Vectorcardiogram in Biventricular Hypertrophy with the Frank System

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THERE is a great number of reports on the characteristic features and criteria of right ventricular hypertrophy and left ventricular hypertrophy in vectorcardiogram published in Japan including the authors' work¹ and others^{2,3} and in other countries.⁴⁻⁶

MASSIE et al.⁷ have reported biventricular hypertrophy with the Grishman method. A report has been published on the configuration of the QRS loop with the Frank method in congenital heart diseases such as ventricular septal defect.⁸ However, there has been no detailed report on the characteristic features and criteria of biventricular hypertrophy. Previously the authors⁹ discussed the QRS loop in biventricular hypertrophy, but no on collected clinical data of cases. In this report, the QRS loop and T loop observed in biventricular hypertrophy with the Frank method were studied in cases of acquired valvular disease having a possibility of developing biventricular hypertrophy, and the criterion of biventricular hypertrophy was presented.

MATERIALS AND METHODS

From the in-patients and out-patients of Center for Adult Diseases, Osaka who were subject to vectorcardiography (VCG) with the Frank method, cases with acquired valvular diseases such as mitral valvular disease and combined valvular disease having a possibility of developing biventricular hypertrophy were selected and divided into the following groups.

- Group A Mitral insufficiency (MI Group)
- Group B Mitral insufficiency with mitral stenosis (Predominant type of mitral insufficiency) (MIs Group)
- Group C Mitral stenosis with mitral insufficiency (MSI Group)

- Group D Mitral stenosis and aortic insufficiency (MS + AI Group)

These diagnoses were made with clinical findings, including phonocardiogram, chest X-ray, and ECG.

In VCG of these patients, a) configuration and direction of inscription of the QRS loop and T loop in three planes, b) the magnitude and direction of maximum QRS and T vector, c) the magnitude of right component (R), left component (L), posterior component (P) and anterior component (A) of the QRS loop in the horizontal plane and R/L, P/L, P+A/R+L were examined.

The configuration of the QRS loop in the horizontal plane was classified as R_{III}, R_{II}, R_I, PP, P, N, L_I, L_{II} and L_{III} types as shown in Fig. 1. In addition, those with the configuration of right bundle branch block were classified as RB type. The cases with $P+A/R+L \geq 1.5$ were classified as P type, cases with $R/L \geq 0.4$ and $P/L \geq 1.2$ as PP type and cases with $R/L \geq 0.4$ and $P/L \geq 1.2$ as RI type.

RESULTS

1. The configuration of the QRS loop in horizontal plane

The types of the horizontal QRS loop in each group are shown in Table I. In Group D (MS + AI Group) all types were observed. In the other 3 groups, cases were distributed in from PP type to L_{II} type except for 1 case, and there was no case of right ventricular hypertrophic types (R_{I-III} types). The one exceptional case belonged to RBBB type (right bundle branch block), but the QRS loop of that case was inscribed clockwise with the efferent limb dislocated to the left, presenting an unusual configuration. One case in MI Group (Fig. 2-C) was diagnosed several years

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TABLE I THE TYPES OF THE HORIZONTAL QRS LOOP IN EACH GROUP

	R_1	PP	P	N	L_1	L_2	L_3	RB
<i>MI Group</i>		1		3	1	1		
<i>MI_s Group</i>				3				
<i>MSI Group</i>		1	3	1	5	2		1
<i>MS + AI Group</i>	2	1	3	2	2	7	3	2

Fig. 1. The types of the QRS loop in horizontal plane. R_I – R_{III} types, PP–Posterior Pip type, P–Posterior type, N–Normal type, L_I – L_{III} LVH types.

Fig. 2. Vectorcardiogram of three cases in Group A (Mitral Insufficiency Group).

ago and had been treated with digitalis. Recently his liver became enlarged. This case belonged to PP type, but the other cases in MI Group belonged to N and L type (Fig. 2-A, B). Three cases in MI_s Group showed N type. Thus, it might be said that in the case of mitral insufficiency or predominant type of mitral insufficiency, the QRS loop in the horizontal plane indicated a normal type or left ventricular hypertrophic types (L_I – L_{III} types). In some cases of MSI Group, MS + AI Group and MI Group accompanied by right ventricular failure, a transitional type of right ventricular hypertrophy was observed. In cases be-

longing to MS + AI Group in which aortic insufficiency predominated, severe types of left ventricular hypertrophy such as L_{II} and L_{III} types increased in number.

However, in such classification, the characteristic configuration of the QRS loop in biventricular hypertrophy could not be pointed out.

2. The magnitude of the maximum QRS vector in horizontal plane

As for the number of cases with the maximum QRS vector over 2.0 mV, which is the authors' criterion for left ventricular hypertrophy, there were 10 cases out of 21 cases in MS + AI Group, but there was only 1 case (exactly 2.0 mV) in MI Group, none in MI_s Group and 2 cases out of 13 cases in MSI Group.

