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Electrocardiographic detection of left atrial enlargement

Correlation of P wave with left atrial dimension by echocardiography

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The validity of various electrocardiographic P wave measurements was tested in 48 patients by ccmparing them to left atrial dimensions determined by echocardiography (echo), a proved method of left atrial size estimation. Of all the measurements considered, only the width of the P wave (PW), the P terminal force in lead V1 (PV1), and the PW/PR segment ratio (PW/PR) showed statistically significant correlations with left atrial size measurements by echo, with r values of 0·746, 0·491, and 0·479, respectively. The results indicated that P widths in excess of 105 ms were present in all the patients who had left atria equal to or greater than 3·8 cm by echo and in 11 per cent of patients without atrial enlargement (false positives), and that when measurements were less than 105 ms left atrial enlargement was unlikely.

Changes in the pattern of atrial depolarization have long been recognized as reflecting haemodynamic or anatomical changes affecting the atria. Changes in the morphology of the P wave in the electrocardiogram have been considered useful indications of left and right atrial abnormalities. The validity of these assumptions in the estimation of left atrial size has been tested against direct observations at the time of surgery (Saunders *et al.*, 1967; Martins de Oliveira and Zimmerman, 1959), measurements from various radiological views of the heart (Arevalo, Spagnolo, and Feinstein, 1963), and from postmortem studies (Abildskov, 1957). These techniques, however, have significant drawbacks, namely, that *x*-ray studies measure only gross changes in the atria and postmortem studies are non-physiological, static measurements. By cineangiography, however, a better demonstration of left atrial contour has permitted more accurate measurements to be made (Soloff and Zatuchni, 1958; Kasser and Kennedy, 1969). But in view of the invasive nature and complexity of this procedure its utility in evaluating a large population is limited

Echocardiography, on the other hand, has been shown to provide a good measure of the left atrium (LA) when compared with careful angiographic studies (Hirata *et al.*, 1969), hence providing us with an accurate noninvasive technique for obtaining anatomical measurements.

In the present study the validity of various electrocardiographic measurements believed to reflect left atrial enlargement was tested against echocardiographic measurements of the left atrium.

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Methods

Patients

A total of 48 subjects with various cardiac diseases was studied. Table 1 shows their diagnoses at the time of examination.

Electrocardiograms

12-lead electrocardiograms with 1 mV/cm standardization and a paper speed of 25 mm/s were obtained within 48 hours of the echocardiographic studies. Measurements were carried out without knowledge of the echocardiographic determinations. They included: heart rate, PR interval, PR segment, P axis, P height, and P width (PW), all derived from the limb leads. Lead V1 was used to measure P terminal force (PV1), as described elsewhere (Morris *et al.*, 1964 (Fig. 1A). The width of the P wave was determined in the limb lead in which it

was widest, generally lead II or rarely lead I, and measured with the help of a magnifying lens in the manner shown in Fig. 1B. The ratio PW/PR segment (PW/PR) (Macruz, Perloff, and Case, 1958) was also calculated.

TABLE 1

Diagnosis	*Number* *Men*	*Women*	*Total*
Aortic valve disease	3	0	3
Mitral valve disease	4	2	6
Hypertension	2	3	5
Ischaemic heart disease	9	3	12
Mitral valve prolapse	1	4	5
Combined valve lesions	3	1	4
Cardiomyopathy	2	1	3
Ventricular septal defect	1	0	1
Pericardial effusion	1	0	1
Aortic coarctation	0	1	1
Normals	4	3	7
Total			48

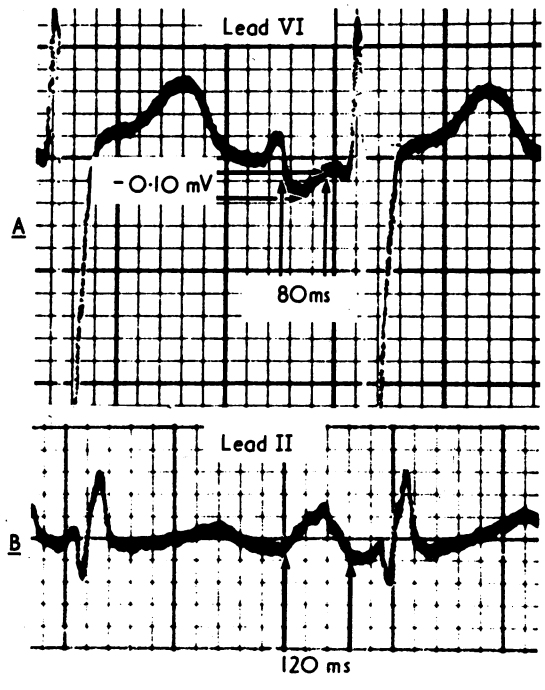

FIG. 1 *(A): Method of measurement of the P terminal force in lead V1, and (B) P wave duration in lead II.*

Echocardiograms

These were obtained in the dorsal decubitus position with a Unirad ultrasonoscope series 100 interfaced with an Electronics for Medicine VR6 strip chart recorder. Tracings were obtained at a paper speed of 25 mm/s, with the transducer positioned at the third or fourth intercostal space. On recognition of the characteristic mitral valve echo the transducer was tilted upward and medially in order to record the aortic root, at the level of the aortic leaflets, with the left atrium behind it.

