Autocorrelation of Electrocardiographic Activity during Ventricular Fibrillation

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Mathematical analysis of periodic and semiperiodic functions by the use of special electronic computers was applied to electrocardiographic recordings of ventricular fibrillation from hypothermic dogs. Preliminary experiments revealed a definite periodic component 1 to 3 min. after onset of fibrillation which practically disappeared in 5 min.

The electric activity of the fibrillating ventricle is often described as completely asynchronous, which may be taken to imply that the electrocardiographic record of such activity reflects a random combination of individual components. However, extensive cinemato- graphic studies by Wiggers and associates suggested that the degree of asynchronism may vary at different stages of the process.

The purpose of the experiments reported here was to explore whether the technic of autocorrelation could be applied to the study of ventricular fibrillation in evaluating the degree to which it is composed of random or periodic components.

Autocorrelation is a method of mathematical analysis which detects and extracts any periodic components present in a record which, on inspection, may show an apparently irregular type of activity. The theory and some of the applications of the method have been reviewed by Wiener. Basically, it is a method of harmonic analysis with major emphasis on information about fundamental period. Such a period of regular oscillation, if present, will be apparent even in the case where the irregularities in the original record are so large as to almost completely mask the regular function. In essence, the analysis consists of correlating each point of the curve with another in the same curve occurring at a fixed time interval later. If a periodic component is present, the correlation will be highest when this interval is equal to the periodicity of the component. Thus, an autocorrelation analysis involves a very large number of computations which, for all practical purposes, can be performed only through the use of electronic computers. This method has been applied in the analysis of electric patterns associated with brain activity (EEG) and records of intestinal motility.

In the present studies, ventricular fibrillation was induced in dogs by the use of hypothermia in combination with mechanical stimulation of the ventricle. Hypothermia was used primarily to avoid the complications of rapid, progressive anoxia of the myocardium, and because the hypothermic ventricle is highly susceptible to the development of fibrillation. The facilities of the specially constructed recorder and analog computer of the Research Laboratory of Electronics at the Massachusetts Institute of Technology were kindly made available for these studies.

The analysis of the results from an animal 1 to 3 and 5 to 7 min. after the onset of ventricular fibrillation is shown in figure 1 with sections

![Fig. 1. Autocorrelation analysis of ventricular fibrillation in a hypothermic dog (heart temperature 19.5 C.), and parts of concurrent electrocardiogram (lead II). In the correlogram each recorded line represents the autocorrelation function over the entire record (2 min.). The height of the line represents the relative magnitude of the function. The delay time (r) is shown on the abscissa, each large interval on the record representing 0.2 sec. and the ∆r (between recorded lines) is 10 msec. A., 1 to 3 min. following onset of fibrillation; B, 5 to 7 min. following onset of fibrillation.](http://circres.ahajournals.org/doi/10.1161/01.RES.5.6.657)
from concurrently obtained electrocardiographic records. The analysis of record A shows the presence of a definite periodic component, while that of record B shows no definite periodicity with the possible exception of a very slow component with relatively low autocorrelation coefficients. In fact, the total activity was considerably reduced in the second record compared to the first. This is apparent in the electrocardiographic recordings and can be quantitatively determined by comparing the magnitude of the first autocorrelation coefficient in each of the correlograms. Similar results were obtained from other electrocardiographic leads in this and in another animal. Each correlogram represents the analysis of an electrocardiographic record of 2 min. duration.

These findings suggest that ventricular fibrillation has an early phase with definite periodicity which is soon followed by a later phase of relative asynchronism. The fact that this latter phase develops only a few minutes after the onset of fibrillation even in the hypothermic myocardium argues against the possibility that anoxia may play a role in its development.

The first phase probably corresponds to the period termed *convulsive incoordination* by Wiggers and associates, while the second phase may correspond to the period of *tremulous incoordination* (Herzzittern). The very early and very short period of *tachysystole* was not included in the analysis of the first record.

These pilot experiments indicate that autocorrelation may be a useful tool for the accurate analysis of the various types of ventricular fibrillation resulting from different stimuli and under different conditions. Furthermore, the results of autocorrelation may be subject to further analysis by Fourier transformation, again with the aid of electronic computers. This latter analysis will give quantitative measures of the characteristics of the various periodic and random components present.

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