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Lung function tests and a 'vertical' P wave axis in the electrocardiogram

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Chapman, T. T. (1974). *Thorax*, **29**, 106–109. **Lung function tests and a 'vertical' P wave axis in the electrocardiogram.** The relationship between a vertical P wave axis and impaired lung function was studied in 1,144 patients with chronic non-specific lung disease. There was a significant relationship between a vertical P wave axis and reduction in forced expiratory volume (FEV_1), FEV_1 as a percentage of vital capacity (FEV_1% VC), residual volume (RV), and transfer factor (TF); this relationship was closest in the case of the FEV_1% VC. There was no significant correlation between P wave axis and the forced inspiratory volume (FIV_1).

Spodick (1959a and b) suggested that a vertical P wave axis of 90° or thereabout, in the frontal axis of the electrocardiogram, is the only distinctive electrocardiographic finding in diffuse lung disease.

Prineas, Tibblin, and Rose (1968) examined the electrocardiograms of 237 middle-aged men; 12% had a vertical P wave axis, and, in this group, the FEV_1 was 30% lower than in those with a negative P wave. Further, the yearly decline in FEV_1 was 40·4 ml per year in those with a vertical P wave and 22·4 ml per year in the normal group. These authors concluded that it was not clear whether the effect was positional or due to early cor pulmonale.

Perlman *et al.* (1971) found vertical P waves among control patients without cough, phlegm or shortness of breath and they concluded that these changes were not specific for chronic respiratory disease. However, lung function tests were not carried out in this series.

In the present study, lung function tests and electrocardiograms were performed in 1,114 patients who had been referred for respiratory assessment with chronic non-specific lung disease (Ciba Guest Symposium Report, 1959). Patients with a clinical diagnosis of asthma were not included. The object was to demonstrate if there was any relationship between an abnormal P wave axis and the degree of abnormality of one or more lung function tests.

METHODS

A vertical P wave axis was determined by the following criteria: when the P wave axis was flat in lead 1, of equal heights in leads 2 and 3, and definitely negative in aVL, the axis was taken to be greater than 90° and was regarded as abnormally vertical. Those tracings with an isoelectric P wave were not included in the vertical group, the axis in this instance being 60° or less.

FEV_1 and vital capacity (VC) values were determined either by use of a Vitalograph dry spirometer or a 9-litre bell spirometer, and FIV_1 volumes were measured on the bell spirometer.

RV examinations were done by the helium closed-circuit system and the gas transfer (TF) by the steady-state end-tidal procedure (Bates, Woolf and Paul, 1962).

All spirometry manoeuvres were repeated at least three times, the highest value being accepted when the operator was satisfied that a maximum effort was obtained. TF measurements were repeated once and the average of the two was accepted.

The FEV_1, TF, and RV were expressed as a percentage of the predicted normal value for each individual patient. These were all estimated from sex, height, and age. The values for FEV_1 were taken from the nomogram of Kory, Callahan, Boren, and Syner (1961), the TF from the tables of Bates, Macklem, and Christie (1971), and the RV from the nomogram of Goldman and Becklake (1959).

RESULTS

After dividing the patients examined into those with a vertical P wave axis and those with a

TABLE I

CATEGORIES FOR ANALYSIS INCLUDING PATIENT NUMBERS IN EACH SECTION

Category	FEV_1 % VC	FEV_1 (ml)	FEV_1 % Normal	TF % Normal	RV % Normal	FIV_1 % VC
1	<40	<1,000	<50	<50	>159	<40
Vertical P wave	330	350	444	153	86	37
Normal P wave	185	227	350	92	58	52
Total	515	577	794	245	144	89
2	40–59	1,000–1,499	50–69	50–69	140–159	40–59
Vertical P wave	168	106	57	112	34	130
Normal P wave	264	182	168	145	18	165
Total	432	288	225	257	52	295
3	60–79	1,500–1,999	70–89	70–89	120–139	60–79
Vertical P wave	32	43	28	61	24	219
Normal P wave	139	107	82	107	33	214
Total	171	150	110	168	57	433
4	>79	>1,999	>89	>89	<120	>79
Vertical P wave	0	31	1	66	141	104
Normal P wave	24	98	12	153	226	116
Total	24	129	13	219	367	220

normal P wave axis, the range for each measurement of lung function was arbitrarily subdivided into four categories for the purpose of analysis. In each case, category 1 represents the greatest degree of abnormality and category 4 the least.

The number of abnormal and normal P waves in each category for the five lung function tests used is shown in Table I.

In the Figure the numbers of patients with abnormal P waves are displayed as a percentage of the total number of patients in each category.

The association between the number of patients with vertical P waves and the degree of abnormality of lung function was tested statistically using the χ^2 test. The results obtained are expressed in Table II and the measurements are listed according to the degree of association.

