SIGNIFICANCE OF STATISTICAL CHARACTERISTICS OF THE SINUS RHYTHM OF THE HEART

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UDC 617-002.3-07:616.12-008.31-072.7:31

A statistical analysis was made of long continuous records of RR intervals of the ECG of 64 patients with pyogenic surgical infections. The following indices were examined: the mean RR interval ($\overline{RR}$), standard deviation (σ), range of variation (V), first and third correlation coefficients, excess, asymmetry, $\overline{RR}/\sigma$ ratio, and the form of the autoregression cluster. In three groups of patients differing in the severity of their condition, the values of σ, $\overline{RR}/\sigma$, and V were found to differ statistically significantly. These differences were clearly reflected in the size and shape of the autoregression cluster. The results suggest that the statistical chracteristics of long records of the cardiac rhythm can be used for the objective assessment of the severity of the patient's condition and the efficacy of his treatment.

KEY WORDS: cardiac rhythm; statistical analysis of the cardiac rhythm.

Physicians and physiologists are paying ever-increasing attention to the analysis of the principles governing the cardiac rhythm. During long recordings of RR intervals of the ECG, this type of analysis, with the use of statistical methods, has revealed a number of hitherto unknown principles. In particular, definite differences have been found in the characteristics of the sinus rhythm which the physician cannot detect by physical or the ordinary electrocardiographic investigation. These findings have proved very informative for the assessment of the state of healthy subjects and patients in widely different situations: during training and flights of astronauts [1, 4], during determination of the level of training of athletes [2, 5, 7], assessment of the degree of emotional and mental loading [12, 13, 14], postoperative observation of patients [3, 8, 9, 11], in patients with cardiovascular diseases and neurocirculatory dystonia [6], and so on.

No reference could be found in the literature to the study of the cardiac rhythm of patients with pyogenic surgical infections. Yet such investigations could be of great interest if they helped to obtain objective data reflecting the severity of the patients' condition. This was the main purpose of the investigation described below.

EXPERIMENTAL METHOD

The statistical indices of the cardiac rhythm of 64 patients with surgical infections were studied.

Depending on the severity of the suppurative process the patients were divided into three groups: group 1) patients with acute pyogenic infections with no marked toxic symptoms (25); group 2) patients with marked pyogenic-resorptive fever (19); group 3) patients with septicemia (20).

The EKG was recorded continuously for 2 min, after which the following statistical indices were calculated by computer: the mean value of the RR interval ($\overline{RR}$), the standard deviation (σ), the minimal and maximal values of RR, the range of variation ($V = RR_{max} - RR_{min}$), the first and third coefficients of correlation (ACF-1, ACF-3), the excess, asymmetry, and $\overline{RR}/\sigma$ ratio. The autoregression cluster also was examined as an integral graphic index, incorporating the first sixth of the statistical indices listed above. To plot the autoregression cluster, values of RR_i were plotted along the ordinate and RR_{i+1} along the abscissa, where i is the serial number of the RR interval. The advantage of the autoregression cluster over the other indices mentioned above lies in its clear reflection of the internal interdependence of the process. If internal interdependence is strong its shape is that of an ellipse with a long axis along the bisectrix of the angle of coordinates, whereas if it is weak, the cluster is either highly diffuse or highly compressed [10].

A. V. Vishnevskii Institute of Surgery, Academy of Medical Sciences of the USSR, Moscow. (Presented by Academician of the Academy of Medical Sciences of the USSR M. I. Kuzin.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 84, No. 11, pp. 628-630, November, 1977. Original article submitted April 15, 1977.

TABLE 1. Statistical Characteristics of Cardiac Rhythm (M ± m)

Group of subjects	$\overline{RR}$	σ	Range of variation	Asymmetry	Excess	ACF -1	ACF-3	$\overline{RR}/\sigma$
1	0,809±0,113	0,032±0,010	0,179±0,055	0,032±0,359	1,263±5,606	0,512±0,229	0,377—0,256	27,156±7,064
2	0,690±0,112	0,021±0,008	0,129±0,066	—0,126±1,996	7,363±22,7	0,656±0,221	0,450±0,208	35,60±11,502
3	0,626±0,087	0,009±0,003	0,045±0,017	0,065±0,584	0,493±1,460	0,274±0,342	0,385±0,221	78,05±18,465
Healthy persons*	0,909±0,151	0,069±0,033	0,302±0,105			—	—	—

*Data for healthy persons taken from Voskresenskii and Venttsel' [4].

