Original article

Vertical P-wave axis: the electrocardiographic synonym for pulmonary emphysema and its severity

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KEYWORDS

Chronic obstructive lung disease
Electrocardiogram (ECG)
Pulmonary emphysema
Pulmonary function test

ABSTRACT

Background: The correlation between vertical P-wave axis (P-axis >60°) and pulmonary emphysema was investigated on a very large controlled series to see if P-axis verticalisation as lone criterion can be effectively used to screen emphysema in general population. Correlation between degrees of P-axis verticalisation and the severity of the obstructive lung disease (as per global initiative for chronic obstructive lung disease [GOLD] criteria) was also studied to see if this criterion can be used for gross quantification of the chronic obstructive pulmonary disease (COPD) in routine clinical practice. **Materials and methods:** Around 6500 unselected, routine electrocardiograms (ECGs) were reviewed which yielded 600 ECGs with vertical P-axis in sinus rhythm. 635 ECGs from the same continuum were selected with P-axis ≤60° matched for patient's age and sex serving as controls. Charts were reviewed for the diagnosis of COPD and emphysema based on medical history, pulmonary function tests, and imaging studies.

Results: Prevalence of emphysema in patients with vertical P-axis was strikingly higher than in the control group: 85% vs 4.4%. The sensitivity and specificity of vertical P-axis for diagnosing emphysema was 94.76% and 86.47%, respectively. Vertical P-axis and forced expiratory volume (FEV1) were inversely correlated (Pearson correlation coefficient = −0.683). Prevalence of severe COPD was strikingly higher in patients with P-axis >75° as compared to the group with P-axis 60°–75°: 96.3% vs 4.6%. Close to 80% of the emphysema patients with P-axis >85° had very severe disease (FEV1 <30%). **Conclusion:** P-axis verticalisation is highly effective for screening emphysema and degree of verticalisation provides a gross quantification of the disease.

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Introduction

Emphysema of any pathogenesis, nearly always due to chronic obstructive pulmonary disease (COPD) and rarely due to alpha-1 antitrypsin deficiency (AAD) produces a state of abnormal lung hyperinflation and has been shown to carry an association with a vertical frontal P-wave axis^{1,3,9} by several studies done on small patient populations. A vertical P-wave axis (>60°) during a sinus rhythm can be easily determined by a simple glance at the electrocardiogram (ECG); an entirely

inverted or dominantly negative P-wave in lead aVL and alternatively a P-wave in lead III larger than the P-wave in lead II was observed. Our study aims to investigate the reproducibility of the relationship between vertical P-axis and emphysema on a very large controlled series primarily to determine if verticalisation of the frontal P-wave vector as a lone criterion can be used as a standard guideline for screening emphysema in a general population. In addition, we wanted to investigate the correlation between the degrees of P-axis verticalisation and the severity of the obstructive lung disease as per the global initiative for chronic obstructive lung disease (GOLD) criteria to see if this criterion can be used for the gross quantification of the COPD in routine clinical practice.

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Materials and methods

Unselected, consecutive routine ECGs of 6500 patients were reviewed from the hospital TraceMaster Vue system yielding 600 ECGs with P-wave axis $>60^\circ$ in normal sinus rhythm (NSR) after exclusion criteria. Around 635 patients from the same ECG continuum were selected with P-wave axis $<60^\circ$ in sinus rhythm matched for age and sex serving as the control group (Table 1). Inclusion criteria were age >45 years,^{1–4,7} NSR and availability of past medical history, imaging studies and/or pulmonary function tests. Patients <45 years old were excluded since vertical P-wave axis is a normal finding in healthy children and in many young adults. Any rhythm other than sinus was also excluded. Charts were then reviewed for the diagnosis of the COPD and emphysema based on the medical history, pulmonary function tests and imaging studies including chest radiographical and computed tomography (CT) scans. Diagnosis of emphysema or lung hyperinflation was primarily based upon the radiological evidence. The radiologist reporting of the imaging studies (including chest radiographs and CT-scans) was mainly used for the diagnosis of any emphysematous changes. The severity of the chronic obstructive lung disease was determined based upon the forced expiratory volume (FEV1) value. A direct comparison of the FEV1 value was done with the electrocardiographic P-wave axis in those patients whose pulmonary function tests (PFTs) were available within the last 6 months (from the date of the ECG study) determining any statistical correlation. Statistical analysis was done by using Statistical Package for Social Sciences (SPSS Inc., Chicago, IL, version 15.0 for Windows). The means and standard deviations of the P-wave axis and age were calculated and the data were checked for skewness by Kolmogorov Smirnov tests of normality. Mann–Whitney U test was applied for comparison of the 2 groups as the data for P-wave axis were skewed. Qualitative or categorical variables were described as frequencies and proportions. Proportions were compared using χ^2 /Fisher's exact test whichever was appropriately applicable. *P* values <0.05 were considered statistically significant.

