A Vectorcardiographic Study on Mitral Stenosis

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Although routine scalar electrocardiogram is an important tool for recognition of right ventricular hypertrophy, minimal or moderate degree of right ventricular hypertrophy are not infrequently overlooked by this method. On the other hand, recent studies have indicated the superior sensitivity of the vectorcardiogram in this purpose.

In order to find out a characteristic pattern of vectorcardiogram in right ventricular hypertrophy, a quantitative analysis was made on QRS and T loop of 33 catheterized cases with pure mitral stenosis, and the results were compared with the hemodynamic date.

Diagnostic significance of rightward displacement of half-area and terminal QRS vector has been pointed out.

The recognition of the presence of right ventricular hypertrophy is important for the evaluation of the severity of the mitral stenosis. Although routine scalar electrocardiogram is an important tool in this purpose, minimal or moderate degree of right ventricular hypertrophy are often overlooked by this rather classical method.

Recently, several investigators have pointed out the superior sensitivity of the vectorcardiogram (VCG) in detecting right ventricular hypertrophy\(^3\)-\(^8\). In the present study, an analysis of the hemodynamic data and the VCG findings was attempted in the patients with pure mitral stenosis.

Materials and Methods

The VCGs of 33 patients with pure mitral stenosis, 14 males and 19 females, were selected for the study. All the patients were between 20 and 59 years of age. Right heart catheterization was performed in all cases either at the Third Department of Internal Medicine, Faculty of Medicine, University of Tokyo or at the Massachusetts General Hospital in Boston, U.S.A. The cases with systemic arterial hypertension were excluded. The right ventricular systolic pressure was more than 60 mmHg in 14 cases, between 40 and 59 mmHg in 10 and less than 40 mmHg in 9.

The normal control group consisted of 54 healthy subjects, 34 males and 20 female, between the ages of 20 and 39. The normal range was set as mean ±2 X standard deviation.

All VCGs were recorded with the FRANK system of electrode placement\(^9\) using the machines of FVC-3 of Fukuda Medical Electronic Co. in Japan or PV-3 of Hart Electronics Co. in U.S.A. The vector loops were interrupted 500 or 400 times per second. The sagittal plane was viewed from the left.

Measurements were made on the direction of instantaneous 0.01, 0.02, 0.03 and 0.04-second QRS vectors, half-area QRS vectors (HAV) and terminal QRS vectors as well as on the direction of Maximum T vectors. The direction of the terminal QRS vector was measured in the horizontal plane using the method described by BRISTOW\(^7\): the direction was measured at the point at which the QRS loop turned abruptly to return to the isoelectric spot. The direction of the vectors were plotted using the reference frame proposed by HELM\(^9\).

The magnitude of the vectors were not measured in the present study except in the maximum left and maximum right vectors in the horizontal plane.

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RESULTS

1. Normal range

The results on 54 normal cases are summarized in Table I. The values for the direction of 0.01-second vectors were not presented because of the widely scattered distribution. The present results showed good agreement with the previous reports. \(^{70}\)

The angle of the terminal vector was greater than 240° in all but one case. The direction of inscription of QRS loop was counterclockwise in the sagittal and horizontal planes in all but one exception.

2. Mitral stenosis

Two representative VCGs are illustrated in Figs. 1 and 2, while the results of the measurements are shown in Figs. 3–8.

Frontal plane: As shown in Fig. 3, the most remarkable finding of the QRS loop in the frontal plane was the displacement of the HAV to the right. Abnormal rightward displacement of HAV outside of the normal range (70°) was seen in 17 cases (52%) of the whole materials and 13 of 14 cases (93%) with the right ventricular systolic pressure of 60 mmHg or more. A statistically significant positive correlation was demonstrated between the direction of HAV in the frontal plane and the right ventricular systolic pressure \(r = +0.62, p < 0.01\) as shown in Fig. 4.

