AUTOMATIC INTEGRAL FREQUENCY ANALYSIS OF THE ACCELERATION KINETOCARDIOGRAM

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Frequency and amplitude analysis of acceleration kinetocardiograms (KCGs) was carried out by means of an automatic integrator. Differences were found in the frequencies of the KCG components, depending on the place of recording (right or left ventricle) and the periods of cardiac activity. The basis of the KCG consists of vibrations in the low-frequency range from 4-12 Hz.

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Besides qualitative and quantitative methods, integral frequency analysis can be used to interpret kinetocardiographic curves. This implies extracting from the total signal of the kinetocardiogram (KCG) its regular periodic components and then carrying out frequency integration and measuring the parameters of these components.

Harmonic analysis of the displacement KCG led Andreev and co-workers [1] to the conclusion that mathematical expression of the shape of the curve in conjunction with clinical data extends the diagnostic possibilities. However, the method which they use, despite its undoubted virtues, is highly complicated and requires special knowledge in the field of mathematical analysis of harmonic oscillations.

We have used a method of automatic analysis of the frequencies composing the acceleration KCG.

EXPERIMENTAL METHOD

The KCG was recorded from the projection zone of the left and right ventricles in 50 persons (healthy subjects and patients with cardiovascular diseases). The KCG was analyzed by means of a Japanese EA-101

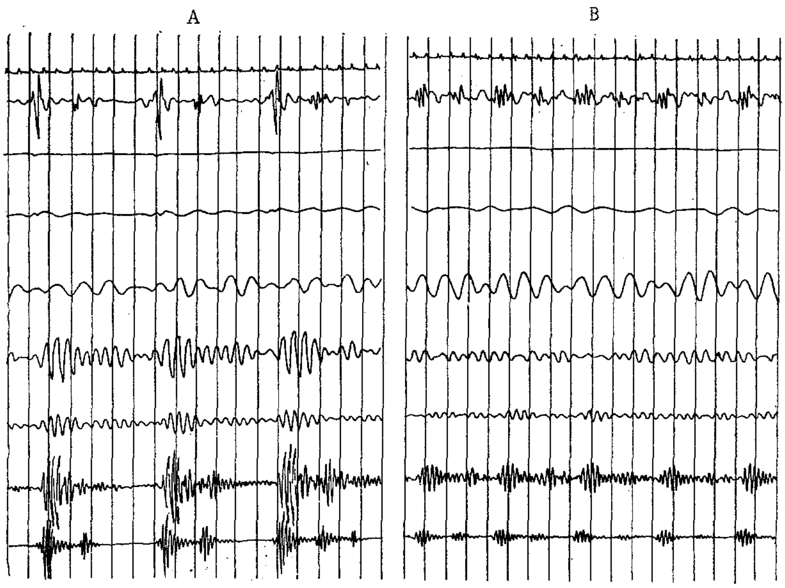

Fig. 1. Frequency components of left-ventricular (A) and right-ventricular (B) KCG (description in text).

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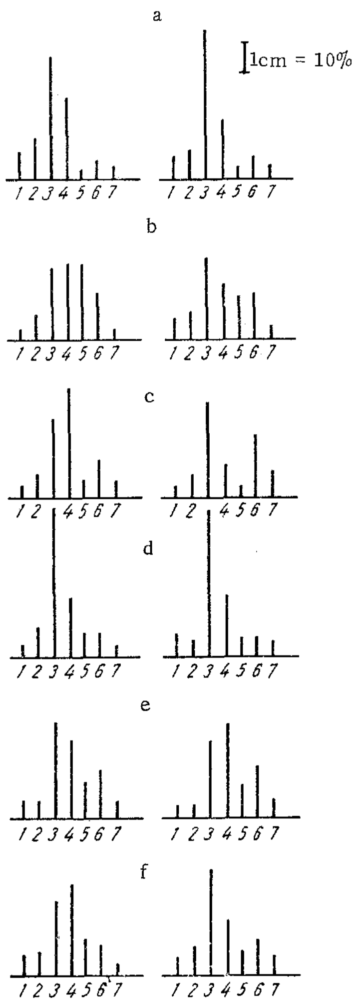

Fig. 2. Periodograms of KCG of right (on the right) and left (on the left) ventricles of patients with cardiovascular diseases: mitral stenosis (A), auricular fibrillation (B), aortic incompetence (C), essential hypertension (D), patent ductus arteriosus (E), and of healthy subjects (F). 1) 1-2 Hz, 2) 2-4 Hz, 3) 4-8 Hz, 4) 8-12 Hz, 5) 12-20 Hz, 6) 20-30 Hz, 7) 30-60 Hz.

automatic computer. An 8-channel inkwriting polygraph was used. The paper winding speed was 30-60 mm/sec.

