Usefulness of Vectorcardiography for Assessment of Severity of Right Ventricular Overloading in Congenital Heart Disease

1. Pulmonary Stenosis with Intact Ventricular Septum

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Frank lead vectorcardiograms of 17 catheterized patients of pulmonary stenosis with intact ventricular septum were reviewed in order to determine the usefulness of vectorcardiography as an indicator of the hemodynamic status. A close correlation was observed between the vectorcardiographic change and right ventricular pressure. Among the measurable parameters, the half-area QRS angle in the frontal plane, ratio of right/leftward QRS forces and maximum T angle were thought to be of great value for assessment of the severity of pulmonary stenosis.

ALTHOUGH an accurate assessment of the severity of congenital heart disease is impossible without cardiac catheterization, it is desirable to search for other clinical means of prediction of the hemodynamic status, because this procedure is time-consuming and is not entirely without risks.

The present series of our investigation was attempted in order to determine the usefulness of the vectorcardiograms as an indicator of the hemodynamic status in congenital heart disease. Pulmonary stenosis with intact ventricular septum and secundum type atrial septal defect have been the main subjects for our study up to the present time, since the hemodynamic abnormalities are relatively simple in these two diseases. In the first part of the present report, the vectorcardiograms of pulmonary stenosis will be reviewed, and a vectorcardiographic and hemodynamic correlation will be attempted in atrial septal defect in the second part of the

study.

MATERIALS AND METHODS

The Frank lead vectorcardiograms of 17 cases of proved pulmonary stenosis with intact ventricular septum were reviewed. There were 8 males and 9 females, and the patients ranged in age from 17 to 55 years. Right heart catheterization was performed in usual manner in all the cases, while an angiographic study was made in 5. The peak pressure of the right ventricle ranged from 35 to 240 mm Hg.

The method of recording and analysis of the vectorcardiograms was the same as previously described^{1,2}. The QRS loop was dissected 500 times per second. The sagittal plane was viewed from the right. The magnitude of maximum rightward QRS vector was measured in each plane, and the spatial magnitude of the vector was later calculated using the Pythagorean theorem.

RESULTS

1. Configuration of the QRS loop

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Representative vectorcardiograms are illustrated in Figs. 1-3. In the mild cases, the main part of the QRS loop was directed to the left, inferiorly and usually posteriorly and the configuration of the entire loop was normal. A normal QRS loop was observed in 5 of 7 cases in which the right ventricular peak pressure was 64 mmHg or less. On the other hand, a classical pattern of the QRS loop was seen in 9 cases with right ventricular peak pressure of 70 mmHg or more. In these moderate and se-

vere cases, the main part of the QRS loop was directed to the right, inferiorly and anteriorly, and the loop was inscribed clockwise in the horizontal plane. A figure-of-eight configuration of the QRS loop in the horizontal plane was observed in 3 cases in which the right ventricular peak pressure was 35, 58 and 96 mmHg respectively.

2. Half-area QRS angle in the frontal plane

The half-area QRS angle was between 12 and 90 degrees in the mild cases with right ventric-

Fig. 1. A vectorcardiogram of a 29-year-old man with mild pulmonary stenosis. The right ventricular pressure was 50/0-10 mmHg. The vectorcardiogram was within normal limits.

Fig. 2. A vectorcardiogram of a 20-year-old man with moderate pulmonary stenosis. The right ventricular pressure was 116/0-10 mmHg. Although the QRS loop showed a classical change of right ventricular hypertrophy, the direction of the T loop was normal.

ular peak pressure of 64 mmHg or less. A significant right axis deviation, half-area QRS angle of more than 90 degrees, was present in 5 of 6 cases of moderate pulmonary stenosis with right ventricular peak pressure of between 70 and 120 mmHg. The half-area QRS angle of 4 severe cases with right ventricular peak pressure of more than 150 mmHg was 110 degrees or more (Table I). As shown in Fig. 4, a significant positive correlation was demonstrated between the right ventricular peak pres-

sure and the half-area QRS angle in the frontal plane ($r = +0.73$, $p < 0.01$).

3. Ratio of right/leftward QRS forces

A significant positive relationship was observed between the right ventricular peak pressure and the ratio of right/leftward QRS forces ($r = +0.70$, $p < 0.01$). This ratio was less than 0.5 in 5 of 7 cases with right ventricular peak pressure of 64 mmHg or less, while in 4 cases with marked elevation of right ventricular peak pressure more than 150 mmHg

Fig. 3. A vectorcardiogram of a 26-year-old man with severe pulmonary stenosis. The right ventricular pressure was 240/4-10 mmHg. There was a characteristic QRS loop indicative of right ventricular hypertrophy and an abnormal displacement of the T loop posteriorly and superiorly.

TABLE I CORRELATIONS OF VECTORCARDIOGRAPHIC OBSERVATIONS TO RIGHT VENTRICULAR PRESSURE IN PULMONARY STENOSIS

	-69 mmHg	Right ventricular peak pressure 70-149 mmHg	150 mmHg-
Number of cases	7	6	4
<i>Sense of inscription of the QRS loop in the horizontal plane</i>			
Counterclockwise	5	0	0
Figure-of-eight	2	1	0
Clockwise	0	5	4
<i>Half-area QRS angle in the frontal plane</i>			
90°-119°	0	5	0
120°-	0	1	4
<i>Spatial magnitude of maximum rightward vector</i>			
0.5-0.99 mV	1	4	1
1.00 mV-	0	1	3
<i>Ratio of right/leftward forces</i>			
0.5-1.19	2	4	0
1.20-	0	1	4
<i>Abnormal orientation of the T loop</i>	0	0	4

the ratio was 1.20 or more. The ratio of right/leftward forces was between 0.5 and 1.2 in 5 of 6 cases in which the right ventricular peak pressure was between 70 and 120 mmHg (Table I).

