A Constructed Method of the QRS Loop in Right Ventricular Hypertrophy

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VECTORCARDIOGRAPHIC study of left and right ventricular hypertrophy in clinical cases has been reported by many authors^{1,2,3,4,5}. YAMAGAMI⁶ also investigated the displacement of the QRS loop in experimental right ventricular hypertrophy.

The present authors described the change of the QRS loop with the Frank system in right ventricular hypertrophy and divided them into three groups: 1) Mitral stenosis group (systolic overloading type), 2) Atrial septal defect group (diastolic overloading type) and 3) Pulmonary emphysema group.

The characteristic change in ASD group was an anterior displacement of the afferent limb of

the sagittal QRS loop, and that in MS group was a right-posterior displacement of the afferent limb of the horizontal QRS loop. It was supposed that the difference of the QRS loop in both groups might be due to the difference between systolic and diastolic overload. Namely, in ASD group, the anterior displacement of the afferent limb might be caused by the delay of depolarization process which was due to the dilatation of the right ventricle. However, no one had proved the reason of that difference theoretically.

In the present paper, the present authors tried to explain that reason with the authors' constructed method of the QRS loop.

Fig. 1. A) Direction of vector in each segment, B) Time history of vector in each segment, C) Constructed QRS loops in three planes.

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METHOD

The left ventricle in a heart model was divided into 6 segments (Lai, Las, Lmi, Lms, Lpi, Lps), the right ventricle into 6 segments (Rai, Ras, Rmi, Rms, Rpi, Rps) and the septum into 2 segments (RS, LS) (Fig. 1).

The duration of depolarization process was divided into 8 stages (Stage 0–Stage 8). The depolarization process was referred to the reports of TOYOSHIMA and other investigators and the directions of activation wave in those segments were determined. The direction of activation wave in each segment was decided to be constant during the depolarization process.

The direction of each segment vector was perpendicular to that of activation wave. The angles of elevation and azimuth of each segment vector were estimated and direct cosine l , m , n of each segment vector were calculated (Table I).

The magnitudes of each stage in each segment vector were shown in Fig. 1. The magnitude in the left ventricle was three times of that in the right ventricle.

RESULTS

When the vectors in the right ventricle were increased, the following conditions were adopted.

TABLE I DIRECT COSINE OF VECTOR IN EACH SEGMENT

	l	m	n
<i>Lai</i>	866	0	500
<i>Las</i>	750	500	433
<i>Lmi</i>	750	–500	–433
<i>Lms</i>	837	259	–483
<i>Lpi</i>	0	–866	–500
<i>Lps</i>	0	0	–1000
<i>LS</i>	–836	259	483
<i>Rai</i>	–259	0	967
<i>RmS</i>	–224	500	837
<i>Rmi</i>	–750	–500	433
<i>Rms</i>	–836	259	483
<i>Rpi</i>	–433	–866	–251
<i>Rps</i>	–866	0	–500
<i>RS</i>	836	259	–483

l =direct cosine to X axis m =direct cosine to Y axis
 n =direct cosine to Z axis

1. The duration and start of depolarization in the right ventricle were unchanged.

a) The vectors of all segments in the right ventricle except the right side of the septum (RS) were increased.

When the vectors of Rai-Rps were multiplied

Fig. 2. Horizontal QRS loops when magnitude of each vector in the right ventricle except RS is multiplied.

Fig. 3. Horizontal QRS loops when magnitude of each vector in the right ventricle including RS is multiplied.

by 1.5, 2, 2.5 or 3 ($R \times 1.5$, $\times 2$, $\times 2.5$, or $\times 3$), the horizontal QRS loop became long and narrow along the anteroposterior axis (Z axis), and the afferent limb was dislocated right-posteriorly. In case of $R \times 3$, the horizontal QRS loop was inscribed clockwise.

b) The vector of RS was multiplied as same as vectors of the right ventricle.

The afferent limb of the QRS loop in horizontal plane was dislocated right-posteriorly, and the initial QRS vector in horizontal plane was directed to left-anteriorly in proportion to increase the number.

c) The vector of Rps was duplicated. Thereafter, all vectors in the right ventricle were multiplied by 1.5–3.

The horizontal QRS loop became narrow along the right-posterior to left-anterior axis. In case of $R \times 3$, the direction of inscription of the QRS loop was clockwise, and the posterior dislocation of the afferent limb was marked.

