Electrocardiography and Vectorcardiography in Right Ventricular Hypertrophy from Chronic Bronchitis

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It is generally accepted that, on the basis of necropsy studies, the electrocardiogram is an insensitive guide to right ventricular hypertrophy due to chronic bronchitis. Furthermore, haemodynamic evidence of pulmonary heart disease usually precedes the development of electrocardiographic patterns of right ventricular hypertrophy (Johnson *et al.*, 1950). It is, therefore, common to see patients in whom pulmonary heart disease is suspected yet the scalar electrocardiogram shows no QRS changes. Studies made in this laboratory during the past 10 years have shown that the vectorcardiogram is a more sensitive test for right ventricular hypertrophy. This fact is illustrated by an analysis of 50 cases of chronic bronchitis seen in hospital practice.

PATIENTS AND METHODS

Fifty men, average age 58 years, with chronic bronchitis as defined in the Ciba Guest Symposium (1959) were investigated. Eighteen men were in congestive cardiac failure at the time of the study and six others gave a past history of heart failure. None of the patients had kyphoscoliosis or systemic hypertension.

Seventeen-lead electrocardiograms were recorded on each patient. The criteria used for P pulmonale waves were those of the New York Heart Association (1953) and the axis of the P wave in the frontal plane was calculated by the method of Spodick (1959). Each electrocardiogram was examined for evidence of right ventricular hypertrophy using three sets of criteria (Sokolow and Lyon, 1949; Milnor, 1957; Goodwin and Abdin, 1959) (Table I). The cube system of electrode placement (Grishman, Borun, and Jaffe, 1951)

was used for the vectorcardiograms, and records in the horizontal, sagittal, and frontal planes were made on the apparatus described by Jones and Roberts (1962). By this method the QRS complex appears as a closed loop. Fig. 1 shows a normal QRS loop looked at in the horizontal plane and its relation to the chest leads V1 and V5.

RESULTS

Vectorcardiograms. A detailed study of the vectorcardiograms in the three planes was made and the QRS loops in the horizontal plane were found to present five distinct patterns. A comparison of the vectorcardiograms with those of healthy adults showed that only type I was normal (Brown, 1963). These patterns are described in Table II, using the nomenclature of Grishman and Scherlis (1952), and illustrated in Fig. 2. Although the frontal and sagittal plane vectors are not illustrated, their description is included in Table II.

Electrocardiograms. One record showed atrial fibrillation and eight had P pulmonale waves. In 19 electrocardiograms the axis of the P wave in the frontal plane exceeded 80°. The number of electrocardiograms which showed right ventricular hypertrophy (Table I) varied from 12 to 22 according to the criteria used. The criteria of Sokolow

TABLE I
DIAGNOSIS OF RIGHT VENTRICULAR HYPERTROPHY

Authors	No. of patients
Sokolow and Lyon (1949)	22/50
Milnor (1957)	12/50
Goodwin and Abdin (1959)	20/50

Received August 21, 1967.

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FIG. 1.—Horizontal section through the chest showing the relationship of a normal QRS vector loop to the unipolar leads V1 and V5. E, electrodes used to record the vectorcardiogram.

and Lyon were present in three patients when those of Goodwin and Abdin or Milnor were absent. The reason for this finding was that the S wave in V5 exceeded 7 mm. One electrocardio-

TABLE II POSITIONS OF QRS LOOP			
Type	Horizontal plane		Frontal and sagittal planes
I	To left	CCW	Downwards and to left
II	Backward and to left	CCW	Backward and to left
III	Backward, first to left, then to right	CCW	Backward, first to left, then to right
IV	Forward and to right	CW	Forward, or forward and upward, first to left, then to right
V	Figure-of-eight first part is forward and to left, larger second part is forward and to right	CCW	Forward and to left, then upward and to right

CW = clockwise; CCW = counterclockwise

gram showed right ventricular hypertrophy according to Goodwin and Abdin when the other criteria were absent. This was due to a dominant R wave in V4R. A total of five traces had a dominant R

FIG. 2.—Horizontal plane vectorcardiogram showing the five types found in chronic bronchitis. The direction of inscription is indicated by arrow heads.

TABLE III

COMPARISON OF VECTORCARDIOGRAMS WITH ELECTROCARDIOGRAMS

No. of patients	Type of vectorcardiogram	No. of patients with electrocardiographic evidence of right ventricular hypertrophy			No. of patients with P pulmonale	No. of patients with P axis exceeding 80°
		Sokolow and Lyon (1949)	Milnor (1957)	Goodwin and Abdin (1959)		
10	I	0/10	0/10	0/10	1/10	3/10
11	II	1/11	0/11	0/11	1/11	2/11
13	III	10/13	5/13	9/13	3/13	7/13
12	IV	10/11	7/11	10/11	3/12	6/12
4	V	1 with RBBB, QRS = 0.12 sec.	0	1	0/4	1/4
		1				
		2 with incomplete RBBB, QRS = 0.10 sec.				
		1 with complete RBBB, QRS = 0.12 sec.				
Total	50	22	12	20	8	19

