EXPERIMENTAL INVESTIGATION OF THE SVEC III ORTHOGONAL VECTOR-CARDIOGRAPHIC SYSTEM WITH A SIMPLIFIED Z LEAD

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Electrocardiograms and vector cardiograms were recorded experimentally by means of ordinary and simplified SVEC III recording systems. Comparison of the curves by a visual and a special mathematical method showed that electro- and vector cardiograms recorded by these systems do not differ significantly. Consequently, to determine the electrical vector of the heart it is possible to use a simplified system, which is much more convenient for practical measurements.

Corrected orthogonal systems of leads for vector cardiography possess many advantages which make them particularly suitable when automatic methods of processing the electrocardiographic information are used [2]. From the qualitative point of view one of the best corrected systems of leads is the SVEC III system [5]. However, during practical recording of the vector cardiogram by the SVEC system difficulties are encountered because of the large number of electrodes (14) which must be fixed separately to the subject's body at anatomical reference points. Particularly great inconvenience is caused by the placing of the four spinal electrodes of the Z_S lead. Because of the anatomical position of the heart in the chest and its known properties as an electrical generator, it was decided to replace the four spinal electrodes of the SVEC III system by one electrode located on the spine approximately opposite the geometric center of the cardiac ventricles. Theoretical calculations and experiments on physical models described in an earlier paper [3]

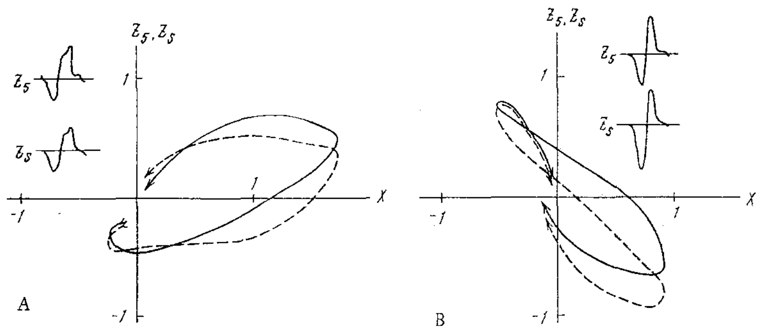

Fig. 1. Comparison of scalar electrocardiograms in Z leads and transverse projections of vector-cardiographic loop recorded by ordinary (broken line) and modified (continuous line) orthogonal system of SVEC III leads. Zones of QRS complex for two cases (A and B) with the most marked difference between the curves are shown as an example.

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showed that the suggested simplified Z lead with five electrodes (described as Z_5) is in no way inferior in its measuring characteristics to the ordinary 8-electrode Z_S lead.

To continue the investigation of whether the Z_S lead can be replaced by the Z_5 lead, an experimental synchronized recording of the EKG was made by means of the SVEC III system with the ordinary and simplified Z leads on a group of healthy subjects and patients to determine the extent to which the resulting curves differed.

EXPERIMENTAL METHOD

A group of men aged 20-65 years, consisting of 25 healthy subjects and 15 patients with various pathological changes of the ventricular myocardium was investigated. Signals from X_S, I_S, Z_S, and Z_5 leads were recorded synchronously on paper tape moving at a speed of 100 mm/sec by means of the Mingograph 42B instrument. The scalar curves thus obtained for the QRS complex were represented as samples taken every 5 msec with an accuracy of 5% of the maximal value. Projections of the vector cardiogram on the plane of coordinates were plotted from these samples. A visual comparison of the scalar electrocardiograms and the vector-cardiographic loops obtained by the use of Z_S and Z_5 leads was then made, and the same curves were compared by means of a special mathematical method using an electronic computer.