Although the direction of 0.03-second vector was in the normal range in almost all cases, 0.04-second vector was displaced to the right in 14 cases. The QRS loop was usually inscribed clockwise. A counterclockwise inscription of QRS loop in the frontal plane was observed in 4 cases with normal right ventricular pressure.

The direction of maximum T vector was within normal limits except in 5 cases.

Sagittal plane: Significant anterior displacement of HAV in the sagittal plane was observed in 8 cases (26%) of the whole group and 5 of 14

![Fig. 1. Vectorcardiogram of a 33-year-old woman with tight mitral stenosis and right ventricular pressure of 90/0–3. Vector loops were interrupted 400 times per second. The direction of half-area QRS vector was 82° in the frontal plane. There was a large terminal deflection directed to the right and posteriorly. The direction of terminal vector was 228°.](image)

![Fig. 2. Vectorcardiogram of a 45-year-old man with mitral stenosis and right ventricular pressure of 60/0–3. Vector loops were interrupted 500 times per second. Half-area QRS vector was directed to the right and inferiorly, while 0.04-second QRS vector was directed to the right and anteriorly. There was a large terminal portion directed to the right and posteriorly.](image)

### Table I Measurements of QRS and T Loop of Young Healthy Subjects

<table>
<thead>
<tr>
<th></th>
<th>Frontal</th>
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<th>Sagittal</th>
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<th>Horizontal</th>
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<td>Mean</td>
<td>S. D.</td>
<td>Mean</td>
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<td>Direction of 0.02° Vector</td>
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<td>171</td>
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<td>0.03° Vector</td>
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<td>22</td>
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<tr>
<td>0.04° Vector</td>
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<td>76</td>
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<td>Figure-of-eight</td>
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<td>Counterclockwise</td>
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<td>49</td>
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<tr>
<td>T loop</td>
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<td>Direction of Long Axis</td>
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<td>125</td>
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cases with the right ventricular systolic pressure of 60 mmHg or more. However, the direction of 0.02–0.04-second vectors was in the normal range in most cases.

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The direction of inscription of QRS loop was usually clockwise, and a figure-of-eight configuration was observed in one case with right ventricular pressure of 68/1 mmHg, while a counterclockwise inscription was seen in two cases with the right ventricular systolic pressure of 120 and 130 mmHg respectively.

Abnormal posterior displacement of maximum T vector was seen in 9 of 20 cases in which the direction of T vector was measurable.

**Horizontal plane:** Anterior displacement of HAV was seen in 3 cases with marked elevation of right ventricular systolic pressure, while significant posterior displacement of HAV was observed in 10 cases. Such posterior displacement was mainly due to the presence of a large terminal vector directed to the right and posteriorly. Abnormal large terminal vector directed more anteriorly than 240° was observed in 24 cases of the whole group (77%) and 13 of 14 cases with right ventricular systolic pressure of 60 mmHg or above. As shown in Figs. 7 and 8, a statistically significant negative correlation was demonstrated between the direction of the terminal vector and the right ventricular systolic
Fig. 5. Scattergrams indicating direction of the 0.02, 0.03, 0.04-second and half-area QRS vectors and maximum T vectors of the patients with mitral stenosis in the sagittal plane. Shaded area shows the normal range.

Fig. 6. Scattergrams indicating direction of the 0.02, 0.03, 0.04-second and half-area QRS vectors and maximum T vectors of the patients with mitral stenosis in the horizontal plane. Shaded area shows the normal range.
The maximum T vector was displaced posteriorly in 7 cases.

**DISCUSSION**

Several studies reported on the VCG of mitral stenosis have generally agreed in finding the most characteristic changes in the horizontal plane\(^2\)–\(^4\), \(^10\)–\(^18\). In accordance with these studies, a large terminal vector directed to the right and posteriorly was frequently observed in the present series. According to \textsc{Schaub}\(^{15}\), a large terminal deflection directed to the right and posteriorly is caused by the hypertrophy of the outflow tract or crista supraventricularis of the right ventricle. The diagnostic significance of such terminal vector has been pointed out\(^4\).

