Vectorcardiogram of Combined Ventricular Hypertrophy: Posterior Counterclockwise Loop (Frank System)

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Most vectorcardiographic studies of ventricular hypertrophy have concentrated on the diagnostic features of isolated or predominant left or right ventricular hypertrophy. Analysis of the vectorcardiograms of adult patients to establish readily recognizable diagnostic criteria of biventricular hypertrophy have been relatively sparse. Some authors have rejected the possibility of making this diagnosis vectorcardiographically, even when the presence of combined hypertrophy has been established clinically and pathologically.

We have analysed the vectorcardiograms of a selected group of patients with clinical, radiological, and haemodynamic evidence of biventricular hypertrophy, in an attempt to establish vectorcardiographic criteria for the diagnosis of this condition. Certain identifiable qualitative and quantitative features of the horizontal plane loops were found to be characteristic of combined hypertrophy in approximately two-thirds of the patients studied.

PATIENTS AND METHODS

From a group of 59 patients with combined ventricular hypertrophy, 40 were selected for analysis, 28 men and 12 women (Table I). Ages ranged between 17 and 68 years. The presence of biventricular hypertrophy was determined on the basis of the following criteria. (1) Clinical evidence of aetiological types of heart disease often associated with biventricular hypertrophy. (2) Radiological evidence of the usual criteria in a cardiac series. (3) Haemodynamic studies associated with chamber enlargement on the bases of (a) elevation of the left ventricular end-diastolic pressure greater than 14 mm. Hg, with a pulmonary capillary "wedge" pressure above 15 mm. Hg, and (b) pulmonary artery systolic pressure greater than 40 mm. Hg, or pulmonary

vascular resistance greater than 300 dynes. sec. cm.⁵, in association with an increase in right ventricular end-diastolic pressure above 6 mm. Hg. (4) In many cases the diagnosis of biventricular hypertrophy was confirmed during open-heart surgery performed for valvular replacement.

Data concerning the total group of 59 patients are tabulated in Table I. The vectorcardiograms of 40 patients were the subject of this study.

The vectorcardiograms of 19 patients with biventricular hypertrophy on the bases of the above criteria were not analysed, as their loops precluded the diagnosis of combined hypertrophy. In this group, 9 showed left ventricular hypertrophy; 4 right ventricular hypertrophy; 2 right bundle-branch block; 2 left bundle-branch block; one patient had a large linear loop, and one had a large biphasic anterior and posterior loop pattern in the horizontal plane.

TABLE I
 COMBINED VENTRICULAR HYPERTROPHY
 IN 59 PATIENTS

		Combined ventricular hypertrophy	
		Identified	Not identified
Patients	59	40	19
Male	42	28	14
Female	17	12	5
Age range (yr.)	17-68	17-68	19-64
Aetiology			
Rheumatic	46	32	14
Multivalvular	24	16	8
Mitral incompetence and stenosis	15	12	3
Mitral incompetence	5	4	1
Aortic stenosis	4	2	2
Ventricular septal defect	4	3	1
Hypertensive	2	2	—
Aortic pulmonary window	1	1	—
Coarctation	1	—	1
Atrial septal defect	2	—	2
Ischaemic heart disease	1	—	1

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The Frank system was employed, with the chest electrodes at the fourth intercostal space and the patient supine. Recording equipment consisted of a portable Sanborn amplifier and oscilloscope. Horizontal, right sagittal, and frontal loops were photographed on Polaroid film directly from the oscilloscopic screen. The loops were interrupted, so that each dash represented 2.5 msec. The calibration was such that 1.0 mV equalled 5.0 cm. displacement. Conventional reference frames from 0° to 360° were employed for angular measurements in all planes, with the right sagittal plane aligned, so that 0° was anterior, 90° inferior, and 180° posterior.

The horizontal plane QRS loop was studied for the following data: (1) direction of inscription, (2) duration of the entire QRS loop in msec., (3) duration of the S loop in msec. (that portion of the loop in the right posterior quadrant), (4) angle of the maximum QRS vector, or the half area vector in loops in which the long axis was indeterminate, (5) angle of the maximum S vector, (6) magnitudes of the maximum QRS vector and the maximum S vector, (7) angle of the maximum T vector.

In the frontal and sagittal planes only the following characteristics of the QRS loop were noted: (1) direction of inscription, (2) angle of the maximum or half area QRS vector, and (3) angle of the maximum T vector.

RESULTS

The results are set out in Table II.

Horizontal Plane (Fig.)

