined.

The second type as in Fig. 3 showed no distortion on the down slope and there was no prolongation of the build-up time. The shunt calculated from the dye-dilution curve was 51%, and that obtained by the Fick's method was 59%, both values being approximately the same. The second type of the curves was found in 7 out of 26 cases examined.

The third type of the dye-dilution curves shown in Fig. 4 was obtained from a 3-month-old female with patent ductus arteriosus after the dye injection into the pulmonary artery, showing that there was a prolongation of the build-up time attaining 4.5 sec.

Fig. 1.

Fig. 2.

Fig. 1. Correlation between the shunt magnitudes obtained by Fick's method and those calculated from the dye-dilution curves without correction of the build-up time.

Fig. 2. The first type of the earpiece dye-dilution curve obtained from a 6-month-old infant with ventricular septal defect (Case No. 4). The indicator was injected into the pulmonary artery. The left-to-right shunt ratio estimated by Fick's method was 50%, and 48% when calculated from the dye-dilution curve: ta 3.5; tp 6.0; tap 2.5; tl 6.8; ts 2.2; ta' 6.8; tp' 10; tap' 3.2; Cp 62; K 53; Cp' 30; and Cp'/Cp 48%.

Fig. 3.

Fig. 4.

Fig. 3. The second type of the dye-dilution curve of a 2-month-old infant with ventricular septal defect (Case No. 8). The indicator was injected into the pulmonary artery. There was no distortion on the down slope. The build-up time was not prolonged. The shunt estimated by Fick's method was 59%, and that calculated from the dye-dilution curve was 51%: ta 2.0; tp 5.0; tap 3.0; tl 6.0; ts 1.7; ta' 6.0; tp' 9.0; tap' 3.0; Cp 63; K 62; Cp' 32; and Cp'/Cp 51%.

Fig. 4. The third type of the dye-dilution obtained from a 3-month-old infant with patent ductus arteriosus (Case No. 7). The indicator was injected into the pulmonary artery. Solid lines were drawn when tap of 4.5 sec was used, and broken lines were drawn when tap of 3.0 sec, in place of 4.5 sec, was used.

By using tap of 4.5 sec, the shunt calculated from the curve was found to be 47%, which was far smaller than that estimated by Fick's method (70%).

The prolongation of the build-up time, as seen in the dye-dilution curves of type 3, may have resulted from the overlapping of shunted dye to initial circulating dye, because of the rapid pulmonary circulation time in infancy.³ It seemed, therefore, that the prolongation of the build-up time developed more exaggerated in infants with larger defect. The third type of the curves was found in 17 out of 26 cases examined. In the case with the dye-dilution curves of type 3, we made some correction of the build-up time in order to obtain the shunt magnitude similar to that obtained by Fick's method in the following way: The build-up time was fixed at 3.0 sec when the indicator was injected into the pulmonary artery, and at 3.5 sec when the indicator was given by the central injection other than that into the pulmonary artery. For example, figures drawn with solid lines in Fig. 4 were obtained when the build-up time of 4.5 sec was adopted: ta 2.5; tp 7.0; tl 8.7; ts 3.6; ta' 8.6; tp' 13.2; tap' 4.5; Cp 100; K 95; Cp' 47; and Cp'/Cp 47%. In the same figure (cf. Fig. 4), figures drawn with broken lines were made when the build-up time of 3.0 sec, in place of 4.5 sec, was adopted: ta 2.5; tp 5.5; tl 6.5; ts 2.2; ta' 6.5; tp' 9.5; tap' 3.0; Cp 97; K 99; Cp' 66; and Cp'/Cp 68%.

Correlation between the shunt magnitudes obtained by Fick's method and those calculated from the dye-dilution curves with the correction of the build-up time was shown in Figs. 5-8.

Fig. 5 included 49 curves in which the indicator was injected into the pulmonary artery.

Fig. 6 included 12 curves with the indicator injection into the right ventricle,

Fig. 5.

Fig. 6.

Fig. 5. Comparison of the shunt magnitudes calculated by the Fick's method with those estimated from the earpiece dye-dilution curves recorded after the injection of the indicator into the pulmonary artery. $\circ$: Under 1 y. $\bullet$: Over 1 y.

Fig. 6. Comparison of the shunt magnitudes calculated by the Fick's method with those estimated from the earpiece dye-dilution curves recorded after the injection of the indicator into the right ventricle, right atrium and inferior vena cava. $\circ$: Under 1 y. $\bullet$: Over 1 y.

Fig. 7.

Fig. 8.

Fig. 7. Comparison of the shunt magnitudes calculated by the Fick's method with those estimated from the earpiece dye-dilution curves recorded after the injection of the indicator into the left atrium. •: Over 1 y.

Fig. 8. Comparison of the shunt magnitudes calculated by the Fick's method with those estimated from the earpiece dye-dilution curves recorded after the injection of the indicator into peripheral veins. •: Over 1 y.

15 curves into the right atrium and 3 curves into the inferior vena cava.

Fig. 7 included 7 curves in which the indicator was injected into the left atrium. Fig. 8 included 18 curves in which the indicator was injected through peripheral veins.

As will be seen from Figs. 5–8, it was apparent that there was a good correlation between the shunt magnitudes obtained by Fick's method and those calculated from the dye-dilution curves with correction of the build-up time in the third type of the curves in infants.

References

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