

THE ELECTROCARDIOGRAM IN EMPHYSEMA WITH COR PULMONALE—A preliminary report.

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The electrocardiogram in right ventricular hypertrophy has been extensively studied by Sokolow and Lyon (1949), Myers (1948), Zuckermann (1948), Milnor (1957), Phillips (1958), Goodwin and Abidin (1959), Roman, Walsh and Massie (1961) and Millard (1967). However, except for the studies of Roman, Walsh and Massie and Millard, who studied right ventricular hypertrophy in emphysema, the studies have included right ventricular hypertrophies due to congenital heart disease and mitral stenosis. As it is now known that emphysema per se may cause electrocardiographic changes (Spodick, 1959; Wasserberger *et al*, 1959; Littman, 1960; Selvester and Rubin, 1965 and Fowler, 1965) it was thought desirable to confine our study to emphysema and cor pulmonale alone. Further, owing to the difficulties encountered in defining the electrocardiographic features of emphysema as distinct from right ventricular hypertrophy, a suitable grading of right ventricular hypertrophy in cor pulmonale has not thus far been possible. In an attempt to resolve some of these problems, the following pilot study, based solely on autopsy-proven cases of emphysema and cor pulmonale, was undertaken.

MATERIALS AND METHODS

Selection of Patients—A total of 23 patients were studied, all with autopsy-proven emphysema and right ventricular hypertrophy. Of these 23 patients, 16 were retrospective patients and 7 were prospective patients. With the exception of 2 patients the electrocardiograms were done within 3 months of death. In 2 patients (Case No. 11, N.C.S. and Case No. 19, C.N.C.) the electrocardiograms were done within 6 months of death.

The Autopsy criteria for Right Ventricular Hypertrophy were:

1. Thickness of right ventricular wall measured 5 mm. or more (Walker *et al*, 1955;

Spain and Handler, 1946 and Scott and Garvin 1941).

2. Absence of autopsy evidence of other types of heart disease.

In addition, in the 7 prospective cases, the criteria of Fulton, Hutchinson and Jones (1952) were applied; right ventricular hypertrophy being present when the ratio of:

$$\frac{\text{Weight of left ventricle plus septum}}{\text{Weight of right ventricle}}$$

is less than 2.1.

Recording of Electrocardiogram—A 12 lead electrocardiogram (3 standard leads, 3 unipolar leads and 6 precordial leads taken in the standard positions) was recorded with a direct writing Cambridge Electrite Cardiograph. The following observations were noted:

1. The frontal P axis ($\bar{A}P$) calculated by the Method of Grant (1957).
2. The P configuration in Leads II, III and aVF.
 - a) P pulmonale—peaked P wave, more than 2.5 mm.
 - b) Gothic P wave—peaked P wave, less than 2.5 mm.
 - c) Cupula P wave—normal P wave.
3. The frontal plane QRS axis ($\bar{A}QRS$) calculated by the method of Grant (1950).
4. The QRS configuration in the following leads.
 - i) aVR
 - ii) V4R (only in the prospective series)
 - iii) V₁
 - iv) V₅
5. The position of the transitional QRS complex in the precordial leads.
6. T wave inversion in right precordial leads and standard limb leads II and III.
7. Lead I sign (isoelectric P, QRS less than 1.5 mm., T less than 0.5 mm.)—Fowler (1965)

TABLE I.

NAME	AGE	LEAD I SIGN	THICKNESS OF R.V. (m.m.)	ÂP		P CONFIGURATION (m.m.)									BIPHASIC P WAVE in V ₂ and BEYOND	ÂQRS		aVR		V ₄ R		V ₁		V ₅		TRANSITIONAL COMPLEX	ST-T INVERSION
						Pulm.			Gothic			Cupula				+	-	+	-	+	-	+	-				
				II	III	aVF	II	III	aVF	II	III	aVF															
1 C.K.L.	63 M	present	5	90		4	4	4							absent	80		QS	rS	rS	R		V ₃ -V ₄	absent			
2 LAC.	67 M	present	5	0									-3	3	0	absent	80		Qr		rS	RS	V ₃	absent			
3 WSC	99 M	present	5	90					2	2	2				absent	95		Qr		rS	rS		V ₅ -V ₆	absent			
4 NCH.	63 M	present	6	90		3	3	3							absent	95		QS	rS	rS	RS	V ₄	present				
5 ANH	55 M	present	6	90		25							0	0	absent		90	qR		rS	rS	rS	V ₆	absent			
6 GKP	52 M	present	6	80		25	25	25							absent		90	qR			rS	RS	V ₄ -V ₆	absent			
7 CCC	61 M	present	6	90		25	25	25							present	180		qR			qR	rS	V ₆	present			
8 HM.	55 M	present	6	85		25	25	25							present	100		rSr		rS	rS		V ₆	absent			
9 K.T.	63 M	present	7	90		3	3	3							present	105		QS	qR	qR		rS	V ₅ -V ₆	absent			
10 T.K.L.	39 M	absent	7	80		5	4	5							present	157		qR		rS	QS	QS	>V ₆	present			
11 NCS	71 M	present	7	90		3	3	3							present	80		Qr			rS	RS	V ₄	absent			
12 PS	79 M	present	7	70								1	1	1	present	90		QS			rS	rS	V ₅ -V ₆	absent			
13 LHM	61 M	present	7	90					2	2	2				absent	85		rS			rS	rS	V ₅ -V ₆	absent			
14 TAK	74 M	present	7	90		25	25	25							absent	95		rSr			rS	rS	V ₆	absent			
15 WKS	63 M	absent	7	90					2	2	2				absent	105		QR		rSr		rS	V ₅ -V ₆	present			
16 TSL	56 F	present	7	90								2	2	2	absent	90		QR			rS	rS	V ₆	present			
17 LLP	59 M	present	8	90		25	25	25							absent	115		qR			RS	rS	>V ₆	present			
18 WCS	42 M	absent	8	70		3			2	2					absent	125		qR			qR		RS	V ₅ -V ₆	absent		
19 CNL	52 M	present	9	90					2	2	2				present	105		rSr			rS	rS	>V ₆	present			
20 CHP	53 M	absent	10	90								0.5	0.5	0.5	present	120		R			rS	rS	>V ₆	absent			
21 AS	59 M	present	12	50								1	1	1	present	150		R		qR	R		rS	>V ₆	present		
22 KTL	56 M	absent	13	90		4.5	4.5	4.5							present	110		QR			RS		rS	>V ₆	present		
23 KKH	60 M	present	17	100								0.1	0.1	0.1	present		100	qR				RS	rS	>V ₆	present		

