Electrocardiographic Patterns of Respiratory Disease in a Working Population

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Chronic bronchitis in its later stages is not infrequently accompanied by cardiac complications. Attempts to study the earlier stages of the process in epidemiological surveys of the general population have been frustrated by the extremely low prevalence of the classical electrocardiographic signs of right atrial and right ventricular hypertrophy.

In recent years several reports (Chappell, 1966; Fowler *et al.*, 1965; Millard, 1967; Okafuzi, 1966; Selvester and Rubin, 1965; Spodick *et al.*, 1963) have described other kinds of electrocardiographic abnormality associated with chronic obstructive lung disease, and in particular a constellation of changes in P wave axis and QRS amplitude (Selvester and Rubin, 1965). All these studies have concentrated on electrocardiographic abnormalities at an advanced stage of lung disease and have been carried out on hospital patients. The frequency of such abnormalities in the general population has not yet been reported; nor is it known whether the association already found with advanced disease would hold also in relation to lesser degrees of ventilatory defect. The present study was undertaken in order to answer these questions, and was based on examination of a group of middle-aged working men in London.

SUBJECTS AND METHODS

The group examined, which formed part of a larger study of the evolution of bronchitis (C. M. Fletcher, F. E. Speizer, C. M. Tinker, and I. D. Hill, personal communication, 1967), consisted of men from the Chiswick Engineering Works of the London Transport Board. At the start of the bronchitis survey all male employees aged 30 to 59 years had in 1961 been asked to complete a self-administered questionary: 61 per cent (347) did so. The

bronchitis study group was selected from among the respondents as follows (Table I): (a) 100 per cent of men with *either* chronic productive cough *or* a chest illness in the previous 3 years; (b) 50 per cent of the remaining non-smokers; (c) 20 per cent of the remaining cigarette smokers. The study group also included (d) a 30 per cent random sample of the men who failed to complete the original questionary. (This sampling scheme tends to select a group in which both of the two extremes of ventilatory function are relatively overrepresented, whereas men with average function are relatively under-represented.)

Of the 347 men who formed the original study group in 1961, 237 were examined for this present study. These were the men who had electrocardiograms measured on each occasion in 1961, 1963, and 1966. The remaining 110 men had initial $FEV_{1.0}$ values and frequency of electrocardiographic abnormalities that were similar to those in the remainder of the study. Therefore it is unlikely that the loss of these men has seriously affected the main conclusions drawn below.

The men were examined twice a year. The information used in this report was mainly that obtained in May to July of 1961, 1963, and 1966, and comprised the following.

(1) *Symptomatic Assessment by Standard Questionary.*
(a) Dyspnoea was recorded as positive if the subject answered "yes" to the question, "Are you troubled by shortness of breath when hurrying on level ground, or

TABLE I

STUDY POPULATION

Group (see text)	No. in each group	No. in present study
(a) Cough/chest illness (100%)	160	112
(b) Non-smokers (50%)	43	30
(c) Smokers (20%)	70	48
(d) Non-respondents (30%)	74	47
Total	347	237

walking up a slight hill?" (b) Phlegm was recorded as positive if a subject answered "yes" to the question, "Did you usually bring up phlegm from your chest first thing in the morning last winter?"

(2) *12-lead Electrocardiogram.* A single-channel, direct-writing cardiograph was used (Cambridge Transrite Mark II), with deflection standardized at 1 cm. = 1 mV. The electrocardiograms were all read by one of us. The tracings were recorded as positive when the following changes were present (modified Selvester and Rubin, 1965). P wave frontal plane axis in the limb leads greater than +60 degrees (generally easily identified by a flat or negative P wave in lead aVL) and in addition at least one of the following. (a) Low voltage of QRS complex (<0·7 mV) in bipolar limb leads. (b) (i) Clockwise rotation of the heart with the S wave in lead V4 equal to or greater than the R wave in lead V4; and in addition (ii) *either* a QRS frontal plane axis of +70 degrees or more, *or* indeterminate axis, *or* QRS frontal plane axis of −30 degrees or beyond. (c) Low voltage of QRS complex (<0·7 mV) in lead V6.