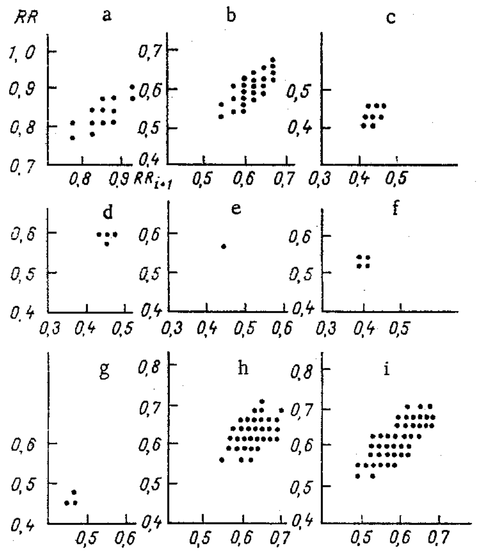

Fig. 1

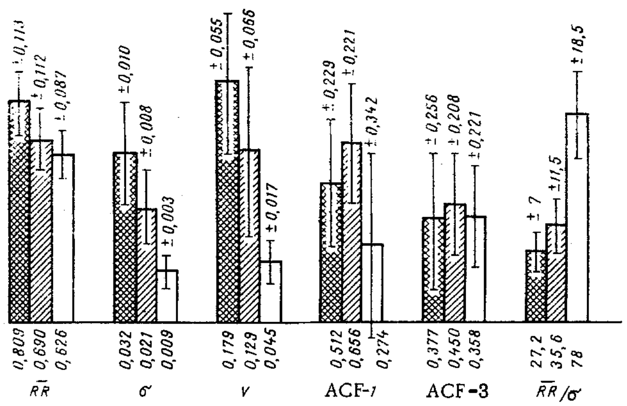

Fig. 2

Fig. 1. Appearance of autoregression cluster of different patients (in each case obtained by analysis of a continuous 2-min EKG record). a) Healthy subject; b) patient with mastitis but with no marked toxic manifestations; c) patient with pyogenic-resportive fever; d-f) patient with septicemia over a period of 6 months from admission until death; g-i) patient with septicemia during 3 months from admission until recovery.

Fig. 2. Values of statistical characteristics for patients with conditions of different severity. Cross-hatching) group 1; oblique shading) group 2; unshaded columns) group 3.

EXPERIMENTAL RESULTS

The autoregression cluster characterizing the sequence of RR intervals of the healthy subject at rest is shaped like an ellipse (Fig. 1a).

In the patients of group 1 the autoregression cluster in most cases, just as with healthy subjects, remained elliptical in shape (Fig. 1b). The statistical indices of the cardiac rhythm of the patients of this group are given in Table 1. Comparison of the results of statistical analysis of the cardiac rhythm of the patients of this group with the corresponding indices for healthy subjects shows very little difference.

In the patients of group 2 a marked decrease in $\overline{RR}$, σ, the range of variation, and the size of the autoregression cluster was observed (Fig. 1c). The $\overline{RR}/\sigma$ ratio was increased (Table 1). In most patients the cluster lost the elliptical shape characteristic of healthy subjects, reflecting a decrease in internal interdependence of the consecutive values of the $\overline{RR}$ intervals as observed in healthy subjects. With an improvement in the patients' condition a distinct tendency was observed for these indices to return to normal (an increase in size of the cluster, its return to an elliptical shape, normalization of the statistical indices).

Comparison of the results of statistical analysis of consecutive RR intervals of the patients of this group with the corresponding indices for healthy subjects revealed more marked changes in the cardiac rhythm than in the patients of group 1.

In the patients of group 3 the changes were severest of all. Definite stabilization of the rhythm, compression of the autoregression cluster, a decrease in RR, σ, and the range of variation, and an increase in the RR/σ ratio were observed (Table 1, Fig. 1d-f). The dynamics of changes in the autoregression cluster of patient L. during treatment is illustrated in Fig. 1g-i. This patient was admitted in a serious condition with suppurative mastitis, septicemia, and multiple metastatic abscesses and septic endomyocarditis. Her condition on discharge was good. The cluster illustrated in Fig. 1g corresponds to the patient's serious condition on admission, the cluster in Fig. 1h to an improvement in her state, and the cluster in Fig. 1i to her condition on discharge. Autoregression clusters plotted from the ECG of patient B., with suppurative mastitis, septicemia, and septic endomyocarditis, are illustrated in Fig. 1d-f. This patient's condition remained serious throughout her stay in the Institute, and her illness ended fatally. The autoregression cluster remained highly compressed all the time.

