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Evaluation of Phonocardiography in Congenital Heart Diseases: with Special Reference to the Influence of the Double Stenosis of the Right Ventricular Outflow Tract on the Systolic Murmurs in Tetralogy of Fallot†

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IN THE PREVIOUS issue^{1,2)}, it was shown that the classification of the systolic murmur in the tetralogy of FALLOT afforded a useful clue to the evaluation of the type of stenosis, infundibular or valvular.

The common use of the angiocardiology and the good results of complete surgical repair of tetralogy of FALLOT has offered good chances to consider more precisely the sound phenomena generated from the various combination of the double stenosis at the right outflow tract.

The purpose of this paper is to emphasize the diagnostic value of phonocardiogram and its limitations.

MATERIALS AND METHODS

The phonocardiographic studies were limited on the forty patients with tetralogy of FALLOT who were subjected to complete surgical repair.

Indication for the complete repair was chiefly determined by the angiocardiology appearances of the right ventricular outflow tract and main pulmonary trunk.

EXTERNAL PHONOCARDIOGRAPHY

High pass filter circuits (18/Oct. Nf 400c/s) were used to obtain phonocardiograms in each

case, its tracing was taken at high speed (100 cm/sec). Interval of Q-M. S. M. was measured from Q (ECG) to the aortic components of the 2nd sound.

Systolic murmurs were classified into 4 types according to these duration and pattern of systolic murmur. (Fig. 1)

	176 cases (1966)	81 cases (1960)
TYPE - A	40 (22.7%)	25 (29.1%)
TYPE - B	114 (64.8%)	51 (59.3%)
TYPE - C	15 (8.5%)	6 (7.0%)
TYPE - D	7 (4.0%)	4 (4.6%)

Fig. 1. Classification of Systolic Murmur.

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Fig. 2. The relations between $\frac{Q-M. S. M.}{Q-IIa}$ values and angiocardiographic classification of infundibular stenosis with or without pulmonary valvular stenosis examined during surgeries.

- I) Type A, where the systolic murmur did not continue to the 2nd heart sound.
 II) Type B, there the systolic murmur continued to IIa and the maximal amplitude appeared in the first 85 per cent of the duration of the systole.
 III) Type C, where the systolic murmur continued to IIa and terminated in crescendo fashion. This type was limited in the cases whose values of $\frac{Q-M. S. M.}{Q-IIa}$ remained over 85

Fig. 3. Type -B murmurs combined with or without pulmonary valvular stenosis.

per cent.

IV) Type D, where the systolic murmur was faint, and variable in form, in other words, no specific type of the ejection murmur was observed.

DIRECT PHONOCARDIOGRAPHY²⁾

A tiny ceramic microphone (diameter 2.7 cm, height 1.0 cm), sterilized with ethylen oxide gas and covered by a thin sterilized rubber glove, is kept in contact with the epicardium and great vessels by a surgeon's hand.

SELECTIVE RIGHT VENTRICULAR ANGIOCARDIOGRAPHY

Selective right ventricular angiocardiography was performed on 40 cases. The saphenous route was preferred to the others if possible and the catheter advanced down to the apex

TABLE I THE INCIDENCES AND THE CLASSIFICATION OF SYSTOLIC MURMURS OF THE CASES WHO UNDERWENT SURGICAL PROCEDURES

Total correction				Shunt operation		Total cases	
Classification		No.	%	No.	%	No.	%
Type A		5	12.5	8	21.1	40	22.7
Type B		29	72.5	23	60.5	114	64.8
Type C		5	12.5	4	10.5	15	8.5
Type D		1	2.5	3	7.9	7	4.0
		40		38		176	

from March 1960 to March 1966

from 1956 to 1966

Fig. 4. Case 1. a) and b) Lateral projection of the selective ventricular angiography and its schema. This film shows the localized subvalvular stenosis, small infundibular chamber, pulmonary valvular stenosis. c) External PCG reveals the mid-systolic murmur on the 3rd. intercostal space of the left sternal border. d) Direct epicardial PCG depicts the two different peaks of systolic murmur, on the right ventricular and the pulmonary artery tracing, respectively.

of the right ventricle. In 28 cases, films were taken with ELEMA-SCHÖNANDER monoplane equipment; initially cut-film was used but latterly roll-film. In the other 12 cases cine-angiography was carried out. The an-

giocardiograms of 40 cases were studied and analysed for the following features. In the lateral projection, the site and nature of the right ventricular outflow tract obstruction, including an assessment of the size of the

TABLE II CLASSIFICATION OF STENOTIC TYPES BY THE ANGIOCARDIOGRAPHIC AND SURGICAL FINDINGS

	<i>Tubular Stenosis</i>	<i>Localized Subvalvular Stenosis</i>	<i>Formation of Infundibular Chamber</i>	<i>Total</i>
<i>Angiocardiographic Findings</i>	16	8	4	28
<i>Valvular Stenosis confirmed by surgery</i>	8	5	2	15

Fig. 5. Case 2 a) Lateral projection of the selective right ventricular angiogram, b) its schema.
c) Phonocardiographic changes before and after Brock's operation.

Fig. 6. Case 3, a) systolic b) diastolic lateral views of the selective right ventricular angiograms reveals the localized subvalvular stenosis and suggests the mild valvular stenosis.
c) External PCG shows the type-A murmur, value of $\frac{Q-M. S. M.}{Q-IIa}$ is 55.7 per cent.

pulmonary valve stenosis if possible, were recorded. Infundibular stenosis was divided into the following 3 forms; tubular, localized subvalvular and formation of infundibular chamber.

MORPHOLOGICAL FINDINGS IN SURGERY

At the time of complete surgical repair, the existences of the pulmonary valvular stenosis were examined.