Cases with L type, N type, and P type of the horizontal QRS loop in those groups were divided into two groups by the magnitude of the maximum QRS vector; the first group consisted of cases with the maximum QRS vector less than 2 mV and the second group consisted of cases with the maximum QRS vector over 2 mV. As shown in Table II, it was reasonable that in N type and P type only one case had the maximum QRS

Fig. 3. The horizontal QRS loop is belonged to the L type, but the direction of the maximum QRS vector in horizontal plane is more posterior than -45° , and the magnitude is less than 2.0 mV. A–MI Group, B–MSI Group, C–MSI + AI Group.

TABLE II THE RELATION BETWEEN THE TYPES OF THE HORIZONTAL QRS LOOP AND THE MAGNITUDE OF THE MAXIMUM QRS VECTOR

	<i>L-type</i>		<i>N type</i>		<i>P type</i>	
	2.0 mV	2.0	2.0	2.0	2.0	2.0
<i>MI Group</i>	1	1	3			
<i>MI_s Group</i>			3			
<i>MSI Group</i>	5	2	1		3	
<i>MS + AI Group</i>	4	8	1	1	3	1

TABLE III THE ABNORMAL CASES OF THE HORIZONTAL T LOOP WITH MAXIMUM QRS VECTOR OVER 2.0mV

<i>The location of the T loop</i>	<i>left ant.</i>			<i>left post.</i>	<i>right ant.</i>	<i>right post.</i>
	<i>linier</i>	8	<i>clockwise</i>			
<i>MI Group</i>		1		1	1	
<i>MI_s Group</i>			1			
<i>MSI Group</i>	1	1	1	4	1	1
<i>MS + AI Group</i>	1	1		10	3	

vector over 2.0 mV; even in L type, cases with the maximum QRS vector less than 2 mV were one case in MI Group, 5 cases in MSI Group, and 4 cases in MS + AI Group (Fig. 3).

Therefore the magnitude of the maximum QRS vector could not contribute to the criterion of biventricular hypertrophy.

Then, the QRS loop in 10 cases of less than 2 mV in L type were analysed. The horizontal QRS loop in 4 of these cases was displaced left-posteriorly with the tip being narrow (Fig. 3). The QRS loop in a usual L type was dislocated to the left and somewhat posteriorly, but it was located more posteriorly. This posterior dislocation might be due to biventricular hypertrophy.

Of course in some cases of L type with maximum QRS vector over 2 mV the QRS loops were dislocated to the left and more posteriorly, but the dislocation of the QRS loop in those cases was effected mainly by left ventricular hypertrophy.

3. Location and configuration of the T loop in horizontal plane

There were a few cases whose location of the T loop in horizontal plane was left-anteriorly as in normal cases, but as shown in Table III, the T loop in many cases was dislocated left-posteriorly. In some cases, the T loop was located right-anteriorly and in rare cases, the T loop was located right posteriorly. Even though the T loop was located left-anteriorly, the direction of inscrip-

tion of the T loop was a figure of 8 or clockwise in 5 cases. Such inscription was one of authors' criteria of right ventricular hypertrophy. A left-posterior displacement of the T loop was observed in cases with an ischemic change of the anterior wall due to coronary sclerosis, but it was also one of the characteristic finding of right ventricular hypertrophy in valvular diseases excluding children (Figs. 4, 5).

In L type with maximum QRS vector less than 2 mV, one case out of the 4 cases showed the T loop located left-posteriorly, but in the others it was dislocated right-anteriorly or right-posteriorly. However, in 3 cases of the other 6 cases in L type, the T loop in horizontal plane was located to the left with a figure of 8 or clockwise inscription. Therefore, it was considered that these three cases also showed a possibility of biventricular hypertrophy.

Among the 11 cases belonging to L type with maximum QRS vector over 2 mV, the T loop in 3 cases was located left-posteriorly. In these cases, the QRS loop indicated a sign of left ventricular hypertrophy and the T loop that of right ventricular hypertrophy. These findings, therefore, might be considered to be due to biventricular hypertrophy. Even in N type, the maximum QRS vector in one case was greater than 2 mV and the T loop was located left-posteriorly.

Among the cases belonging to N type whose maximum QRS vector was less than 2 mV and

Fig. 4. The horizontal QRS loop is belonged to the L type, but the direction of inscription of the horizontal T loop is the figure of eight or clockwise A, B-MSI Group.