TABLE II

χ^2 VALUES AND SIGNIFICANCE OF ASSOCIATION BETWEEN P WAVE AXIS AND LUNG FUNCTION PARAMETERS

P Wave Axis/Parameter	χ^2	n	P
FEV_1 %VC	148	3	<0·001
FEV_1	102	3	<0·001
FEV_1 %Normal	88	3	<0·001
TF %Normal	55	3	<0·001
RV %Normal	45	3	<0·001
FIV_1 %VC	4	3	<0·05

It can be seen that the first five tests show a high degree of association ($P<0·001$) between changes in lung function and the P wave axis. In the last measurement (FIV_1 %VC), the association is not significant at the 5% level.

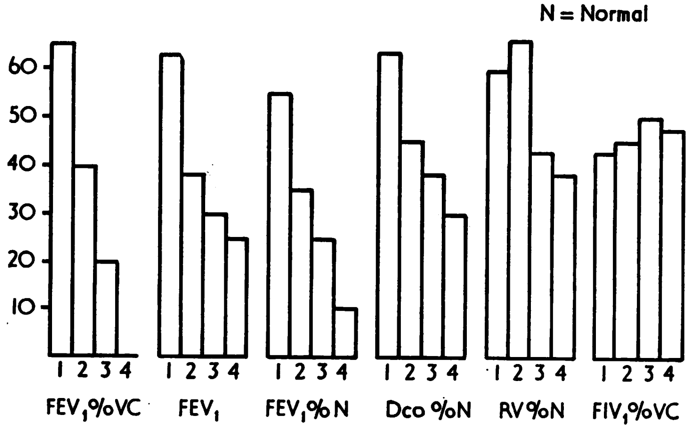

FIGURE. *Number of patients with vertical P waves expressed as a percentage of the total number of patients in each lung function category.*

DISCUSSION

As stated in the introduction, the occurrence of a vertical P wave axis in association with chronic diffuse lung disease is well recognized. It is the experience of this department that when there is a vertical P wave axis there is usually a disturbance in lung function and symptoms of respiratory disease. Occasionally, no symptoms are present, and the abnormality is picked up during an ECG examination for some other reason. These cases are referred for pulmonary assessment.

The mechanism of the P wave changes in lung disease is not clear. Perlman *et al.* (1971) postulated that hyperinflation of the chest causes the heart to rotate clockwise and become more vertical. Treiger and Lundy (1934) pointed out that a pneumothorax on either side will cause the QRS axis to shift to the right, i.e., to the vertical plane, and this may also apply to the P wave. Littmann (1960) suggested that the alteration in the ECG axis was due to the fact that over-inflated lung is a poor conductor of electrical impulses and that the lung herniates itself around the heart and great vessels, thus modifying the normal conductance pathways. The anatomical position of the heart is, therefore, not altered, and the 'vertical' P wave axis is more apparent than real.

Other studies, such as that of Caird and Wilcken (1962), have shown that right atrial hypertrophy is more common in patients with antemortem P wave changes. Both these factors, however, may relate to severe obstructive lung disease rather than to each other. This is supported by the fact that patients with cor pulmonale due to causes other than obstructive lung disease tend not to have the same degree of vertical P wave axis rotation (Fowler *et al.*, 1965).

There would, therefore, appear to be fairly general agreement that the phenomenon is associated with overinflation of the lung.

Overinflation of the lung is nearly always the result of chronic airways obstruction which can most conveniently be measured by the FEV_1. Thus, when the results are examined in order of significance, the highest correlation between a vertical P wave axis and the lung function tests is in the $FEV_1\%VC$ and next in the FEV_1 in absolute values.

The steady-state gas transfer is frequently disturbed in severe chronic airways obstruction, probably due to a disturbance in ventilation-perfusion relationships. When expressed as a percentage of the normal, it shows a highly significant relationship with a vertical P wave.

It might be expected that the residual volume as a percentage of the predicted normal value would show the most significant relationship to P wave axis changes. However, although the results are highly significant, there was a greater relationship with the other tests mentioned above. This is rather surprising and does not support entirely the hypothesis of Littmann and the suggestion of Perlman *et al.* (1971) that an increased residual volume should correlate with right atrial hypertrophy and P wave changes. The results were similar when the residual volume was expressed as a percentage of total lung capacity.

The FIV_1 may be well preserved in obstructive lung disease. This may be due to several factors, such as the increase in activity of the accessory muscles of respiration, or increased compliance in patients with emphysema. It is not surprising, therefore, that there was no significant correlation between the $FIV_1\%VC$ and changes in the P wave axis.

We therefore conclude that severe airways obstruction is usually present when a definite vertical P wave axis is seen in the electrocardiogram. This is most marked when measured as $FEV_1\%VC$ and, to a lesser extent, when FEV_1 is expressed in absolute values or as a percentage of the predicted normal. In addition, it is probable that when this P wave alteration occurs there will also be significant disturbances in the transfer factor and residual volume.

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