RESULTS

The incidences of the 4 types in the classification of the systolic murmur of all cases of FALLOT's tetralogy shown in Fig 1. and the number of the cases of total correction and palliative procedures are shown in Table I.

The incidences of the types of infundibular stenosis assessed by the selective right ventricular angiocardiology are shown in Table II.

Fig. 2 shows the relations between $\frac{Q-M.S.M.}{Q-IIa}$ values and angiocardiology classification of infundibular stenotic types with or without pulmonary valvular stenosis examined during surgeries.

In Fig. 3, the phonocardiographic type B is grouped into two, depending upon whether the pulmonary valvular stenosis exists or not. And the values of $\frac{Q-M.S.M.}{Q-IIa}$ in the valvular stenotic groups stay always above 65 per cent, whereas those in the non-valvular stenotic groups are less than 65 per cent.

DISCUSSION

Since the angiocardiology was introduced in our clinic, the indication of corrective operation for FALLOT's tetralogy have been decided by it. And the incidences of the B and C types in the phonocardiographic classification of the patients who underwent the complete corrective surgery was significantly higher than those of the patients who were subjected to the conservative operations as shown in Table I.

There might be no relations between three forms of infundibular stenosis and phonocardiographical classifications so far. All cases whose

$\frac{Q-M.S.M.}{Q-IIa}$ were 65 per cent had the valvular stenosis to be necessary to correct surgically, as shown in Fig 3.

There are several problems on diagnostic reliability on phonocardiography in examining the double stenosis of FALLOT's tetralogy.

Sometimes the cardiovascular sounds recorded on the chest walls are modified in their characteristics so that the diagnosis can be mislead phonocardiographically, as shown in the following cases.

Case 1 (Fig. 4): An 11 year old boy with the diagnosis of tetralogy of FALLOT was admitted to our hospital. His angiocardiology appearances had clearly demonstrated the localized subvalvular stenosis, but obscurely the pulmonary valvular stenosis. Preoperative external phonocardiogram registered on the 3rd. intercostal space of the left sternal border showed the midsystolic murmur which were calculated as 61.7 per cent in $\frac{Q-M.S.M.}{Q-IIa}$, however the direct phonocardiogram during surgery revealed the two different peaks of systolic murmurs, one was the mid-systolic murmur figured 60 per cent in $\frac{Q-M.S.M.}{Q-IIa}$ on the right ventricular tracing, the other was the late systolic murmur calculated at 91 per cent on the pulmonary artery.

It can be explained that the weak cardiovascular sounds generated from the cardiovascular cavities and the great vessels can be damped so that it does not transmit to the surface of chest wall.

Case 2 (Fig. 5): A 12 year old boy, admitted in our hospital as tetralogy of FALLOT, was subjected to the right heart catheterization, but the catheter could not be inserted into the pulmonary artery. Therefore, the type of his stenosis of the outflow tract, infundibular or valvular, could not be determined by means of pull through technique. His $\frac{Q-M.S.M.}{Q-IIa}$ value was 89 per cent. According to this findings, the type of his stenosis was considered more likely to be valvular stenosis. Existence of the pulmonary valvular stenosis was confirmed

during surgery. BROCK's operation was performed. Postoperative course was uneventful. The grade of his cyanosis and physical activity were highly improved. Postoperative PCG was markedly changed from the late systolic murmur to the mid-systolic murmur and the value of $\frac{Q-M. S. M.}{Q-IIa}$ decreased to 58 per cent.

The angiocardiogram which was taken three years after the operation revealed the very narrow tubular stenosis and the marked post-stenotic dilation of pulmonary trunk.

In general, the intensity and the pattern of the systolic ejection murmur are influenced by the velocity of flow through the narrow portion.

In this case, blood stream velocity through the infundibular stenosis might be slowed down by the tight valvular stenosis, so that the mid-systolic murmur originated from the infundibular stenosis could not be recorded preoperatively on his PCG, even if his infundibular stenosis was tight enough to produce the murmur.

On the contrary, if there is the severe infundibular stenosis the velocity of the blood stream through the pulmonary valve will be slowed down; in addition, existence of pulmonary valvular stenosis will cause the late appearance of the maximal velocity.

The systolic murmur produced from the stenotic pulmonary valve will be faint. The following case seems to be very suitable to explain such a phenomenon.

Case 3. (Fig. 6): A 4 year old boy has been diagnosed as type A according to his systolic murmur. And the peak of his systolic murmur appeared in late systolic phase. The value of $\frac{Q-M. S. M.}{Q-IIa}$ was 55.7 per cent. If the valvular stenosis had not existed in this case, the value of his $\frac{Q-M. S. M.}{Q-IIa}$ would have been smaller than 55.7 per cent. And the peak of the mur-

mur would have been moved to early systolic phase.

SUMMARY AND CONCLUSIONS

Problems in the diagnostic use of phonocardiography were described.

a) It was unable to find any relations between the wave-forms of systolic murmurs of FALLOT's tetralogy and the types of infundibular stenosis suspected angiographically.

b) The values of $\frac{Q-M. S. M.}{Q-IIa}$ remained above 65 per cent in the cases who had the valvular stenosis required the surgical repairs.

c) It was confirmed by the direct epicardial phonocardiography that there are two factors to reduce the value of the diagnostic use of the external phonocardiography to detect the existences of the double stenosis, valvular and infundibular, in FALLOT's tetralogy. The first one is damping effect of the chest wall through which the external phonocardiograms are taken. And the other is the influence of the velocity of the blood flow through the stenotic portion. When the valvular stenosis play a more important role than the infundibular stenosis in formation of systolic ejection murmur, it is difficult to detect the existences of the infundibular stenosis on phonocardiogram, and vice versa.

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