It is obvious from the present study that, besides the terminal portion, the middle portion of QRS loop is also displaced to the right in the presence of significant elevation of right ventricular systolic pressure. Although the direction of 0.02 and 0.03-second vectors was unaffected in any plane even in the presence of marked elevation of the right ventricular pressure, rightward displacement of 0.04-second vector was frequently observed in the frontal and horizontal planes. This result is in good agreement with \textsc{Cohen}'s description\(^{17}\), which indicates that the direction of the initial portion of QRS loop was unchanged in the presence of right ventricular hypertrophy, while the middle and terminal portions were displaced to the right in generalized hypertrophy with dilatation of the right ventricle. \textsc{Toole}\(^{16}\) also pointed out the importance of the rightward deviation of the heart vector during the period from 0.04 to 0.05 second after the onset of ventricular conduction as one of the most characteristic finding of right ventricular hypertrophy.

A clockwise inscription of QRS loop in the horizontal plane has been considered to be another characteristic finding of the right ventricular hypertrophy\(^{17}\)–\(^30\). However, such abnormal inscription was not observed in any case in the present series. In our experience, clockwise inscription of the horizontal QRS loop, frequently observed in congenital heart disease, is rather rare in mitral stenosis, although anterior
displacement of HAV was not so infrequent in the presence of marked elevation of right ventricular systolic pressure.

As the result of the rightward displacement of the middle and terminal portions of QRS loop described above, the displacement of HAV to the right in the frontal plane was seen in a majority of the present series. A linear relationship was demonstrated between the direction of HAV and the right ventricular systolic pressure in this plane. Similar positive correlation was demonstrated between the right ventricular systolic pressure or the mean pressure of the pulmonary artery and the direction of mean QRS axis calculated from scalar electrocardiogram.

A significant posterior displacement of T loop was observed in 9 cases in the present study. The direction of the maximum T vector seems to be of diagnostic value, but abnormal T loop was not consistently observed. Harumt has pointed out that the direction of inscription of T loop is more important than the direction of maximum T vector per se, because the former may be reversed even when the latter is still within normal range.

So far as the diagnosis of right ventricular hypertrophy is concerned, McCaugham recommended to measure the percentage area of the right-posterior portion of QRS loop, while Toyama calculated the right vector/left vector ratio. In our present study, these measurements seem to be useful, since significant relationship was demonstrated between the right ventricular systolic pressure and the direction of the terminal vector or right vector/left vector ratio. However, it should be pointed out that the direction of HAV in the frontal plane is also a valuable parameter for diagnosis of right ventricular hypertrophy. Diagnostic significance of right axis deviation in scalar electrocardiogram has been pointed out by several investigators repeatedly. As pointed out before, rightward displacement of HAV outside of the normal range was observed in all but one case with the right ventricular systolic pressure of 60 mmHg or above in the present series.

SUMMARY

1. A vectorcardiographic and hemodynamic correlation was made on 33 cases of pure mitral stenosis.

The most characteristic finding in mitral stenosis was the rightward displacement of the middle and terminal portions of QRS loop, while the initial 0.01–0.03-second vectors were not affected even in the presence of marked elevation of the right ventricular systolic pressure.

2. As the result of the rightward displacement of the middle and terminal portions of QRS loop, a large terminal vector directed to the right, posteriorly and superiorly was observed in a majority of the cases, and the HAV was displaced to the right in the frontal plane. A linear relationship was demonstrated between the direction of HAV in the frontal plane and the right ventricular systolic pressure. On the other hand, a clockwise inscription of QRS loop in the horizontal plane was not observed in any case of the present series.

3. It was pointed out that the rightward displacement of HAV in the frontal plane together with the presence of a large terminal deflection directed to the right and posteriorly is a significant sign for the diagnosis of right ventricular hypertrophy. Abnormal displacement of T loop posteriorly was not consistently observed in this series.

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REFERENCES


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