A VECTORCARDIOGRAPHIC STUDY OF RIGHT VENTRICULAR SYSTOLIC OVERLOADING WITH THE FRANK SYSTEM

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In clinical research and practice, vectorcardiography is now being used as an additional procedure to electrocardiography. It is expected that any additional diagnostic procedure in certain situations would give additional informations. The VCG and ECG present a different display of the same information; it is quite possible that some characteristics may be revealed in one type of display and may be hidden in another, which is, of course, the justification for clinical vectorcardiography.

In 1952 Cabrera and Monroy1 presented the new concept on the cardiac performance from the hemodynamic view points. The work performed by any machine is equal to a certain mass times the energy gain of that mass. This means that the work performed by the heart as a pump would be equivalent to the mass of blood ejected times the mean pressure of the corresponding arterial vessel.

Consequently, any increase in heart work, i.e., any ventricular overloading, could be due to an increase in the volume of blood per beat (volume overloading or diastolic overloading) or to an increase in the mean arterial pressure (pressure overloading or systolic overloading). Mitral stenosis and pulmonary stenosis2-5 are expected to cause the right ventricular systolic (pressure) overloading, while atrial septal defects6-8 is considered to cause the right ventricular diastolic (volume) overloading. The concept of volume and pressure overloading of the cardiac chambers has been quite useful in the interpretation of vectorcardiogram of patients with right ventricular overloading. The vectorcardiographic manifestations associated with right ventricular overloading correlate very well with
the type of overloading (i.e., pressure or volume) and fairly well with the degree of overloading. Morphological observations of vectorcardiogram are important, but unless the quantitative methods of analysis are applied, it may remain in subjective and superficial observations.

In this study, an attempt was made to measure QRS loop areas as a quantitative analysis. The purpose of this paper is to present the characteristics of the QRS sE-loop of patients with right ventricular systolic overloading (R.V.O.).

**MATERIALS AND METHODS**

The VCGs of sixteen patients with pure mitral stenosis, ten with mitral stenosis with slight mitral insufficiency and one with pulmonary stenosis, were selected for the study (right ventricular overloading, R.V.O., group). The normal control group consisted of fifty healthy subjects between the ages of 16 and 41 (Normal group).

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**Fig. 1** The reference frame for angular measurements and area measurements.
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The Frank lead system was used, with the patient in a supine position. The fifth intercostal space at the sternum was used as the level for the chest electrodes.

The VCGs were photographed in the horizontal, left sagittal and frontal projections with 35-millimeter film. It was later projected on a screen and tracings were made on section papers for analysis. Standard calibration factors of millivolt were similarly enlarged. The total QRS loop area, as well as the QRS loop area in each quadrant, was determined by planimetry in the enlarged tracing of each projection. In order to compare such areas from patient to patient, an arbitrary unit of area was determined and used as follows. The length of the I-millivolt signal in the enlarged tracings was known. This length was squared.

![Fig. 2 The method of the measurement of R/L and P/L.](image)

The resulting area actually represented 1 square millivolt and is hereafter referred to as a unit area. The measured QRS loop area was divided by the area of this unit, to give a result in numbers of units area.

The measured QRS loop area in each quadrant was divided by the total QRS loop area and is hereafter referred to as a percent area. The reference frame employed for angular measurements and area measurements is shown in Fig. 1. Leftward, rightward, and posterior electromotive forces in the horizontal plane are shown in Fig. 2. The ratio of the rightward force to the leftward force, R/L, and the ratio of the posterior force to the leftward force, P/L, were calculated. Vectorcardiographic analyses were primarily limited to the horizontal plane and the frontal plane in this study.

RESULTS

*The QRS loop area in the horizontal plane (Fig. 3 and Fig. 4):* Cases with
the QRS loop area in the I quadrant less than 25% and less than 0.3 units are encountered more frequently in the R.V.O. group than in the normal group. In this series of patients with R.V.O., cases with the QRS loop area in the II quadrant over 10%, and cases with the QRS loop area in the III quadrant over 10% and over 0.1 unit, are found more frequently as compared to the normal series. Figure 5-A presents the ratio of the QRS loop area in the II quadrant.