For integral frequency analysis, the KCG was recorded on the first channel, and its components were recorded in parallel on the other seven channels, within the range from 1 to 60 Hz in the following frequency intervals: 1-2, 2-4, 4-8, 8-12, 12-20, 20-30, and 30-60 Hz (Fig. 1).

The components were integrated simultaneously by means of an integrator attachment, summating the isolated frequencies for a period of 10 sec and recording by means of a separate pen a periodogram consisting of 7 spurs (of an epoch), the amplitude of which reflects the oscillation energy of 7 types of frequencies (Fig. 2). The relative percentage of each frequency in the epoch was determined by the formula:

$$\frac{A}{A + A_1 + \cdots A_7} \cdot 100,$$

where A_1, A_2, and so on represent the amplitude of the epoch spurs in mm. No fewer than 5 epochs were recorded for frequency integration.

EXPERIMENTAL RESULTS

The analysis showed that on all investigated segments of the KCG there is a series of periodic components. Their number varied in different subjects from 5 to 7. The part of the ECG corresponding to the phase of isometric contraction contained mainly high-frequency components (30-60 min), but during the phase of asynchronous contraction, slower oscillations of the order of 4-8 Hz appeared. The segment of the curve corresponding to the phase of expulsion consisted of vibrations of the order of 8-20 and 20-30 Hz. The diastolic part of the kinetocardiogram consisted of lower frequencies (4-8 Hz). Slow vibrations (of the order of 1-4 Hz) were present in all parts of the kinetocardiogram constituting the cardiac cycle.

The amplitudes of the isolated frequencies also varied from units to tens of millimeters, but did not exceed 70 mm. Besides frequencies clearly visible on the KCG, the analyzer also detected a number of components not directly observable. A segment of the KCG of a healthy person recorded from the projection zone of the left ventricle is shown in Fig. 1A. In this case the frequency analyzer distinguished components with frequencies of 2-60 Hz and amplitudes of 2-36 mm, the maximum lying in the region of vibrations of 4-12 Hz. A segment of the KCG of the same person recorded from the projection zone of the right ventricle is shown in Fig. 1B: a shift toward lower frequencies, mainly in the range 4-8 Hz, can be observed, and the amplitude of the high-frequency component was considerably reduced. Statistical analysis of 100 epochs recorded on ten healthy persons is given in Table 1. It shows that the relative percentage reaches a maximum in the frequency regions of 4-8 and 8-12 Hz. The mean values of the first range are 25.2±2.2%, on the KCGs recorded from the projection zone of the left ventricle and 34.8±2.7% for the right ventricle ($P < 0.01$). Whereas in the range 4-8 Hz the amplitude characteristics of the KCG waves were higher for the right ventricle, in the range 8-12 Hz the amplitude of the spurs of the periodogram was greater for the left ventricle (30.4±2.1%) than for the right (17.9±1.9%) ($P < 0.002$). In the ranges 1-2, 2-4, 12-20, and 20-30 Hz, differences between the results obtained by frequency analysis of the KCG of the left and right ventricles were small and were not statistically significant, but in the range of higher frequencies (30-60 Hz)

TABLE 1. Relative Percentages of Frequency Components of Left-Ventricular and Right-Ventricular KCG of Healthy Subjects (M±m)

Zones of recording of KCG	Ranges of frequencies (in Hz)						
	1–2	2–4	4–8	8–12	12–20	20–30	30–60
Left ventricle	6,8±0,7	8,1±1,1	25,2±2,2	30±2,1	12,3±1,7	10,4±1,2	4,09±0,3
Right ventricle	7,5±0,6	0,7±0,9	34,8±2,7	17,9±1,9	10,6±1,8	11,4±1,1	6,7±0,9

differences between the frequency components were again found. On the integral curve for the zone of the right ventricle they amounted to 6.7±0.9%, compared with 4.09±0.3% for the projection zone of the left ventricle ($P < 0.05$).

To sum up, it can be said that the mechanical activity of the heart is accompanied by generation of vibrations, the energy maximum of which lies in the range of low frequencies (4-12 Hz), and which are evidently largely due to the kinematics of the heart.

LITERATURE CITED

1. L. B. Andreev, E. N. Bozdarenko, and N. V. Kovalenko, Kardiologiya, No. 6, 69 (1964).