Technicians can easily be trained to make these measurements, and it takes an experienced reader 40 seconds at the most to classify any electrocardiogram.

(3) *One-second Forced Expiratory Volume* (FEV$_{1.0}$). A Gaensler spirometer (McKerrow, McDermott, and Gilson, 1960) was used to make the measurements. Five readings were made on each occasion and the mean of the last three readings was recorded. In order to allow

for the effects of age and height, each subject's value was converted to a standardized FEV$_{1.0}$ (SFEV), by adjusting to age 40 years and height 170 cm. Rate of change on FEV$_{1.0}$ was expressed as a linear regression of FEV$_{1.0}$ on time, using all measurements (ranging in number from 5 to 13) between the summer of 1961 and the summer of 1966.

In addition, the ratio of FEV$_{1.0}$ to forced vital capacity (FEV$_{1.0}$/VC%) was estimated in 1965.

RESULTS

The relations between FEV$_{1.0}$/VC per cent (in 1965) and electrocardiographic changes are set out in Table II. The proportion of men with positive electrocardiograms was approximately 12 per cent in each year. The mean FEV$_{1.0}$/VC per cent was statistically significantly lower for these subjects in each of the 3 years for which electrocardiograms were available.

Means of the 3 individual SFEV values estimated in 1961, 1963, and 1966 were computed for the following 4 groups, which are not mutually exclusive (Table III): (a) all men whose electrocardiogram was positive on all 3 occasions; (b) all men who were phlegm-positive on all 3 occasions; (c) all men who were dyspnoea-positive on all 3 occasions; and (d) all men who were negative for electrocardiogram, dyspnoea, and phlegm on all 3 occasions. Com-

TABLE II

MEAN FEV/VC PER CENT IN 1965 IN RELATION TO ELECTROCARDIOGRAPHIC FINDINGS IN 1961, 1963, AND 1966

	Electrocardiogram					
	1961		1963		1966	
	Positive	Negative	Positive	Negative	Positive	Negative
Mean FEV/VC per cent 1965	60·4*	69·9*	63·2†	70·0†	60·7‡	70·2‡
No. of men	23	214	35	202	30	207

* p < 0·001; † p < 0·01; ‡ p < 0·001.

TABLE III

MEAN SFEV (SEE TEXT) FOR THE PERIOD 1961 TO 1966 IN MEN WITH PHLEGM OR DYSPNOEA OR POSITIVE ELECTROCARDIOGRAM CHANGES COMPARED WITH MEN CONSISTENTLY NEGATIVE FOR THESE SYMPTOMS AND SIGNS

	Electro-cardiogram positive (a)	Phlegm positive (b)	Dyspnoea positive (c)	Phlegm, dyspnoea, and electro-cardiogram negative (d)
Mean SFEV (l.) for 1961, 1963, and 1966	2·49*	3·10†	3·22‡	3·60
No. of men	7	71	14	75

(Subjects who were symptom-positive or electrocardiogram-positive on only one or two occasions are not included in this Table.)
Difference from (d): * p < 0·001, † p < 0·001, ‡ p < 0·05.

parisons of these means showed striking differences: the mean SFEV's for the dyspnoea-positive group and also for the phlegm-positive group were significantly lower than for the symptom- and electrocardiogram-negative group. The lowest mean SFEV was recorded in the electrocardiogram-positive group (30% lower than the mean value for the symptom- and electrocardiogram-negative group), and this was significantly lower than the equivalent value for the symptom- and electrocardiogram-negative group.