2. The duration of depolarization in the right ventricle and the right side of the septum was prolonged 10 msec.

The afferent limb of the horizontal QRS loop protruded rightward. The direction of inscription of the QRS loop was the figure of eight in

case of $R \times 2.5$, and clockwise in case of $R \times 3$. Those QRS loops were similar to those in systolic overload of clinical right ventricular hypertrophy except the marked rightward dislocation of the terminal portion in case of $R \times 1.5$.

3. The start of the depolarization in the right ventricle was delayed 10 msec.

The QRS loop in horizontal plane became elliptical along the X axis, and the afferent limb protruded right-posteriorly. In case of $R \times 3$, the QRS loop was inscribed with the figure of eight.

4. The start of the depolarization in the right ventricle was delayed 20 msec.

The horizontal QRS loop became long and narrow along the X axis, and the main portion was dislocated left-posteriorly. The terminal portion was displaced right-anteriorly, and the direction of inscription of the QRS loop in case of $R \times 3$ was the figure of eight. However, the rightward protrusion of the terminal portion was remarkable.

5. The increasing ratio of the vectors in Rp was less than those in Ra and Rm, and the start of the depolarization was delayed 20 msec.

The horizontal QRS loop became long and

Fig. 4. Horizontal QRS loops when magnitude of each vector in the right ventricle is multiplied after duplication of magnitude of Rps.

Fig. 5. Horizontal QRS loops when magnitude of each vector in the right ventricle is multiplied with the prolongation of depolarization process (from 80 msec to 90 msec) in the right ventricle.

narrow and the main portion was displaced left-posteriorly. The terminal portion was displaced right-anteriorly. The direction of inscription of the horizontal QRS loop was the figure of eight in cases of $R_a, m \times 2.5$ and $R_a, m \times 3$. In the sagittal QRS loop, the afferent limb protruded anteriorly beyond the efferent limb. Consequently, the configuration of the QRS loop was similar to that in cases with atrial septal defect.

6. The duration of the depolarization in the right ventricle was prolonged 10 msec. with the same conditions as above case 5.

The horizontal QRS loop was narrow and the

terminal portion protruded markedly right-anteriorly.

In order to construct the horizontal QRS loop similar to the systolic overload of the right ventricular hypertrophy, the following conditions were necessary: 1) Increasing the vectors in the right ventricle including the rightside of the septum, and 2) Prolongation of the depolarization process in the right ventricle.

Otherwise, in the diastolic overload, the necessary conditions were as follows: 1) Delay of the start of the depolarization in the right ventricle and 2) Increasing the vectors in the right ventricle (the increasing ratio of the seg-

Fig. 6. Horizontal QRS loops when magnitude of each vector in the right ventricle except RS is multiplied with the 20 msec delay of start of depolarization process in the right ventricle.

Fig. 7. Horizontal QRS loops when magnitude of each vector in the right ventricle except RS (increasing ratio of R_p is a half of R_a and R_m) is multiplied with the 20 msec delay of start of depolarization.

Fig. 8. The QRS loops in three planes in cases with the same condition of Fig. 7.

ment R_a , and R_m was greater than that of R_p .)

DISCUSSION

CABRERA⁷ described the electrocardiographic findings of systolic and diastolic overload in ventricular hypertrophy. Indeed, the electrocardiographic patterns in mitral stenosis were somewhat different from those in atrial septal defect. In vectorcardiography¹, the afferent limb of the horizontal QRS loop in mitral stenosis was dislocated right-posteriorly except the severe case of right ventricular hypertrophy with the horizontal QRS loop located right-anteriorly.

On the contrary, in atrial septal defect, the afferent limb of the horizontal QRS loop was displaced right-anteriorly, and that in the sagittal plane protruded anteriorly. It was supposed that those vectorcardiographic differences in both diseases might be due to those between systolic overload and diastolic overload. However, no one proved the theoretical illustration.

A few years ago, the present authors⁸ reported the constructed method of the QRS loop, a modification of SELVESTER's method⁹, had illustrated the reason of the QRS loops in myocardial infarction and intraventricular block. In the present study, that method was improved. Namely, the right ventricle was divided into 6 segments, the left ventricle into 6 segments and the septum into 2 segments. The direction and

magnitude of each segment vector were newly determined.