Electrocardiographic features in 23 patients with emphysema and cor pulmonale.

RESULTS

The electrocardiographic features in the 23 patients are tabulated in Table I. It appears that as right ventricular thickness increases, the 'classical' features of right ventricular hypertrophy make their appearance viz: right axis deviation of more than $+110^\circ$ and dominant R in aVR and V₁.

The results can be distributed into two groups. Group I: Electrocardiographic features present when the right ventricular thickness is equal to or less than 7 mm. Group II: Electrocardiographic features present when the right ventricular thickness is more than 7 mm. The following features are then noted (Table II):

1. A frontal plane P axis of more than $+80^\circ$ and P pulmonale occur as frequently in Group I as in Group II.
2. In Group I, the following features are present:
 - a) Frontal plane QRS axis of more than $+80^\circ$ but less than $+110^\circ$.
 - b) Transitional complex between V₄-V₆ in most cases.
3. In Group II, the following features occur more frequently:

- a) A QRS of more than $+110^\circ$.
- b) Dominant R in aVR.
- c) Dominant R in V₁
- d) Transitional complex beyond V₆.
- e) T wave inversion in right praecordial leads.

In Group II the lead I sign of Fowler occurs less frequently.

DISCUSSION

Even from the results of this small sample, it appears that the electrocardiographic features fall into 2 groups, depending on the degree of right ventricular thickness.

1. Group I—with right ventricle thickness equal to or less than 7 mm., in which the features attributable to emphysema are present viz. verticalisation of the P axis with P pulmonale, verticalisation of the QRS axis, 'clockwise rotation' of the heart with the transitional complex between V₄-V₆ and the lead I sign.
2. Group II—with right ventricle thickness more than 7 mm. in which the features of 'classical' right ventricular hypertrophy are present viz: right axis deviation of more than

TABLE II

RESULTS OF ELECTROCARDIOGRAPHIC FEATURES
IN 20 PATIENTS WITH RVH GROUPED
ACCORDING TO R.V. THICKNESS

	Group I RV 5-7 mm. thick (Total: 14)		Group II RV more than 7 mm. thick (Total: 6)	
	No. of Cases	Proportion and Percentage	No. of Cases	Proportion and Percentage
Å P more than 80°	13	13/14 = 93%	5	5/6 = 83%
P. Pulmonale	8	8/14 = 57%	3	3/6 = 50%
Å QRS 80° — 110°	14	14/14 = 100%	1	1/6 = 17%
Å QRS more than 110°	2	2/14 = 14%	5	5/6 = 83%
Dominant aVR	2	2/14 = 14%	4	4/6 = 66%
Dominant V _I	3	3/14 = 21%	3	3/6 = 50%
Transitional V ₄ -V ₆ Complexes	13	13/14 = 93%	6	6/6 = 100%
Transitional complex beyond V ₆	1	1/14 = 7%	5	5/6 = 83%
T wave inversion in right praeordial leads	5	5/14 = 36%	4	4/6 = 66%
Lead I sign	12	12/14 = 86%	3	3/6 = 50%

TABLE III

RESULTS OF ELECTROCARDIOGRAPHIC FEATURES IN
7 PATIENTS WITH RIGHT VENTRICULAR HYPERTROPHY
GROUPED ACCORDING TO RATION OF LV+S/RV,
RV THICKNESS AND SUGGESTED GRADING

	$\frac{LV + S}{RV}$	RV Thickness (mm.)	Grading of R.V.H. in Emphysema
4 NCH	1.9	6	Grade I
7 CCC	1.9	6	Grade II - III
1 CKL	1.6	4	Grade I
5 ANH	1.6	6	Grade I
9 KT	1.55	7	Grade II - III
10 TKC	1.15	7	Grade II - III
20 CHP	0.90	10	Grade II - III

+110°, dominant R in aVR and V₁ with T wave inversion over the right praecordial leads.