Within each group, the changes described above were more marked in the more seriously ill patients. As the results given in Table 1 and Fig. 1 show, with an increase in the severity of the patient's condition from group 1 to group 3, the values of $\overline{RR}$, σ, the range of variation, and size of the autoregression structure all decreased. The $\overline{RR}/\sigma$ ratio increased. Improvements in the patients' condition was reflected quantitatively by restoration of the normal statistical indices of the cardiac rhythm (Fig. 1g-i).

The severity of the state of the patients studied was determined not only by the severity of the suppurative process but also by the concomitant diseases. This fact was evidently reflected in the values of the statistical indices and was one reason for their scatter within each group. Nevertheless, when the patients were distributed by groups according to the severity of the suppurative condition, indices such as σ, V, and RR σ in these groups differed statistically significantly (Fig. 2). They differed particularly clearly in the patients of groups 2 and 3, and this is of considerable interest because when the ordinary signs are used to decide to which of these groups a particular patient belongs, the problem is frequently very difficult.

The statistical characteristics of the sinus rhythm thus varied with the severity of the patients' condition and they were connected with the development of their underlying disease. These general principles were reflected most closely by the $\overline{RR}/\sigma$ ratio, whereas the range of variation and ACF-1 were less sensitive characteristics. Indices such as excess, asymmetry, and ACF-3 were uninformative. The differences in the character of the sinus rhythm described above were discovered both by comparing the patients of the three groups, differing in the severity of their condition, and also in all cases of dynamic observation of individual patients.

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DETERMINATION OF THE NONUNIFORMITY OF VENTILATION BY THE HELIUM MIXING TIME IN THE LUNG – SPIROGRAPH SYSTEM

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UDC 616.24-008.4-072.7

Dependence of the helium mixing time in the lung–spirograph system of factors influencing its value was analyzed. In the case of uniform ventilation of the lungs graphs were plotted by means of which the "ideal" mixing time was determined. It is suggested that nonuniformity of lung ventilation be judged by the amount by which the mixing time obtained during investigation of the patient's respiration exceeds the "ideal" time found for the same patient from the graph.

KEY WORDS: ventilation of the lungs; helium method; residual lung volume.

The helium method is usually used to determine the residual lung volume. In the course of this investigation data are obtained on the time during which almost uniform mixing of helium takes place in the lung–spirograph system. Attempts are often made to judge the nonuniformity of the lung ventilation by the mixing time without allowing for how it depends on other factors: the longer the mixing time, the greater the nonuniformity of ventilation. However, the mixing time depends not only on the nonuniformity of lung ventilation, but also on indices such as the minute alveolar ventilation, the functional reserve capacity, the volume of the spirograph and initial helium concentration in it, and also on the experimental conditions. The problem thus arises of allowing for the dependence of the helium mixing time in the system on the factors listed above, so that the nonuniformity of alveolar ventilation can be estimated on the basis of this parameter.

The mixing time which the patient should have if his lungs were uniformly ventilated may be called the "ideal" mixing time. Clearly, the greater the nonuniformity of the patient's pulmonary ventilation, the more the mixing time will exceed the "ideal" value found for the same patient, other conditions being the same.

An equation was obtained for determining the "ideal" mixing time t:

$$t = \left(V_1 V_2 \ln \frac{c_0 u \Delta t}{\Delta c V_1}\right) : [u (V_1 + V_2)], \tag{1}$$

where V_1 is the volume of the spirograph (the bell and dead space of the instrument) before the beginning of the test; c_0 the initial fractional helium concentration in the spirograph; V_2 the functional residual capacity (FRC) of the patient's lungs determined during the investigation; u the minute alveolar ventilation (MAV); Δt and Δc parameters characterizing the conditions for stopping the investigation.

The time of stopping the investigation can be chosen in different ways by different investigators for this gives different interpretations of the degree of uniformity of mixing. In the general sense the conditions of stopping the investigation can be defined as follows: The investigation is stopped when changes in the helium concentration in the spirograph decrease to a certain small value Δc at time intervals Δt chosen for the observation. Since the aim of the investigation is to compare results obtained in practice with those calculated theoretically, it is important that during theoretical calculation the values of Δt and Δc be chosen to be the same as the conditions of stopping the investigation during experimental determination of the mixing time.

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 0007-4888/77/8411-1662$07.50