Inscription. In all 40 patients QRS loops were inscribed in a counterclockwise direction (CCW),

TABLE II
IDENTIFIED BIVENTRICULAR HYPERTROPHY
IN 40 PATIENTS

	Horizontal	Right sagittal	Frontal
Inscription	Counter-clockwise (40)	Clockwise (31) Figure-of-eight (8) Counter-clockwise (1)	Clockwise (30) Figure-of-eight (8) Counter-clockwise (2)
QRS duration	50-150 msec. Av. 68.9 (SD 17.6)		
S duration	15-65 msec. Av. 30.5 (SD 13.1)		
Maximum QRS angle	210°-345° Av. 296.5° (SD 29.1)	85°-182° Av. 134.6 (SD 32.8)	0°-180° (37 cases) Av. 93.6 (SD 65.5)
Maximum S angle	202°-265° Av. 240.9° (SD 17.2)		
QRS magnitude	0.4-2.8 mV Av. 0.96 (SD 0.55)		
S magnitude	0.2-1.6 mV Av. 0.68 (SD 0.36)		
T angle	148°-315° Av. 70°	0°-329° Av. 136.2°	Wide scatter Av. 155°

with marked posterior displacement of the entire loop.

Duration. The QRS duration ranged between 50 and 150 msec., with an average of 68.9 msec. (SD 17.6). S loop duration was 15 to 65 msec., with an average of 30.5 msec. (SD 13.1).

Angular Range. The maximum QRS, or half area vectors, were between 210° and 345°. The average angle of the 40 cases was 296.5° (SD 29.1). The angles of the maximum S vectors were between 202° and 265°, with an average of 240.9° (SD 17.2).

Magnitude. The maximum QRS vector ranged between 0.4 and 2.8 mV, with an average of 0.96 mV (SD 0.55). The magnitudes of the maximum S vectors were between 0.2 and 1.6 mV, with an average of 0.68 mV (SD 0.36). The average S loop duration was 44.3 per cent of the average QRS duration. The maximum S magnitude was 70.8 per cent of the average maximum QRS magnitude. The maximum T vectors occupied the left posterior, left anterior, and right anterior quadrants between 315° and 148°, with an average orientation of 70°.

Right Sagittal Plane

Inscription. Clockwise, 31; figure-of-eight, 8; counterclockwise, 1.

Angular Range. The maximum QRS vector was between 85° and 182°, with an average of 134.6° (SD 32.8). The T vector ranged between 0° and 329°, average 130.2°.

Frontal Plane

Inscription. Clockwise, 30; figure-of-eight, 8; counterclockwise, 2.

Angular Range. The maximum QRS vectors were between 0° and 180°. In 3 cases there was superior displacement between 204°-330°. The average maximum QRS vector was at 93.6° (SD 65.5). The T vector in this plane was widely dispersed in all quadrants, with an average orientation of 155°.

DISCUSSION

The lack of well-established criteria for the vectorcardiographic diagnosis of combined ventricular hypertrophy may be attributed to a variety of factors. It has been held that a proportionate increase of both the right and left ventricular free

FIG. Typical posterior counterclockwise loop of biventricular hypertrophy. Horizontal plane.

walls results in a cancellation of opposed vectorial forces, with each chamber tending to counterbalance the influence of the other and produce, in effect, a relatively normal or non-specific QRS loop pattern (Cabrera and Gaxiola, 1960; Elliott, Taylor, and Schiebler, 1963).

Other studies have shown that most cases of biventricular hypertrophy manifest either the exclusive characteristics of right ventricular or left ventricular hypertrophy (Grant, 1957; Katz and Wachtel, 1937; Levine, 1958). This, of course, implies that only one chamber predominates in the production of electromotive forces in the vectorcardiogram and masks either completely, or incompletely, evidence of hypertrophy of the other ventricle. Another factor that precludes the diagnosis of this entity is the frequent presence of conduction disorders, such as incomplete or complete bundle-branch block.

Some have held that the diagnosis of biventricular hypertrophy may be made only if the characteristics of both right and left ventricular hypertrophy are manifested separately in the vectorcardiogram. This opinion has been applied particularly to studies in infants and children with biventricular hypertrophy in which the "pie plate" pattern is present in the horizontal plane (Papadopoulos, Lee, and Scherlis, 1965). This is a counterclockwise loop with equivalent anterior and posterior deflections which are of greater magnitude than the leftward extension of the loop. The large anterior forces have been attributed to the hypertrophied right ventricle and the late posterior forces to the left ventricle. In addition to its presence in infants and children, this pattern is not infrequent in young patients with biventricular hypertrophy, secondary to ventricular septal defects or patent ductus arteriosus. It corresponds to the Katz-Wachtel

complex of the electrocardiogram, with large di-phasic deflections in the mid-praecordial leads (Scott, 1960; Wolff, Morse, and Mazzoleni, 1965).