Fig. 5. A-MS + AI Group. The magnitude of the horizontal QRS loop is greater than 2.0 mV, but the horizontal T loop is located left-posteriorly. B-MSI Group. The magnitude of the horizontal QRS loop is less than 1.0 mV, and the direction of inscription of the horizontal T loop is clockwise.

whose T loop showed a figure of 8 or clockwise inscription, one case had the maximum QRS vector less than 1 mV and one case belonged to L_1 type. There was a possibility of biventricular hypertrophy in the former case.

4. The QRS loop and T loop in frontal plane

In frontal plane there was no characteristic finding in the configuration or the direction of inscription of the QRS loop or in the magnitude of the maximum vector. The same thing could be said of the T loop. In frontal plane, no characteristic finding of biventricular hypertrophy could be obtained.

5. Criterion for the diagnosis of biventricular hypertrophy

The numbers of cases diagnosed as right ventricular hypertrophy, left ventricular hypertrophy or biventricular hypertrophy in the present cases were classified and shown in Table IV.

Out of the 44 cases examined, 12 cases were diagnosed as right ventricular hypertrophy, 9 as left ventricular hypertrophy, and 12 as biventricular hypertrophy. However, 11 cases were found not to satisfy the criteria for ventricular hypertrophy.

DISCUSSION

The authors^{1,9} have proposed 1) maximum QRS vector in the horizontal plane ≥ 2.0 mV and/or 2) maximum T vector in the horizontal plane $\geq +70^\circ$ as the diagnostic criteria of left ventricular hypertrophy on vectorcardiogram. The criterion of the maximum QRS vector being 2.0 mV or more is convenient also from the standpoint of using a calibration curve, but one investigator prefers¹³ the QRS vector over 1.5 mV as criterion. However, his criterion does not seem acceptable because it makes many false positive cases out of normal cases.

Further, the authors have proposed as criteria of right ventricular hypertrophy 1) right component (R)/left component (L) of the QRS loop in the horizontal plane ≥ 0.4 and posterior component (P)/left component (L) ≥ 1.2 and/or 2) the T loop in the horizontal plane being left-posteriorly or being inscribed with the figure of 8 or

TABLE IV THE NUMBER OF CASES DIAGNOSED AS RVH, LVH, BVH OR IN NORMAL IN EACH GROUP

	RVH	LVH	BVH	Normal
MI Group	2	1	1	2
MI _S Group			1	2
MSI Group	3	1	5	4
MS + AI Group	7	7	5	3
Total	12	9	12	11

clockwise. When the criterion of $R/L \geq 0.4$ and $P/L \geq 1.2$ is used, a few false positive cases are detected. When the efferent limb of the QRS loop in the frontal plane is deviated right-inferiorly, right ventricular hypertrophy is assumed, but this quantitative criterion is not yet established.¹⁴

The diagnosis of biventricular hypertrophy is difficult even on the electrocardiogram. Electrocardiographic criteria have been presented by LEPESCHKIN, SODI-PALLARES, PAGNONI, COSBY, ROSEMAN and others. KATZ and WACHTEL reported the criterion for children. However, there is no universal criterion.

With regard to the criterion of ventricular hypertrophy in vectorcardiography with the Grishman method, reports have been published by WHIPPLE¹⁰ and ELLIOT.¹¹ RICHMAN¹² has reported with the Duchosal method, but a number of problems exist yet to be resolved in VCG. Even with the Frank method there is no quantitative criterion.¹⁵

Presently, clinical cases of valvular diseases with the possibility of inducing biventricular hypertrophy such as mitral steno-insufficiency, mitral insufficiency, and aortic insufficiency with mitral stenosis were selected and a study was made on the configurations and directions of inscription of the QRS loop and T loop in three planes and on the magnitude of the maximum QRS vector in the horizontal plane. Some cases of MS + AI Group, showed characteristic changes of right ventricular hypertrophy or left ventricular hypertrophy, but this group was selected because there was a possibility of developing the characteristic pattern of biventricular hypertrophy.

In the present cases, a diagnosis of right ventricular hypertrophy or left ventricular hypertrophy was established on the basis of the configuration of the QRS loop and on the magnitude of the maximum QRS vector in horizontal plane. A definite diagnosis of right ventricular hypertrophy was made on 2 cases and a probable diagnosis on 5 cases; from the maximum QRS vector over 2.0 mV, a diagnosis of left ventricular hypertrophy was made on 10 cases. In a total of 44 cases, a diagnosis of left or right ventricular hypertrophy was made on only 17 cases. In many cases of the remaining 27 cases, it was suggested that change of the QRS loop was possibly due to biventricular hypertrophy.

However, on classification of the QRS loop revealed no definite types.

In cases of L type with the maximum QRS

vector less than 2.0 mV, the QRS loop in 4 cases was dislocated more posteriorly than a position usually observed in left ventricular hypertrophy. Their QRS loops with a tip were not elliptical in the case of P type. In all these cases, the direction of the maximum QRS vector was posterior than -45° . This location which was already reported by the authors,¹ constitutes one of the diagnostic criteria of biventricular hypertrophy.