Fig. 3 Percent area in each quadrant (Horizontal).
○ Normal ■ R.V.O.

Fig. 4 Unit area in each quadrant (Horizontal).
○ Normal ■ R.V.O.
to that in the I quadrant of the horizontal plane, II/I. Cases with II/I ratio over 20%, are encountered more frequently in the R.V.O. group than in the normal group.

![Graph A. II/I](image1)

A. II/I
- Normal
- R.V.O.

Fig. 5

![Graph B. III/I](image2)

B. III/I

![Graph A. Posterior/Left](image3)

A. Posterior/Left
- Normal
- R.V.O.

Fig. 6

![Graph B. Right/Left](image4)

B. Right/Left
Figure 5-B shows the ratio of the QRS loop area in the III quadrant to that in the I quadrant of the horizontal plane, III/I. Cases with III/I ratio over 10%, are found more frequently in the R.V.O. group than in the normal group.

Figure 6-A presents R/L ratio and figure 6-B shows P/L ratio in the horizontal plane. Cases with R/L ratio over 0.4 are encountered more frequently.
in the R.V.O. group while P/L ratio reveals no significant difference between the both groups.

The QRS loop area in the frontal plane: As can be seen in Fig. 7 and Fig. 8, cases with the QRS loop area in the II quadrant over 0.03 units, cases with the QRS loop area in the III quadrant over 20% and over 0.1 unit, and cases with

![Graphs showing unit area in each plane.](image)

Fig. 9 Unit area in each plane.
○ Normal ▲ R.V.O.

![Graph showing F/H ratio.](image)

Fig. 10
○ Normal ▲ R.V.O.
the QRS loop area in the IV quadrant less than 75%, are more frequently en-
countered in R.V.O. group than in the normal group. Figure 9 shows unit area
in each plane. Cases over 0.8 units in the frontal plane are found more frequently
in the R.V.O. group than in the normal group. The R.V.O. group exhibits smaller
unit area in the horizontal and sagittal planes as compared with the normal group.
Figure 10 shows the ratio of the QRS loop area in the frontal plane to that in
the horizontal plane, F/H. Cases with F/H ratio over 1 are encountered more
frequently in the R.V.O. group than in the normal group. The maximal T vector
in each plane is presented in figure 11. Cases with the maximal T vector more
posteriorly located than 0° are more frequently encountered in the R.V.O. group
than in the normal group. As can be seen in the figure 12, cases with QRS-T
angle over 20° are found more frequently in the R.V.O. group than in the normal
group.

DISCUSSION

The concept of volume and pressure overloading of the heart has been useful
in making the interpretation of both electrocardiograms and vectorcardiograms.1-6
The basis of this usefulness is the fact that the spatial vectorcardiograms reflect
the type and, to some extent, the degree of overloading, at least for the right
ventricle.7 The spatial vectorcardiographic alterations associated with volume
and pressure overloading of the right ventricle are determined primarily by
variations in the distribution and degree of right ventricular hypertrophy.
Volume overloading of the right ventricle is associated with localized hypertrophy
of the crista supraventricularis and dilatation of the sinus portion of the right
ventricle, whereas pressure overloading of the right ventricle is associated with
hypertrophy of the entire musculature of the right ventricle. There is no doubt
that the time courses of power and tension for the myocardium differ in volume
and pressure overloading of the right ventricle.

Morphological observations of vectorcardiogram are important, because
VCG are essentially Lissajous pattern constructed from the two scalar electro-
cardiograms. But, unless the quantitative methods of analysis are applied, it
may remain in subjective and superficial observations.

In this study, a method of measurements of QRS loop area were adopted as
a quantitative analysis. In order to compare such areas from patient to patient,
“a unit area” was used which may represent an absolute magnitude of areas.
“A percent area” may represent a relative magnitude of areas in each quadrant
to the total QRS loop area. The VCGs in the patients with R.V.O. were analysed
mainly with these "a unit area" and "a percent area" in this report. An increase in the rightward electromotive force and a decrease in the leftward electromotive force were expected in the R.V.O. group. In this study, the QRS loop areas in the II and III quadrant of the horizontal plane were adopted to represent rightward electromotive forces, while the QRS loop area in the I quadrant of the horizontal plane represents a leftward electromotive force. So, an increase in the QRS loop areas in the II and III quadrants and a decrease in the QRS loop area in the I quadrant of the horizontal plane were expected, and proved in this report.