In the present study of combined ventricular hypertrophy in adults, we have been impressed with the values of the qualitative and quantitative data derived from the horizontal plane QRS loop. In approximately two-thirds of the patients studied, the diagnosis could be established from this projection alone. The typical horizontal loop was counterclockwise, with abnormal posterior displacement. The initial forces were always slightly anterior, either to the right or left. The maximum QRS vector was usually far posterior and leftward, close to the Z axis. The average position of the maximum, or half area QRS vector, was 296.5° (SD 29.1).

A significant S loop, usually involving either the entire afferent limb or a substantial portion of the afferent QRS loop, was present in all 40 cases. The importance of the S loop is emphasized, since its duration was 44 per cent of that of the entire QRS loop. Combined ventricular hypertrophy did not increase the intraventricular conduction time, which was 68.9 msec. (SD 17.6), comparable to that of the normal adult population.

The average maximum S vector was in the right posterior quadrant at 240.9° (SD 17.2). Its average magnitude was 70 per cent of the magnitude of the maximum QRS vector (Fig.).

The qualitative and quantitative features of the horizontal QRS loop are characteristic of combined ventricular hypertrophy in 66 per cent of cases if we exclude several other clinical conditions capable of producing significant posterior displacement of a counterclockwise loop without a conduction defect. Such conditions include mitral stenosis, with mild to moderate pulmonary artery hypertension, pulmonary disease, cor pulmonale, and anterior wall infarction. In mitral stenosis and in pulmonary disease, the QRS loop is posteriorly displaced but the maximum QRS vector is usually of lesser magnitude, particularly in the latter condition. A posterior and triangular-shaped P loop in the sagittal plane may be helpful in the diagnosis of mitral stenosis. A small, relatively narrow QRS loop favours pulmonary disease.

It is difficult to distinguish between combined ventricular hypertrophy and cor pulmonale when the latter presents as a posteriorly displaced counterclockwise horizontal loop. In cor pulmonale, however, the efferent limb swings almost in a straight line, far posteriorly, without a significant leftward extension. Additionally, in cor pulmonale, the P loop is elongated, anterior, and vertical.

Anterior infarction is easily differentiated because the first 10 to 40 msec. of the loop are posteriorly displaced, and the entire loop is usually confined to the left posterior quadrant in the horizontal plane.

The right sagittal QRS loop was of little help in the recognition of combined hypertrophy, for the maximum vector at 134.6° (SD 32.8) was essentially within normal limits. In a few cases, large anterior and posterior excursions of the loop were present.

The frontal QRS loop, more often than not, was inferior with the maximum QRS vector at 93.6° . Inscription was usually CW. Right axis deviation of the maximum QRS frontal plane vector, when present, added weight to the diagnostic features of the horizontal QRS loop and further increased the accuracy of diagnosis.

In approximately one-third of the cases of established combined ventricular hypertrophy, the diagnosis could not be made from the vectorcardiogram. In this group, the diagnoses were obscured by left ventricular hypertrophy, right ventricular hypertrophy, left bundle-branch block, right bundle-branch block, or a non-diagnostic long linear loop in the left posterior quadrant.

The diagnosis of combined ventricular hypertrophy may be made in the majority of cases in which right ventricular hypertrophy develops secondary to left ventricular hypertrophy, so long as the QRS loop remains open and counterclockwise. Sequential changes modifying the loop of left ventricular hypertrophy include further posterior displacement of the entire loop and the maximum QRS vector and the development of a significant S loop. If a conduction disturbance in the form of bundle-branch block appears, the diagnosis of biventricular hypertrophy is precluded, despite its actual presence. In certain cases with high pulmonary artery pressures, the vectorcardiographic characteristics of right ventricular hypertrophy mask the presence of left ventricular hypertrophy.

SUMMARY

A vectorcardiographic study was made of 59 adult patients with known biventricular hypertrophy of varied aetiology. In approximately two-thirds of the patients, a diagnosis of combined ventricular hypertrophy could be made on the basis of certain distinctive qualitative and quantitative changes in the horizontal plane QRS loop. These consisted of abnormal posterior displacement of the loop with counterclockwise inscription and the presence of an S loop of significant duration and magnitude. The frontal plane QRS loop usually showed right axis deviation with

clockwise inscription. The differentiation of combined ventricular hypertrophy from other clinical conditions which produce similar loop patterns in the horizontal plane is also discussed.

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