Measurements were made at end diastole for the aorta and at end systole for the left atrium (Fig. 2) (Hirata *et al.*, 1969). The thickness of the aortic walls was not included in either measurement (Francis and Hagan, 1974).

Left atrial dimension

In patients with hypertension and/or aortic valvular disease the body surface area (BSA) (Dubois method) was used to obtain the atrial size index, expressed in cm/m² BSA. The upper limit of normal is 2 cm/m² BSA (Hirata *et al.*, 1969).

In the rest the aortic root diameter was the correction factor, as suggested elsewhere (Brown, Harrison, and Popp, 1974), left atrial measurements no greater than 120 per cent of the aortic root dimension being considered normal. Further absolute measurements which exceeded 3·8 cm, regardless of body surface area or aortic root size, were considered abnormal. This value represents approximately the mean ± 2 SD in the study by Francis and Hagan (1974), and corresponds to the normal values in our laboratory.

Those electrocardiographic measurements which showed statistically significant correlations with left atrial dimension were then tested for their ability to separate the left atria of normal size from those which were enlarged by measuring the standardized distance (Δ) between the two groups. A patient was considered to have an enlarged left atrium when the index, using the body surface area, was greater than 2 cm/m² BSA, his left atrial dimension was greater by more than 120 per cent of the aortic root size, or its measurement exceeded 3·8 cm, whichever was applicable to each case.

The standardized distance between two populations (in this case 'normal' and 'enlarged left atrium') is a measure of the performance of a given test (Snedecor and Cochran, 1971; Armitage, 1971) and was used here to assess the relative value of each of the electrocardiographic measurements. The specificity and sensitivity of these measurements were also determined.

Results

Table 2 shows the individual correlations and regressions for the electrocardiographic measurements versus the left atrial size. The highest correlations were observed for the PW (Fig. 3) ($r=0{\cdot}746$, $P<0{\cdot}00001$), PV1 ($r=0{\cdot}491$, $P=0{\cdot}00038$) and PW/PR ($r=0{\cdot}479$, $P=0{\cdot}00055$). The ability of each

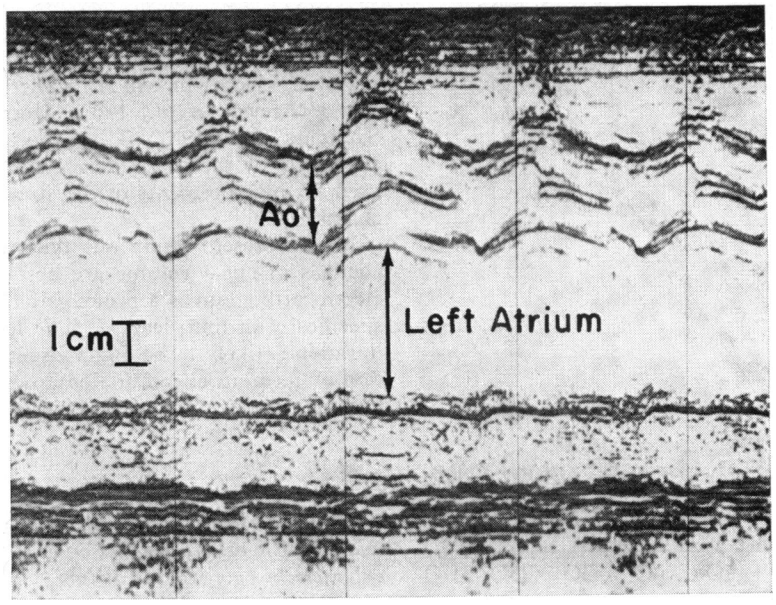

FIG. 2 *Echocardiogram showing the landmarks for measuring left atrial dimension and aortic root diameter (see text).*

TABLE 2 *Correlations of echocardiographic left atrial dimensions with ECG measurements*

	r value	*a*	*b*	*SEE*	*P*
PW	0·746	0·168	0·035	0·57	<0·00001
PV1	0·491	3·04	0·094	0·75	=0·00038
PW/PR	0·479	2·18	0·787	0·76	=0·00055
HR	0·152	2·79	0·0076	0·86	N.S.
PH	0·088	3·20	0·120	0·86	N.S.
PR	0·119	2·99	0·002	0·85	N.S.
P axis	0·181	2·869	0·009	0·85	N.S.

a=intercept; b=slope; SEE=standard error of estimate; PW=width of P wave; PV1=P terminal force in V1; PR=PR segment; HR=heart rate; PH=P wave height.

of these three parameters to separate normal from enlarged left atria was tested by measuring the standardized distance (Δ) between groups (Snedecor and Cochran, 1971). P width separated normals from patients with left atrial enlargement with the largest standardized distance value (1·529, as compared with 0·526 and 0·404 for the PV1 and PW/PR respectively) (Table 3).

