COMPUTER ANALYSIS OF VENTRICULAR ACTIVITY IN THE PRESENCE OF ATRIAL FIBRILLATION

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Abstract:

A complete system is described for the processing and analysis of cardiac spike activity. The emphasis is put on the detection of the following features of the spike train data: stationarity, rhythmic patterns, and serial dependence between intervals. The operation of the system is illustrated with the analysis of a sample of ventricular responses to atrial fibrillation in the dog.

The ventricular response to atrial fibrillation is highly disorganized and the mechanisms creating or significantly influencing the ventricular irregularity are poorly understood. Some of the features of ventricular activity which appear of interest in regard to this problem are the distribution of RR intervals, the mean interval length and its variance, the degree of stationarity of the data and the dependence between intervals. It is the purpose of this paper to describe a computer system in which methods of analysis suitable for the extraction of these various features have been implemented.

The system developed in this laboratory (1,2) is centered around a PDP-9 computer (Digital Equipment Corporation) equipped with standard accessories: teletype, oscilloscope display, Dec-tape and Calcomp plotter. It is suitable for the analysis of a wide variety of biological data, either of the discrete or continuous type. In regard to the kind of bioelectric signals considered here, the analyses described below are available. Their application to the study of ventricular activity during atrial fibrillation is illustrated in Fig. 1.

1) Visual examination of the data

A short recording of cardiac activity during atrial fibrillation is shown in the inset to part A of Fig. 1: right auricular electrogram (RA) and electrocardiogram (ECG). The sequence of RR intervals stored in the computer can be displayed in real time for visual examination by the experimenter. In part D, a train of computer-produced spikes representing the ventricular activity has been reproduced on the Calcomp plotter.

2) Average frequency (Part B)

The average frequency of ventricular activity (spikes/sec) may be plotted continuously if desired. The presence or absence of marked trends in the average frequency is used as an indication of the degree of stationarity of the data.

3) Histograms of intervals (Part A)

The operator can compute and display interval histograms for 5000 intervals or less. The scale of the ordinate is divided by the total number of intervals in order to have an estimate of the underlying probability density function. The stationarity of the data is evaluated further by comparing interval histograms for sub-samples of arbitrary size; usually, partial interval histograms for each quarter of the sample of RR intervals are computed and compared.

Joint interval histograms can be obtained also. These may serve for a preliminary evaluation of the dependence between intervals.

4) Serial correlation coefficients (Part E)

This test is used to evaluate the degree of dependence between successive intervals. It is sufficient to make the computation up to lag 20 since serial dependence beyond that limit is not usually significant. For comparison, the serial correlogram for mixed (random shuffled) RR intervals is given also in order to provide a reference case in which all kinds of dependence between intervals have been destroyed.

5) Normalized expectation density (Part C)

The expectation density is normally used to detect periodicities in the time of arrival of the spikes. The same computation after random shuffling of the intervals gives the autoconvolution curve. It is convenient to normalize these curves relative to the mean ventricular frequency in order to express the relative changes in the probability of occurrence of a given interval in terms of an average probability value of unity.

6) Normalized transition matrix (Part F)

This method gives information about the dependence between intervals, complementary to that provided by the serial correlation coefficients and the normalized expectation density. It is sensitive to all types of dependence, linear or non-linear, and is applicable to any sequence of intervals. A statistical test of significance can also be used to evaluate the overall degree of serial dependence in the sample (3).

These methods were used for the analysis of ventricular activity in the presence of atrial fibrillation. The experiments were performed on dogs anesthetized with intravenous pentobarbital (30mg/kg). Under artificial respiration with a Harvard pump, the chest was opened through the right 5th intercostal space, and the heart cradled loosely in the incised pericardium. Atrial fibrillation was induced by the application of methacholine chloride to the anterior surface of the right atrium, followed by light mechanical stimulation (4).

The application of these methods of analysis to the particular sample of ventricular activity considered in Fig. 1 leads to the following conclusions:

a) The sample of RR intervals is stationary to an acceptable degree.

b) There is a significant dependence between any two consecutive intervals, in the sense that an interval of a given length is usually followed by an interval of about the same length.

c) There is no significant dependence between non-consecutive intervals.

d) There is no periodicity in the time of occurrence of the individual ventricular discharges.

e) There is a periodicity in the interval lengths (period of 204 msec) corresponding to the modal value of the interval histogram.

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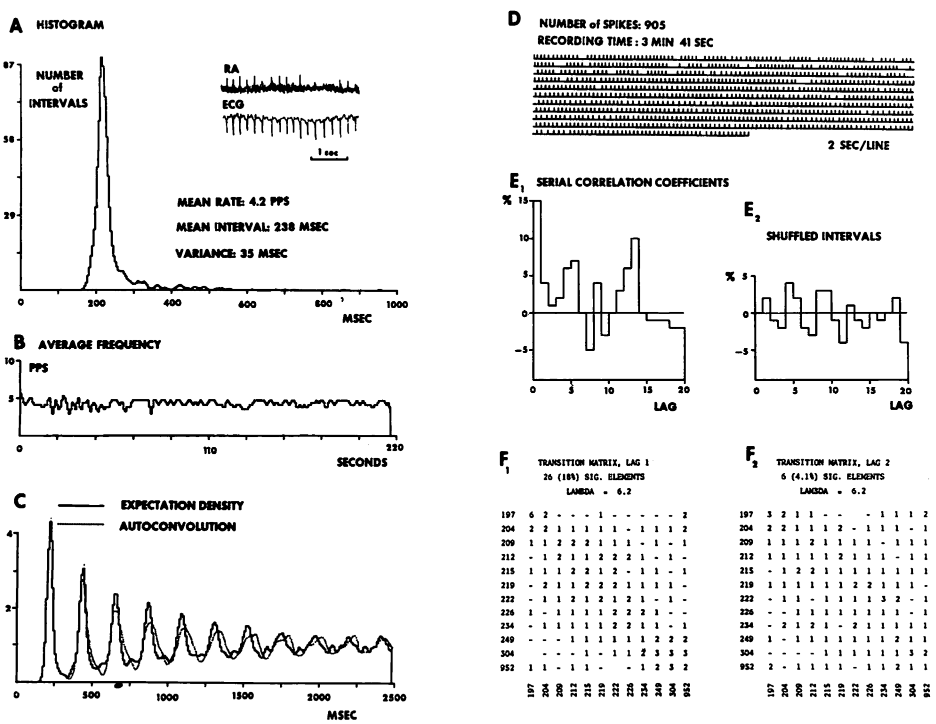

Figure 1