In addition 2 interesting features are noted in Group II:

- a) Marked 'clockwise rotation' of the heart with the transitional complex beyond V₆.
- b) Less tendency for Lead I sign to appear.

It will be noted that the 3 patients with left axis deviation have not been included in Table II, 2 of these (Case No. 5, A.N.H. and Case No. 6, G.K.P.) exhibiting the 'axis illusion' phenomenon of Spodick (1959) and the third Case No. 23 K.K.H. (with right ventricular thickness of 17 mm. and \bar{A} QRS—100° and \bar{A} P—90°) probably due to severe right axis deviation.

In 6 of our prospective cases we attempted grading of right ventricular hypertrophy using the ratio of Weights of LV+S/Weight of RV and RV thickness (Table III). Here again there appears to be a tendency towards separation into 2 groups: 1 group with the 'emphysema' pattern and the 2nd group with the pattern of right ventricular hypertrophy.

Though the number of patients studied is small it does indicate that the electrocardiographic features fall into 2 groups. It is, however, not possible in this study to say how much of the electrocardiographic features of the 'emphysema' group are due to emphysema per se or to right ventricular hypertrophy. Suffice it to say that even when the 'classical' pattern of right ventricular hypertrophy is absent in the electrocardiogram, a significant degree of hypertrophy of the right ventricle is already present, when the patient presents with the 'emphysema pattern'. Spodick (1959) has listed the following abnormalities as present in the 'emphysema' pattern: frontal plane P axis of +70° to 90°, (verticalisation of \bar{A} P), presence of 'Gothic' or 'Pulmonale' P waves in leads II, III, aVF, diphasic P wave in several right praecordial leads (to V₂ and beyond), a frontal plane QRS axis of +70° or more (verticalisation of \bar{A} QRS), deep S waves (more than 2 mm) over the left praecordial leads to V₆ (i.e. 'Clockwise rotation' or posterior orientation of \bar{A} QRS).

We have found the above findings in the majority of our patients in Group I.

Whether patients belonging to Group II can be further subdivided is a moot point. From the 6 patients in the study it is not possible to draw any conclusions. But it should be pointed out that Phillips (1958) has noted changes in the serial electrocardiograms in

4 patients showing a transition through the following stages:

- a) Normal direction of the QRS axis.
- b) Rightward direction of the QRS axis with dominant aVR.
- c) Anterior direction of the QRS axis with dominant V₁.

In our own series of 6 patients with serial electrocardiograms (to be published) we have also noted the tendency of a rightward direction of the QRS axis before it becomes anteriorly directed.

A tentative grading of the electrocardiographic findings of right ventricular hypertrophy in emphysema is therefore suggested:

- Grade 0 —Normal \bar{A} QRS.
- Grade I —Verticalisation of \bar{A} QRS with other features of 'emphysema'.
- Grade II —Right axis deviation of more than +110° with dominant R in aVR.
- Grade III —Rightward direction of \bar{A} QRS of more than +110° with dominant R in aVR plus anterior direction of \bar{A} QRS with dominant R in V₁.

(The value of V₄R in the diagnosis of anterior direction of the QRS axis has not been studied in this series.)



GRADE 0. GRADE I. GRADE II. GRADE III.

As this series has been a predominantly retrospective study, it was not possible to obtain pertinent clinical radiological and physiological data in a standardised manner. In view of the complexity of chronic pulmonary insufficiency and the varying factors producing cor pulmonale in chronic obstructive lung disease, further autopsy—controlled prospective studies with a bigger series are therefore required before a definite grading of right ventricular hypertrophy can be settled. This is currently being undertaken in our unit.

SUMMARY

The electrocardiograms of 23 patients with emphysema and right ventricular hypertrophy confirmed at autopsy were studied.

This study suggests that the electrocardiographic features fall into 2 groups: a group presenting with an 'emphysema' pattern and

a second group with the 'classical' electrocardiographic features of right ventricular hypertrophy. A tentative grading of the electrocardiographic findings of right ventricular hypertrophy in emphysema is suggested.

Three other interesting features have been noted in this study:

1. In patients with established 'classical' right ventricular hypertrophy we have found a marked 'clockwise rotation' of the heart with the transitional complex displaced beyond V_6 .
2. Less tendency for the appearance of the lead I sign of Fowler in 'classical' right ventricular hypertrophy.
3. Our data seems to support the observation that the P axis shift towards the right is an early sign of right ventricular hypertrophy and more sensitive than the changes in the QRS complex.

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