Results

The patients in the groups with P-wave axis $>60^\circ$ and P-wave axis $\leq 60^\circ$ were well matched for age with mean age of

Table 1

P-wave axis: comparison of patient groups with P-wave axis $>60^\circ$ versus $\leq 60^\circ$ ($n=1235$).

Variable	P-wave axis		<i>P</i> value
	$>60^\circ$ ($n=600$)	$\leq 60^\circ$ ($n=635$)	
Age (yr)	68.21 $\pm$ 13.24	67.78 $\pm$ 13.9	0.601
Gender			0.071
Female	335 (55.8%)	322 (50.7%)	
Male	265 (44.2%)	313 (49.3%)	
Smoking	78.7%	36.9%	<0.001
Emphysema	85%	4.4%	<0.001
P-wave axis ($^\circ$)	71 $\pm$ 8.13	31.6 $\pm$ 17.48	<0.001

Data are presented as mean $\pm$ standard deviation, *n* (%) or %

68.2 years and 67.7 years respectively ($P=0.601$). The prevalence of smoking history (over 20 pack years) was found to be 78.7% in patients with vertical P-wave axis as compared to 36.9% in the control group ($P<0.001$). Patients with vertical P-wave axis also had strikingly higher prevalence of emphysema than the control group: 85% vs 4.4% (Table 1). Sensitivity and specificity of the P-wave axis $>60^\circ$ for diagnosing emphysema in the adult age group (>45 years) was 94.8% and 86.5%, respectively (Table 2). The positive and negative predictive values of this lone criterion were found to be 84.2% and 95.6% respectively (Table 2). The mean P-wave axis in emphysema patients was found to be 69.7° as compared to 36.1° in patients without emphysema (Table 3). The degree of P-wave verticalisation was found to have a strong inverse relationship with FEV1; Pearson correlation coefficient being -0.683 ; $P<0.001$ (Table 4). The prevalence of severe obstructive lung disease as defined by GOLD criteria (FEV1 $<50\%$) was strikingly higher in emphysema patients with a high degree of verticalisation (P-axis $>75^\circ$) as compared to those with a lower vertical *P* value (P-axis between 60° and 75°): 96.3% vs 4.6% (Table 5). Interestingly, 80% of emphysema patients in our cohort with P-axis $>85^\circ$ were found to have very severe or terminal disease (FEV1 $<30\%$).

Table 2

Sensitivity, specificity, positive predictive value and negative predictive value of each vertical P-wave axis for emphysema ($n=1235$).

P-wave axis	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)
$>60^\circ$	94.76	86.47	84.19	95.59
$\geq 70^\circ$	91.88	93.82	87.38	95.59
$\geq 80^\circ$	77.40	99.18	94.68	95.59

Table 3

Comparison of patients with and without emphysema ($n=1235$).

Variable	Emphysema		<i>P</i> value
	Yes ($n=538$)	No ($n=697$)	
Age (yr)	69.20 $\pm$ 13	66.96 $\pm$ 14.29	<0.001
P-wave axis	69.71 $\pm$ 11.87	36.1 $\pm$ 20.57	<0.001

Data are presented as mean $\pm$ standard deviation.

Table 4

Correlation between vertical P-wave axis and forced expiratory volume 1 ($n=191$).

	P-wave axis	FEV1
P-wave axis	Pearson correlation	1
	Significant (2-tailed)	-0.683^*
	<i>n</i>	1235
FEV1	Pearson correlation	-0.683^*
	Significant (2-tailed)	0
	<i>n</i>	191

*Correlation is significant at the 0.01 level (2-tailed).

Around 191 emphysema patients with vertical P-axis had available pulmonary function tests within the last six months of the electrocardiogram study. FEV1: forced expiratory volume.

Table 5

Chronic obstructive pulmonary disease prevalence as per severity and degree of P-axis verticalisation ($n=191$).

	P-axis (°)		Total
	60°–75°	>75°	
FEV1 (%)			
<50 (severe and very severe COPD)	5 (4.6%)	79 (96.3%)	84 (44%)
≥50 (mild and moderate COPD)	104 (95.4%)	3 (3.7%)	107 (56%)
Total	109 (100%)	82 (100%)	191 (100%)

Data are presented as n (%) or (%). COPD: chronic obstructive pulmonary disease, FEV1: forced expiratory volume.