TABLE IV

COMPARISON OF VECTORCARDIOGRAMS WITH ELECTROCARDIOGRAMS OF FIVE PATIENTS WITH RIGHT VENTRICULAR HYPERTROPHY AT NECROPSY

Case No.	Type of vectorcardiogram	Electrocardiographic evidence of right ventricular hypertrophy			P pulmonale	P axis in frontal plane greater than 80°
		Sokolow and Lyon (1949)	Milnor (1957)	Goodwin and Abdin (1959)		
24	III	+	-	+	-	+
25	III	+	+	+	+	+
39	IV	+	+	+	-	-
42	IV	+	+	+	-	+
44	IV	+	+	+	+	+

wave in lead V4R when V1 was normal. In a total of seven electrocardiograms the criteria of Goodwin and Abdin and those of Sokolow and Lyon were present when the Milnor findings were absent. Four of the electrocardiograms showed partial or complete right bundle-branch block. The type I vectorcardiogram was found in 10 of the 50 patients, but none of their electrocardiograms showed right ventricular hypertrophy by the criteria used. Eleven men had the type II vectorcardiogram but only 1 of the 11 electrocardiograms showed right ventricular hypertrophy. The criteria of Sokolow and Lyon were found in this record which has already been described. The types III or IV vectorcardiogram were recorded on 13 and 12 patients, respectively. In both these groups the electrocardiographic results varied with the diagnostic criteria (Table III) and a maximum of 10 records in each group showed right ventricular hypertrophy. The type V vectorcardiogram was seen in four patients and in only one of these was right ventricular hypertrophy shown by electrocardiographic analysis. The other traces showed complete or incomplete right bundle-branch block. The vectorcardiogram chosen to illustrate the type

V vectorcardiogram shows both right ventricular hypertrophy and right bundle-branch block.

In order to facilitate comparison of the two methods of investigation, the vectorcardiographic and electrocardiographic findings are set out in Table III. The P pulmonale waves or a P axis in the frontal plane exceeding 80° were seen in all five vectorcardiographic groups.

Necropsies. From necropsies on 5 of the 7 men who died during the study, the thickness of the right ventricle exceeded 5 mm. in all 5. Two of them had the type III vectorcardiogram and 3 showed the type IV. An analysis of the vectorcardiograms and electrocardiograms is shown in Table IV.

DISCUSSION

The vectorcardiograms described above have also been reported by Walsh, Roman, and Massie (1960), Enenkel, Bilger, and Reindell, 1961, and Coelho *et al.* (1962). There is adequate anatomical evidence that types III to V are due to right ventricular hypertrophy, but there is as yet no such proof that type II is due to hypertrophy of the right

ventricle or outflow tract. There is, however, indirect evidence that this type represents right ventricular hypertrophy. Jones *et al.* (1964) found a correlation between this type of vectorcardiogram and pulmonary hypertension on exercise and dilatation of the main pulmonary arteries in men with chronic bronchitis. Secondly, there are isolated reports in which this type of vectorcardiogram changes to type IV, and an example of this is shown in Fig. 3. The records A and B of a 53-year-old man were made at an interval of three years: when first seen, he gave a 20-year history of bronchitis, but he was able to work and his electrocardiogram was normal; three years later he was a respiratory cripple in cor pulmonale, and the electrocardiogram showed right ventricular hypertrophy by all three criteria.

FIG. 3.—Chronic bronchitis: showing a change from type II (A) to type IV (B) vectorcardiogram. Asthma: QRS loops in the horizontal plane during (C) and after (D) a severe attack.

There are several alternative explanations of the type II vectorcardiogram. It can be argued that this vector type is due to the unexplained left ventricular hypertrophy found at necropsy in some bronchitic subjects (Fluck, Chandrasekar, and Gardner, 1966). In left ventricular hypertrophy the QRS loop may be backwards and to the left, but the T vector loop is forwards and to the right (Grishman and Scherlis, 1952). In the author's type II vectorcardiogram the T loop lies in the same general direction as the QRS loop (Fig. 2), a finding that makes left ventricular hypertrophy very unlikely. The type II vectorcardiogram might also be explained by anatomical rotation of the heart about a longitudinal axis. The very limited evidence suggests that anatomical rotation of the heart in generalized lung disease or heart disease is insignificant and unrelated to changes in the

electrical axis (Grant, 1953; Guntheroth, Ovenfors, and Ikkos, 1961). The type II vectorcardiogram could be related to hyperinflation of the lungs, a mechanism used by Caird and Wilcken (1962) to explain the change in the P axis in the frontal plane, but in the 11 patients who had a type II vectorcardiogram, the P axis exceeded 80° in only 2. Extreme hyperinflation of the lungs occurs during severe asthma when the type II vectorcardiogram may be seen (Fig. 3). During the attack the QRS loop in the horizontal (C) plane was backwards and to the left. On recovery, the loop assumed a normal position (D). The corresponding electrocardiogram did not show a pattern of right ventricular hypertrophy. Deductions from the changes in these vectorcardiograms are difficult, because in addition to the hyperinflation of the lungs, severe asthma causes pulmonary arterial hypertension and other signs of acute cor pulmonale (Ambiavagar, Jones, and Roberts, 1967). Selvester and Rubin (1965) have suggested that the type II vectorcardiogram is due to emphysema without right ventricular hypertrophy. A further study of patients at either end of the bronchitic spectrum is planned to find out whether the "blue bloater" and "pink puffer" show characteristic vectorcardiographic changes. The precise interpretation of the type II vectorcardiogram requires necropsy studies, but until these are available it seems reasonable to conclude that this vectorcardiogram is due to right ventricular hypertrophy.

SUMMARY

The electrocardiograms of 50 men with chronic bronchitis were examined for signs of right ventricular hypertrophy. The positive results varied from 12 to 22, depending on the criteria used; 4 additional records showed right bundle-branch block. The vectorcardiograms of these patients were classified. Ten of the vectorcardiograms were normal and 29 showed right ventricular hypertrophy. The remaining 11 vectorcardiograms were abnormal and their significance is discussed. These results suggest that, in the recognition of right ventricular hypertrophy due to chronic bronchitis, the vectorcardiogram is more sensitive than the electrocardiogram.

I should like to thank Dr. E. Sherwood Jones and Dr. D. V. Roberts for helpful advice and for the vectorcardiograms shown in Fig. 3.

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