4. Magnitude of maximum rightward vector

A linear relationship was demonstrated between the right ventricular peak pressure and the spatial magnitude of maximum rightward QRS vector as shown in Fig. 6 ($r = +0.70$, $p < 0.01$). A statistically significant but less remarkable positive correlation was demonstrated between the right ventricular peak pressure and the magnitude of maximum rightward vector measured in the horizontal ($r = +0.57$, $p < 0.05$) or in the frontal planes ($r = +0.64$, $p < 0.01$).

Fig. 4. Relationship between the half-area QRS angle in the frontal plane and the right ventricular peak pressure.

Fig. 5. Relationship between the ratio of right/leftward QRS forces and right ventricular peak pressure.

0.01).

5. Direction of T loop

As shown in Fig. 7 and Table I, an abnormal posterior displacement of the T loop outside of the normal range was seen in 4 cases with right ventricular peak pressure of 150 mm Hg or more. A superior displacement of the loop was seen in 3 of these 4 cases. The maximum T angle was within normal range in the remaining 13 cases.

6. Routine electrocardiogram

A significant right axis deviation of more than 110 degrees was observed in 4 cases with marked elevation of right ventricular pressure over 150 mmHg and 3 cases with moderate pulmonary stenosis in which the right ventricular peak pressure was between 70 and 120 mmHg. A right axis deviation of this degree was present in 1 mild case with the right ventricular

Fig. 6. Relationship between the spatial magnitude of maximum rightward QRS vector and right ventricular peak pressure.

Fig. 7. Direction of maximum T vector. The shaded area shows the normal range (Mean $\pm$ 2 standard deviations) calculated from our previous results.²

peak pressure of 55 mmHg. The relationship between the right ventricular peak pressure and the height of the R wave in lead V_1 was statistically significant but was not very remarkable ($r = +0.58$, $p < 0.05$).

DISCUSSION

There is a controversy on the value of electrocardiogram and vectorcardiogram for assessment of the severity of pulmonary stenosis. A close relationship of electrocardiographic or vectorcardiographic findings to the right ventricular pressure has been observed by DE PASQUALE and BURCH³, BENCHIMOL and LUCENA⁴, CAYLOR and Associates⁵, HUGENHOLTZ and associates⁶⁻⁸, and SCHERLIS and associates⁹. On the other hand, BENTIVOGLIO and associates¹⁰, BOYLE and associates¹¹ and KAHN and associates¹² described that the height of systolic pressure in the right ventricle or systolic gradient across the pulmonary valve cannot be predicted appropriately by the character of the electrocardiogram or vectorcardiogram because of wide individual variations.

A close correlation has been demonstrated in the present study between the vectorcardiographic observations and the severity of pulmonary stenosis. A normal vectorcardiogram was usually observed in the patients in which the right ventricular peak pressure was 64 mmHg or less, while a classical QRS pattern indicative of right ventricular hypertrophy was almost always seen when the right ventricular peak pressure was 70 mmHg or more. A significant positive correlation was demonstrated between the right ventricular peak pressure and the half-area QRS angle in the frontal plane, ratio of right/leftward QRS forces or the spatial magnitude of maximum rightward QRS vector. The relationship between the height of the right ventricular pressure and the electrocardiographic findings was less remarkable, and the vectorcardiogram seemed to be a better tool for the assessment of the severity of the systolic overloading of the right ventricle in pulmonary stenosis.

The present results are in good agreement with the previous descriptions which indicated the significance of half-area QRS angle in the frontal plane and the ratio of right/leftward

QRS forces as parameters for diagnosis of right ventricular hypertrophy^{2,13}. Although there was also a good correlation between the right ventricular peak pressure and the spatial magnitude of maximum rightward vector in accord with the reports by HUGENHOLTZ and associates^{6,7}, the measurement of this spatial magnitude seems to be of limited value because a rather cumbersome calculation does not improve the diagnostic accuracy.

The direction of the T loop is of special significance, because an abnormal posterior and superior displacement of the loop was observed only when a marked elevation of the right ventricular pressure, usually over 150 mmHg, was present. The maximum T angle was within normal range in the moderate cases with a typical QRS configuration indicative of right ventricular hypertrophy.

SUMMARY

Vectorcardiograms of 17 patients with pulmonary stenosis with intact ventricular septum were reviewed.

A characteristic change of the QRS loop indicative of right ventricular hypertrophy was observed in 9 of 10 cases in which the right ventricular peak pressure was 70 mmHg or more, while the vectorcardiogram was usually within normal limits when the right ventricular peak pressure was 64 mmHg or less. There was a significant positive relationship between the height of right ventricular peak pressure and the half-area QRS angle in the frontal plane, ratio of right/leftward QRS forces or the spatial magnitude of maximum rightward vector. An abnormal orientation of the T loop was seen only when the right ventricular pressure was markedly elevated.

The above findings indicate that an appropriate semiquantitative assessment of the severity of right ventricular overloading is possible in pure pulmonary stenosis by vectorcardiographic analysis.

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