Discussion

Previous studies on this subject have found a close correlation between P-wave verticalisation and COPD/emphysema.^{1–8} A plausible mechanism for P-axis verticalisation in lung hyperinflation is that the right atrium is firmly attached to the diaphragm by a dense pericardial ligament around the inferior vena cava.⁹ With progressive flattening of the diaphragm, the right atrium is distorted/displaced inferiorly causing a significant rightward deviation (verticalisation) of the P-wave axis. In contrast, in pure restrictive (fibrotic) lung disease, the P-wave axis tends to be horizontal or leftward, correlating with the degree of diaphragmatic elevation.¹⁰ Our retrospective study utilises an unselected large patient population to find a definite correlation of the vertical P-wave axis and emphysema. The results demonstrated that this lone criterion can be used as an effective screen for pulmonary hyperinflation, using a few simple parameters. The degree of P-wave verticalisation has a strong inverse relationship with FEV1 which quickly provides a gross quantification of severity of the obstructive lung disease. The degree of P-wave verticalisation might also have a significant correlation with the radiological severity of the emphysematous changes/lung hyperinflation which is the basic mechanism for a vertical P-wave axis; however, the radiological quantification was not performed in our study and would be an interesting subject for future studies.

Limitations

P-wave verticalisation can only be used to detect emphysema in patients who have an ECG with NSR. It is of course not uncommon to see a high prevalence of atrial arrhythmias like multifocal tachycardia in patients with obstructive lung disease and in such cases; this principle cannot be applied due to a variable P-wave axis. The other theoretical factors which can possibly affect P-wave axis like height, body habitus, co-existence of restrictive lung disease, etc. are not taken into account to avoid the complexity of interpretation while using vertical P-wave axis as a lone diagnostic criterion.

Conclusion

Despite previous work on this subject in various studies since 1950s, most internists and even specialists (including cardiologists or pulmonologists) are not aware about the practical utility of this relationship. Our study is the largest controlled series so far on this subject which aimed to determine a definite correlation of vertical P-axis with emphysema and severity of obstructive lung disease as per GOLD criteria. P-axis verticalisation can serve as a very effective electrocardiographic screening tool for emphysema in the general population. In fact, this quick bedside screening modality is inexpensive, and at the same time highly sensitive and specific. We propose its inclusion as one of the standard diagnostic guidelines for pulmonary emphysema in patients with age >45 years and emphasise its use in routine clinical practice. The degree of P-wave verticalisation also provides a quick gross quantification of the chronic obstructive lung disease.

References

- Spodick DH. Electrocardiographic studies in pulmonary disease: I. Electrocardiographic abnormalities in diffuse lung disease. *Circulation* 1959;20:1067–72.
- Littman D. The electrocardiographic findings in pulmonary emphysema. *Am J Cardiol* 1960;5:339–48.
- Spodick DH, Hauger-Kleve JH, Tyler MJ. The electrocardiogram in pulmonary emphysema: relationship of characteristic electrocardiographic findings to severity of disease as measured by the degree of airway obstruction. *Am Rev Respir Dis* 1963;88:14–9.
- Spodick DH. Vectorcardiogram in pulmonary emphysema: its relationship to scalar electrocardiographic findings. *Am Rev Respir Dis* 1968;98:634–9.
- Thomas AJ, Apiyasawat S, Spodick DH. Electrocardiographic detection of emphysema. *Am J Cardiol* 2011;107:1090–2.
- Baljeppally R, Spodick DH. Electrocardiographic screening for emphysema: the frontal plane P axis. *Clin Cardiol* 1999;22:226–8.
- Calatayud JB, Abad JM, Khoi NB, Stanbro WJ, Silver HM. P wave changes in pulmonary disease. *Am Heart J* 1970;79:445–53.
- Zuckerman R, Cabrera CE, Fishleder BL, Sodi-Pallares D. The electrocardiogram in chronic cor pulmonale. *Am Heart J* 1948;35:421–5.
- Shah NS, Koller SM, Janover ML, Spodick DH. Diaphragm levels as determinants of P axis in restrictive vs. obstructive pulmonary disease. *Chest* 1995;107:697–700.
- Zambrano SS, Moussavi MS, Spodick DH. QRS duration in chronic obstructive lung disease. *J Electrocardiogr* 1974;7:35–6.
- Spodick DH. Pulmonary emphysema. *Am J Geriatr Cardiol* 2007;16:390.
- Spodick DH. Pulmonary emphysema: classical, quasi-diagnostic ECG. *Am J Geriatr Cardiol* 2006;15:193.
- Spodick DH. Electrocardiology teacher analysis and review—diagnostic ECG in pulmonary emphysema. *Am J Geriatr Cardiol* 1997;6:75.
- Vijayakrishnan R, Spodick DH. Himalayan P waves in the setting of severe hypoxaemia and emphysema. *Can J Cardiol* 2010;26:136.
- Chhabra L, Spodick DH. Transient super Himalayan P-waves in severe pulmonary emphysema. *J Electrocardiol* 2011;45:26–7.