Having established that the electrocardiogram was able to identify a group of men with a lower mean level of ventilatory function, it remained to be seen whether it was also able to predict a future decline in function. From Table IV it can be seen that those men with a positive electrocardiogram show a significantly greater rate of decrease of FEV than do men without these electrocardiographic changes. When the subjects were classified by the presence of either dyspnoea or phlegm the difference in the rate of decrease of $FEV_{1.0}$ between these groups and men without symptoms did not reach statistical significance at the 5 per cent level. This greater rate of decrease in the electrocardiogram-positive group is possibly related to the fact that they had lower values for $FEV_{1.0}$ in 1961. Fletcher (1968) has shown that men with low $FEV_{1.0}$ values have a more rapid rate of decline than men with higher $FEV_{1.0}$ values.

TABLE IV

COMPARISON OF RATE OF CHANGE OF $FEV_{1.0}$ FROM 1961 TO 1966 IN MEN WITH AND WITHOUT ELECTROCARDIOGRAPHIC CHANGES IN 1961, 1963, AND 1966

	No. of men	Mean rate of change of $FEV_{1.0}$ ($\pm$ standard error) in ml. per annum
Electrocardiogram negative on all 3 occasions	170	$-22 \cdot 4^* \pm 3 \cdot 6$
Electrocardiogram positive on at least one occasion	67	$-40 \cdot 4^* \pm 6 \cdot 1$

* $0 \cdot 01 > p > 0 \cdot 005$.

No electrocardiograms had Rs patterns in V1, and QRS frontal plane axis greater that +110 degrees did not occur. P pulmonale (amplitude > 2·5 mm.) was not present in any tracing, nor did any of the 67 subjects with positive tracings show signs of myocardial infarction or ischaemia (pathological Q waves, S–T depression, T wave inversion).

The prevalence of bronchitis is high. Through the courtesy of Dr. Oglesby Paul of Chicago an opportunity recently arose to test whether, in a population where severe bronchitis was less common, the same association would still hold between these electrocardiographic changes and ventilatory defect. One of us was able to examine two groups of electrocardiograms from Paul *et al.*'s survey (1963) of middle-aged men employed at the Western Electric Company, Chicago, consisting of (1) 215 electrocardiograms from men whose $FEV_{1.0}/FVC$ per cent was < 65·3 per cent (i.e. more than one standard deviation below the mean for the whole study, which was 74·5%), and (2) a random sample of 215 of the remaining men. Electrocardiographic changes, as described earlier in this report, were present in 22 per cent of the men with reduced ventilatory function, but in only 8 per cent of the remainder. It appears that the association demonstrated in London is not confined to populations with a very high prevalence of bronchitis.

DISCUSSION

Selvester and Rubin (1965) proposed specific electrocardiographic criteria that clearly separated patients with emphysema from normal subjects and from patients with congenital heart disease with right atrial enlargement, right ventricular hypertrophy, or right bundle-branch block. They found that pulmonary emphysema was associated with a P axis of greater than +60 degrees and posterior and superior displacement of the mean QRS axis. Earlier Spodick *et al.* (1963), examining patients with pulmonary emphysema, had shown that a change towards the vertical of both the P axis and QRS frontal plane axis, and the occurrence of P pulmonale were significantly correlated with increasing respiratory obstruction. Fowler *et al.* (1965), in a hospital study of patients with cor pulmonale (with or without emphysema), showed that a P wave axis of +90 degrees and a low voltage QRS complex (in limb leads < 5 mm. or in lead V5 or V6 < 7 mm.), very low P, QRS, and T complexes in lead I, and an rS pattern in mid-praecordial leads (Fowler called this a QS pattern—in the electrocardiogram reproduced to illustrate this pattern there are, in fact, small initial r waves before each S wave), were all virtually limited to the emphysema group. Chappell (1966) also showed that rightward deviation of P axis, P pulmonale, QRS frontal plane axis of +90 degrees to +180 degrees, and left axis deviation were correlated with severity of airways obstruction. This latter study was carried out on patients with chronic bronchitis, together with varying degrees of emphysema. He showed that this correlation was independent of the emphysema present (as measured radiographically). Millard (1967), relating electrocardiograms to ventricular weights of 46 patients with chronic lung disease, found that a P wave axis of more than +60 degrees was of no value in detecting right ventricu-