EXPERIMENTAL RESULTS

Visual comparison of the scalar and vector curves obtained by the two methods described showed their striking similarity; the scalar electrocariodgrams were hardly distinguishable, while the vector cardiograms had small relative displacements, although the basic features of their shape and the orientation of the loop were absolutely identical (Fig. 1). This raised the hope that ordinary diagnostic data obtained by the use of the orthogonal SVEC III system are suitable (perhaps with small corrections) for diagnosis when the suggested system is used with the simplified Z_5 lead also. Quantiative assessments of differences between the Z_S and Z_5 leads were obtained in order to take into account the possibility of automatic methods of processing the electrocardiograms on computers [4].

The method (algorithm) used in the investigation is a formal procedure which gives a consistent quantitative assessment of deviation of the shape of one curve from the shape of another if they "do not differ too much" from each other. The method remains unchanged, in principle, for comparison of scalar curves, two-dimensional, and three-dimensional vector loops. In this way, the appropriate assessments can be compared. The measure of difference in the shape of the curves is the ordinary relative standard deviation of one curve from the other; before calculation of this criterion, the curves to be compared are superposed on each other by means of a special transformation which had to compensate the following principal errors of measurement: displacement of the zero amplitude level of the signal, differences between the amplification factors of the channels, and the indeterminancy in time of the origin of counting the sample [1].

For instance, if the difference between two series of curves is to be assessed:

$$\begin{gathered} x_1(t),\ x_2(t),\ \dots,\ x_n(t) \\ y_1(t),\ y_2(t),\ \dots,\ y_n(t) \\ a \leqslant t \leqslant b, \end{gathered}$$

the measure of the difference is the value of ε_n determined by the relationship:

$$\varepsilon_n^2 = \frac{\min\limits_{e} \int\limits_0^1 \sum\limits_{i=1}^{n} \left[x_i(\varphi(\tau)) - \sum\limits_{j=1}^{n} l_{ij} y_j(\psi(\tau)) - l_{i,n+1} \right]^2 d\tau}{\int\limits_0^1 \sum\limits_{i=1}^{n} x_i^2(\varphi(\tau)) d\tau},$$

where $\varphi(\tau) = t$ is the inverse function relative to the function

$$\tau = \xi(t) = \frac{\int\limits_a^t \left[\sum\limits_{i=1}^{n} \left(\frac{d}{dt} x_i(t) \right)^2 \right]^{\frac{1}{2}} dt}{\int\limits_a^b \left[\sum\limits_{i=1}^{n} \left(\frac{d}{dt} x_i(t) \right)^2 \right]^{\frac{1}{2}} dt}.$$

and, similarly, $\psi(\tau) = t$ is the inverse function relative to the function

$$\tau = \eta(t) = \frac{\int_a^t \left[\sum_{i=1}^{n} \left(\frac{d}{dt} y_i(t) \right)^2 \right]^{\frac{1}{2}} dt}{\int_a^b \left[\sum_{i=1}^{n} \left(\frac{d}{dt} y_i(t) \right)^2 \right]^{\frac{1}{2}} dt}.$$

For scalar curves $n = 1$, for two-dimensional loops $n = 2$, and for three-dimensional loops $n = 3$.

Parameters of transformation of the curves and values of the criterion of difference were calculated on the BESM-3M electronic computer.

The resultant standard deviation between the curves obtained by the use of Z_S and Z_5 leads was 0.13 ± 0.04 for the unidimensional (scalar) case, 0.07 ± 0.02 for the two-dimensional case, and 0.05 ± 0.01 for the three-dimensional case. The slight deviation (on the average 13%) between the scalar signals of the Z_S and Z_5 leads thus leads to an even smaller deviation between the corresponding vector cardiograms (on the average 5%), which is of the same order of magnitude as the instrumental errors of electrocardiographic recording. This confirms that the suggested modification of the Z lead of the SVEC III system virtually does not change the measuring characteristics of this lead. Consequently, for orthogonal vector cardiography it is expedient to use a modified system of leads possessing the same diagnostic criteria as the ordinary SVEC III system, but much simpler and more convenient in use.

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