Grishman et al. reported the characteristic configurations of the QRS loop in right ventricular hypertrophy. In mitral stenosis, the horizontal QRS loop with cube system was dislocated anteriorly with figure of eight or clockwise inscription, but the horizontal QRS loop with the Frank system was dislocated right posteriorly and finally located right anteriorly. Therefore, the configurations of the QRS loop described by Grishman cannot be adopted in VCG with the Frank system.

Toyama et al. adopted the following criteria of right ventricular hypertrophy; (1) R/L ratio over 0.4. (2) Clockwise inscription or figure of eight of the horizontal T loop. (3) The angle of the maximal T vector in horizontal plane less than 0°. As one of the criteria of right ventricular hypertrophy, McCaughan used the QRS loop area in the II quadrant of the horizontal plane over 20%. The QRS loop area in the II quadrant of the horizontal plane is reported to increase in proportion to the right ventricular systolic pressure. According to Burch, as the degree of overloading progresses from mild to severe, the QRS sE-loop becomes more and more superiorly oriented and to the right. In this series of patients with R.V.O. the following characteristic findings are obtained.

A. The following findings are observed in more than 40 per cent of the patients with R.V.O., while none in the normal group.
1. The QRS loop area in the I quadrant of the horizontal plane is less than 0.3 units area, and less than 25 per cent area.
2. The QRS loop area in the III quadrant of the horizontal plane is greater than 10 per cent area.

B. The following findings are observed in more than 50 per cent of the patients with R.V.O. and these findings in the R.V.O. group are seen 5 times more frequently than in the normal group.
1. The QRS loop area in the I quadrant is less than 0.3 units area.
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2. The ratio of the QRS loop area in the II quadrant to that in the I quadrant of the horizontal plane is greater than 20 per cent area.
3. The ratio of the total QRS loop area of the frontal plane to that of the horizontal plane is more than one.
4. The QRS-T angle in the frontal plane is greater than 20 degrees.

C. The following findings are observed in more than 30 per cent of the patients with R.V.O. are seen three times more frequently than in the normal group, while not fulfilled the requirements of the group B.
1. The direction of the maximal T vector in the horizontal plane is more posteriorly located than 0 degree.
2. The ratio of the rightward forces to the leftward forces (R/L) is more than 0.4.
3. The QRS loop area in the I quadrant of the horizontal plane is less than 25 per cent area.
4. The QRS loop area in the II quadrant of the horizontal plane is greater than 10 per cent area.
5. The QRS loop area in the III quadrant of the horizontal plane is greater than 0.1 unit area.
6. The total QRS loop area in the horizontal plane is less than 0.7 unit area.
7. The ratio of the QRS loop area in the III quadrant to that in the I quadrant of the horizontal plane is more than 10 per cent.
8. The QRS loop area in the II quadrant of the frontal plane is more than 0.03 units area.
9. The QRS loop area in the III quadrant of the frontal plane is greater than 0.1 unit area, or more than 20 per cent area.
10. The QRS loop area in the IV quadrant of the frontal plane is less than 75 per cent area.
11. The total QRS loop area in the frontal plane is greater than 0.8 units area.

SUMMARY

The vectorcardiographic findings in 27 patients with right ventricular systolic (pressure) overloading are presented, in comparison with 50 normal subjects. In this study, a method of planimetric measurements of QRS loop area is adopted as a quantitative analysis of vectorcardiograms. In this series of
patients with right ventricular overloading, (R.V.O.), the rightward forces, represented by the QRS loop area in the II and III quadrant of the horizontal plane, increased, whereas the leftward forces, represented by the QRS loop area in the I quadrant of the horizontal plane, decreased. The characteristic findings of R.V.O. are presented in this series of patients.

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REFERENCES