lar hypertrophy. He also noted that a QRS frontal plane axis of $+91$ degrees to $+180$ degrees was the most reliable electrocardiographic sign of excessive right ventricular weight but that in the presence of left ventricular hypertrophy or myocardial ischaemic patterns, the electrocardiogram was of little value in diagnosis. On the other hand, Rees, Thomas, and Rossiter (1964), using thickness of the right ventricular wall greater than 5 mm. as an index of right ventricular hypertrophy, showed good electrocardiographic separation between coronary artery disease and pulmonary disease confirmed at necropsy. They used QRS frontal plane axis of $+110$ degrees to $+180$ degrees as their criterion for right ventricular hypertrophy.

These findings suggest that—at least in the absence of ischaemic changes—electrocardiographic changes may characterize hospital patients with advanced chronic lung disease. The aim of the present study was to learn whether the same changes also characterize subjects with obstructive lung disease at an earlier stage of its development, namely, among the working population. It had earlier been found among surveys of more than 2000 working men, conducted by the Department of Epidemiology of the London School of Hygiene, that the classical changes of right ventricular hypertrophy were not seen in a single instance—despite the inclusion of lead V4R. Selvester and Rubin (1965) divided their electrocardiographic criteria into "possible" and "probable" groups for diagnosing pulmonary emphysema. We have not done this because two of us (G. Tibblin and R. J. Prineas —unpublished), after examining the electrocardiograms of 760 General Post Office van drivers and engineer workers in London and three county towns in Southern England (population described by Holland and Reid, 1965), found no difference in discriminatory power (as judged by $FEV_{1.0}$) between the criteria for *possible* and *probable* pulmonary emphysema used by Selvester and Rubin (1965).

Further study is required to elucidate the most appropriate cut-off point for each of the characteristics described in the positive electrocardiographic changes. There is also a need to investigate to what extent anatomical positional change, conducting tissue change, and increased heart load factors are responsible for the electrocardiographic changes described.

The selected group of electrocardiographic changes in this study characterized a group of men whose SFEV was lower than in men without these changes. Subjects with positive electrocardiograms also exhibited more rapidly deteriorating $FEV_{1.0}$ values over a period of 5 years. And the men with these electrocardiographic changes tended to have lower $FEV_{1.0}$ values (standardized for age and height) than patients with repeated dyspnoea or repeated winter morning sputum alone. Moreover, these changes were relatively common, affecting at least 1 in 10 of this group of middle-aged working men. They provide a means of identifying either men with present ventilatory defects or subjects with an increased risk of developing ventilatory defect in the future. It remains to be seen whether they also predict an increased risk of heart failure. This will be important to test because previous attempts to gather population study information on cor pulmonale have generally failed because of the very low prevalence of ascertainable signs.

SUMMARY

A particular group of electrocardiographic abnormalities (characterized by a frontal plane axis of the P wave greater than $+60$ degrees together with low voltage of QRS complexes or posterior and superior displacement of the mean QRS axis) has earlier been shown to characterize hospital patients with advanced bronchopulmonary disease. These changes are now reported to be present in approximately 12 per cent of 237 middle-aged working men in London. Among men with these electrocardiographic changes, the mean one-second forced expiratory volumes (adjusted for age and height) were 30 per cent lower than in men with negative electrocardiograms and no respiratory symptoms; this difference, which is highly significant, is considerably greater than the loss of function associated with the presence of respiratory symptoms.

Electrocardiograms were available from these men for 1961, 1963, and 1966. Among men whose electrocardiograms were consistently negative, the mean rate of decline of FEV over this 5-year period was 22·4 ml. per year; among men with one or more positive electrocardiograms the mean rate of decline was 40·4 ml. per year.

It is not at present clear whether these electrocardiographic changes represent merely positional effects, or the early stages of cor pulmonale.

Examination of a sample of middle-aged working men in Chicago revealed a broadly similar association between these electrocardiographic changes and ventilatory defect.

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