When the upper limit of 3·8 cm is chosen as the only indicator of normal atrial size, regardless of corrections for body surface area or aortic size, P width measurements correctly identified all the patients with atria greater than 3·8 cm (100% sensitivity). There were, however, 4 patients who were misclassified (89% specificity). The cut-off point for the P width measurement was selected at 105 ms as the top normal limit. PV1 identified correctly 75 per cent of patients with left atria equal to or greater than 3·8 cm, but there were 6 misclassifications as abnormal (specificity=83%). The PV1 cut-off point was –4 mv ms. PW/PR ratio showed a sensitivity of 58 per cent and a specificity of 89 per cent (Table 4).

Discussion

The left atrium is affected directly by increased ventricular filling pressure, increased resistance across the mitral valve, or volume overload caused by mitral valve regurgitation.

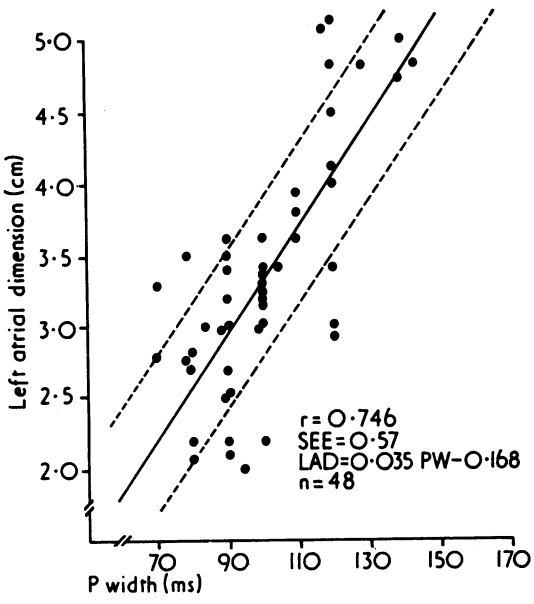

FIG. 3 *Correlation between echocardiographic left atrial dimension and P width from the limb leads of the electrocardiogram.*
SEE = Standard error of estimate. LAD = Left atrial dimension. PW = P wave width.

These haemodynamic alterations may be manifested as changes in atrial pressure and/or volume (Soloff and Zatuchni, 1958; Sauter *et al.*, 1964). Left atrial pressure increases are best reflected in the P wave configuration in V1 (Kasser and Kennedy, 1969; Heikkilä, Hugenholtz, and Tabakin 1973; Chandraratna and Hodges, 1973), whereas the P wave duration in the limb leads seems to correlate best with atrial volume changes (Macruz *et al.*, 1958; Kasser and Kennedy, 1969). There have been, however, studies in which conflicting results were found (Arevalo *et al.*, 1963; Morris *et al.*, 1964, Saunders *et al.*, 1967). These discrepancies can be explained by the different methods these authors used for measurements of the size of the left atrial chamber.

In the present study our findings indicate that changes in atrial volume are best reflected in the electrocardiogram as a prolongation of the P width specifically in limb lead II. The increased P wave duration is likely to be a consequence of prolongation of intra-atrial conduction time. Since intratrial pressures were not determined in the patients of this

TABLE 4 *Specificity and sensitivity of PW, PV1, and PW/PR ratio for detection of left atrial enlargement (normal left atrium < 3·8 cm)*

		PW +	PW −	Total	
Echo	+	12	0	12	Sensitivity = 100%
	−	4	32	36	Specificity = 89%
				48	

		PV1 +	PV1 −	Total	
Echo	+	9	3	12	Sensitivity = 75%
	−	6	30	36	Specificity = 83%
				48	

		PW/PR +	PW/PR −	Total	
Echo	+	7	5	12	Sensitivity = 58%
	−	4	32	36	Specificity = 89%
				48	

TABLE 3

		No.	*Mean*	*SD*	*SEM*	*t*	*P*	Δ
PW (ms)	N	29	92·4	13·3	2·48	5·1805	< 0·00001	1·529
	E	19	114·7	16·4	3·76			
PV1 (ms × mv)	N	29	−2·75	3·85	0·71	2·4932	= 0·016	0·526
	E	19	−5·19	5·69	1·30			
PW/PR Ratio	N	29	1·42	0·51	0·09	1·3671	= 0·178	0·404
	E	19	1·63	0·52	0·12			

N = normal left atrial size; E = enlarged left atrium; PW = P width; PV1 = P terminal force in V1 (see text); PR = PR segment; SD = standard deviation; SEM = standard error of the mean; Δ = standardized distance between N and E groups.

study, any statement as to the validity of the P in V1 as an indicator of atrial pressure overload cannot be made, but, as already mentioned, this has been clearly shown in previous investigations.

It is, therefore, concluded that when P width measurements in lead II of the electrocardiogram exceed 105 ms there is a high likelihood of increased left atrial size. When the measurement is less than 105 ms left atrial enlargement can be excluded almost entirely.

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