A DOUBLE RATIO AS AN INDICATOR OF NORMAL FUNCTIONAL ORGANIZATION OF THE RESTING HUMAN CARDIAC CYCLE

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Nature is a set of cases of three-element organization of living constructions. An example of this organization of elements is the longitudinal organization of the limbs and digits of most warm-blooded animals. A double or complex ratio can be used as a criterion to describe certain properties of living three-element constructions [5]. The double ratio (W) in its general form for any four points (A, B, C, D) on a straight line, in the above order, is determined by the distances between them in pairs, by means of the equation:

$$W = \frac{(AB + BC)(BC + CD)}{BC(AB + BC + CD)}. \quad (1)$$

The double ratio may vary from 1 to ∞ depending on the ratios between the lengths of the segments.

The temporal functional structure of the human cardiac cycle is also a three-element construction: 1) the phase of preparation for ejection of blood (corresponding to the interval of asynchronous and isometric contraction); 2) the phase of ejection of blood (corresponding to the interval of isotonic contraction); 3) the phase of filling of the ventricles with blood (corresponding to the interval of diastole). It has been suggested that discovery of a quantitative relationship between the "composition" of the functional structure and the value of the double ratio may be an important step toward the explanation of the principles governing the temporal organization of pumping activity of the heart.

The aim of this investigation was to study the organization of the normal three-phase functional structure of the human cardiac cycle at rest, using a double ratio. The test object consisted of ECG traces in lead I for a group of healthy persons (51) aged 26-45 years.

EXPERIMENTAL METHOD

Limits of the phases of preparation, ejection, and filling on the ECG curve were established by mutual comparison of the ECG with the dynamocardiogram, phonocardiogram, sphygmograms of the aorta and carotid artery, volume curve of the left ventricle, and pressure curves in the left and right ventricles of the human heart [1, 6]. The double ratio was calculated in accordance with phase duration indicated in Fig. 1, by the equation:

$$W = (a + b)(b + c)/bd, \quad (2)$$

where a is the phase of preparation for ejection, b the phase of ejection of blood, c the phase of filling with blood, and d = a + b + c denotes the duration of the cardiac cycle.

EXPERIMENTAL RESULTS

Five cardiac cycles from each trace were analyzed by equation (2). In cases when we had in our records ECG traces of certain individuals for a period of several years, all traces available were analyzed. It was shown that at rest, despite considerable differences in the

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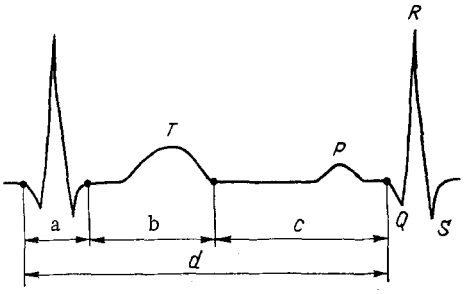

Fig. 1. Position of phases of preparation for ejection, ejection, and filling of ventricles with blood on curves of human ECG. a) Phase of preparation for ejection of blood, corresponding to interval from beginning of Q wave to point where S wave returns to isoelectric line; b) phase of ejection of blood, corresponding to interval from beginning of isoelectric line to end of T wave; c) phase of filling with blood, corresponding to interval from end of T wave to beginning of Q wave; d) duration of cardiac cycle.

values of a, b, c, and d for individual cardiac cycles, the double ratio for all subjects was virtually constant, i.e., it varies within very narrow limits. The value of the double ratio for the group of subjects within 95% confidence limits was 1.20 ± 0.03; deviations from the mean value did not exceed 2.5%.

As a result of additional calculations for determining mean statistical values of a, b, c, and d for the human left and right ventricles at rest [2], values of the double ratio were obtained, namely 1.20 and 1.21 respectively. Values of the double ratio calculated from mean statistical values of a, b, c, and d for age groups 20-29, 60-69, and 70-79 years [3] were 1.23, 1.21, and 1.22 respectively. Time intervals a, b, c, and d were measured by dynamocardiographic [2] and electrokymographic [3] methods. Calculations using results obtained by different methods thus gave virtually identical values of the double ratio. According to data in the literature [1], mean statistical values of a, b, c, and d for adults and children do not differ significantly. Consequently, neither age nor sex has any effect on the value of the double ratio.

Taking into account the facts described above equation (2) can be represented as follows:

$$\frac{\text{Interval ejection} - \text{filling phase}}{\text{Duration of cardiac cycle}} : \frac{\text{Ejection phase}}{\text{Phase of electrical systole}} \cong \text{const.}$$

The reason for constancy of the double ratio in healthy subjects at rest, irrespective of age and sex, is not yet clear. This phenomenon may perhaps reflect the optimal functional organization of the cardiac cycle at which ejection of unit volume of blood from the ventricles is associated with minimal expenditure of energy, in agreement with the principle of optimal construction of living systems [4]. However, there is no doubt that the double ratio can be used as a criterion of the pumping activity of the heart. Considerable deviations from the value of 1.20 must evidently correspond to certain heart diseases. In these cases the double ratio can be used as a diagnostic sign of disturbances of normal cardiac activity.

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