In the previous study, the direction of the vector in each segment was perpendicular to the epicardial surface. But in this time, the directions of the activation wave of the depolarization in each stage were assumed referring to TOYOSHIMA's report, and the direction of the vector was perpendicular to the activation wave. Of course the direction of activation wave might change during the period of depolarization process. However, in the present method, the direction of activation of each stage in each segment was assumed to be constant.

The period of depolarization process was divided into 8 stages per each 10 msec.

Initially, X, Y and Z components in each stage were calculated with the direct cosine l , m , and n in each segment and the magnitude of each vector in each stage and the normal QRS loops in three planes were drawn. Then in order to make the QRS loops similar to those in right ventricular hypertrophy, the vectors of all segments in the right ventricle were multiplied by 1.5, 2, 2.5 or 3 ($R \times 1.5$, $R \times 2$, $R \times 2.5$, $R \times 3$). Consequently, the afferent limb of the horizontal QRS loop was dislocated right-posteriorly. The initial QRS vector was directed left-anteriorly when the vector of the right side of the septum was increased. However, the rightward dislocation of the QRS loop was insufficient when it was compared to that in clinical cases.

It was reported that the hypertrophy of the outflow tract in the right ventricle appeared in cases with systolic overload of the right ventricle. Therefore, in next time the vector of Rps was duplicated before all vectors in the right ventricle were multiplied. But in that condition, the horizontal QRS loop was dislocated more posteriorly and not to the right than that in clinical cases.

Next, the duration of depolarization process in the right ventricle was prolonged 10 msec. at the peak of depolarization in each segment, and consequently, the rightward dislocation of the horizontal QRS loop was remarkable as it was expected. Therefore, it was supposed that the right-posterior dislocation of the horizontal QRS loop in systolic overload of the right ventricle is due to 1) increase the vectors in the right ventricle including the right side of the septum, and 2) prolong the depolarization process in the right ventricle. The degree of the rightward dislocation may depend on the duration of prolongation of depolarization process.

Next, in order to construct the QRS loop similar to that in diastolic overload, the start of depolarization process was delayed.

When the start of depolarization process in the right ventricle was delayed 10 msec. with increasing the all vectors in the right ventricle, the horizontal QRS loop became long and narrow along the X axis (the right to leftward axis), but the afferent limb was not dislocated right-anteriorly. If the start of depolarization process in the right ventricle was delayed 20 msec., the afferent limb of the horizontal QRS loop was dislocated markedly to the right. Then, the increasing ratio of Ra and Rm to Rp was changed from 1; 1 to 2: 1.

Consequently, the horizontal QRS loop was inscribed with the figure of 8 and the afferent limb was dislocated right-anteriorly. The afferent limb of the sagittal plane protruded anteriorly beyond the efferent limb and the QRS loops in both plane were similar to those in atrial septal defect. Therefore, in diastolic overload, it was necessary that the vectors of the anterior and lateral walls were larger than the posterior wall and it might be due to the difference of the distance to the chest wall in each wall caused by the marked dilatation of the

right ventricle.

When the duration of of depolarization process in the right ventricle was prolonged 10 msec. in the above conditions, the horizontal QRS loop was resemble to that in right bundle branch block. Therefore, the prolongation of depolarization process was not necessary in the diastolic overload. That reason may be illustrated as follows: In the systolic overload, the increasing of the vectors in the right ventricle with the prolongation of depolarization process is due to the increasing of the thickness of the right ventricle, but, in the diastolic overload, the increasing of the vectors is mainly due to the shortening of the distance from the chest wall to the antero-lateral wall of the right ventricle caused by the dilatation of the right ventricle. Then the prolongation of depolarization process is not always necessary in the diastolic overload.

SUMMARY

In order to investigate the cause of the QRS loop change in right ventricular hypertrophy, the present authors have employed their constructed method of the QRS loop.

1) increasing the vectors of the right ventricle including the right side of the septum and 2) prolongation of depolarization process in the right ventricle are required to construct the QRS loops in systolic overload of the ventricle.

Next, 1) increasing the vectors of the right ventricle (the increasing ratio of the vectors in the anterior and lateral wall of the right ventricle are larger than that in the posterior wall) and 2) delay of the start of the depolarization process in the right ventricle are necessary in diastolic overload of the right ventricle. Then, the reason of difference of the QRS loops in systolic and diastolic overload is discussed.

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