1. The QRS loop in horizontal plane is classified as L type, but the direction of the maximum QRS vector is more posterior than -45° and is smaller than 2.0 mV in magnitude. In this case, the T loop is small or located left-posteriorly, right-anteriorly or right-posteriorly (Fig. 3A-C).

In cases with the QRS loop located somewhat posteriorly and to the left as seen in usual L type, cases with the maximum QRS vector less than 2.0 mV were found in 3 cases. Their T loops were located to the left or left-posteriorly and showed the figure of 8 or clockwise inscription, although the T loop in the case of left ventricular hypertrophy is reasonable to be dislocated left-anteriorly or anteriorly. The T loop located to the left or left-posteriorly was usually found in the case of right ventricular hypertrophy, and the QRS loop in such cases belonged to N type, P type, PP type and R type. Therefore when the QRS loop belongs to L type with such T loops, a possibility of biventricular hypertrophy is suggested. Then another criterion may be postulated:

2. When the QRS loop in horizontal plane is L type and the T loop is located left-posteriorly or to the left with the figure of 8 or clockwise inscription, even though the maximum QRS vector is less than 2.0 mV and is more anterior by than -45° (Fig. 4-A, B).

Similarly, the following patterns may well be included as one of the criteria.

3. Even though the QRS loop in horizontal plane is L or N type and the maximum QRS vector is 2.0 mV or greater, the T loop is located left-posteriorly or to the left with the figure of 8 or clockwise inscription (Fig. 5-A).

When the horizontal T loop in N type or P type of the horizontal QRS loop shows the figure of 8 or clockwise inscription, even though it is located left-posteriorly or left-anteriorly, the criterion of right ventricular hypertrophy is satisfied and therefore it is excluded from the criterion of biventricular hypertrophy. However, in an N type with the QRS loop being small and less than 1 mV, it might be considered that this would meet

the criterion of biventricular hypertrophy if accompanied by such a T loop.

Thus the following condition is included in the suspectable criterion:

4. When the QRS loop in horizontal plane is N type and is less than 1.0 mV and when the T loop is located left-posteriorly or to the left with the figure of 8 or clockwise inscription (Fig. 5-B).

If the foregoing four criteria are employed as criteria of biventricular hypertrophy, 12 cases would meet the criterion of biventricular hypertrophy, that is 1 case in MI Group, 1 case in MIs Group, 5 cases in MSI Group, and 5 cases in MS + AI Group.

In cases which do not satisfy the criterion of biventricular hypertrophy, 12 cases were diagnosed as right ventricular hypertrophy and 9 cases as left ventricular hypertrophy. Thus in the 44 cases, 33 cases would either satisfy the criteria of right ventricular hypertrophy, left ventricular hypertrophy or biventricular hypertrophy.

As configurations of the QRS loop can be changed depending on a balance between the left and right ventricles in biventricular hypertrophy, it is very difficult to make a simple classification and a criterion of biventricular hypertrophy. In cases with diseases having a possibility of biventricular hypertrophy, various configurations of the horizontal QRS loop are detected. Thus criteria of biventricular hypertrophy are presented, after cases in right or left ventricular hypertrophy are excluded.

However, a left or left-posterior dislocation of the T loop in horizontal plane is also observed when ischemic change develops in the anterior wall. Therefore this criterion should not be applied in cases with coronary heart disease not accompanied by any disease which would produce biventricular hypertrophy.

CONCLUSION

In order to determine the diagnostic criteria of biventricular hypertrophy, the configuration and direction of inscription of the QRS loop and T loop and the magnitude of the maximum QRS vector in horizontal plane were studied in cases of mitral insufficiency, mitral stenosis with mitral insufficiency, and mitral stenosis with aortic insufficiency. When any of the following conditions is met, it is proposed that biventricular hypertrophy can be diagnosed in vectorcardiogram.

1. When the QRS loop in horizontal plane is L type and the maximum QRS vector is less than

2.0 mV and a) When the maximum QRS vector is located posteriorly more than -45° ; b) When the maximum QRS vector is located anteriorly more than -45° and when the T loop in horizontal plane is located left-posteriorly, to the left or left-anteriorly with the figure of 8 or clockwise inscription.

2. When the maximum QRS vector of the QRS loop in horizontal plane is 2.0 mV or more and the T loop in horizontal plane is located left-posteriorly or to the left or left-anteriorly with the figure of 8 or clockwise inscription.

3. When the QRS loop in horizontal plane is N type and the maximum QRS vector is less than 1.0 mV and when the T loop in horizontal plane is located left-posteriorly, to the left or left-anteriorly with the figure of 8 or clockwise inscription.

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