XXIII. CARDIOVASCULAR SYSTEMS[*]

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A. STATUS OF RESEARCH

Work has continued on the analysis of the blood-pressure regulatory system, with emphasis placed on the detailed understanding of the functioning of the components that constitute this system. Arnold N. Kramer and Michael C. Raezer completed Bachelor's theses on "Irregularities in the Normal Heart Beat: A Statistical Analysis," and "Nerve Firing Patterns of Cardio-Inhibitory Vagus Nerve Fibers," respectively. A short account of their results follows.

1. Irregularities in the Normal Heart Beat: A Statistical Analysis

It has been observed[1] that the heart period (reciprocal of heart rate) of chloralose-anaesthetized dogs becomes irregular when high blood pressure raises heart period above a critical value. This is illustrated in Fig. XXIII-1, which shows that to the right of arrow B the heart period undergoes very large and sudden variations. Similar results can be obtained by raising the heart period with morphine. The origin of these irregular beats is vagal, since atropine or the sectioning of the vagus nerves abolishes the effect. The ECG appears to be completely normal during these irregular beats: neither the P-wave nor the P-Q interval shows any discernible change.

Although some results have been reported on the statistical properties of heart period during atrial fibrillation,[2,3] the irregularity during normal beating described above does not appear to have been studied. The purpose of this work is to obtain preliminary results on some of the statistical properties of these irregular beats. The techniques that are used are similar to those described by Gerstein and Kiang[4] and Rodieck et al.[5] for the analysis of interspike intervals of auditory neurons. Throughout the investigation great care is exercised to choose stretches of stationary data, since the results vary with the depth of anaesthesia of the experimental animal.

An illustration of the results obtained in a dog during a run consisting of 379 cardiac cycles is shown in Fig. XXIII-2. Figure XXIII-2a shows the distribution of heart periods
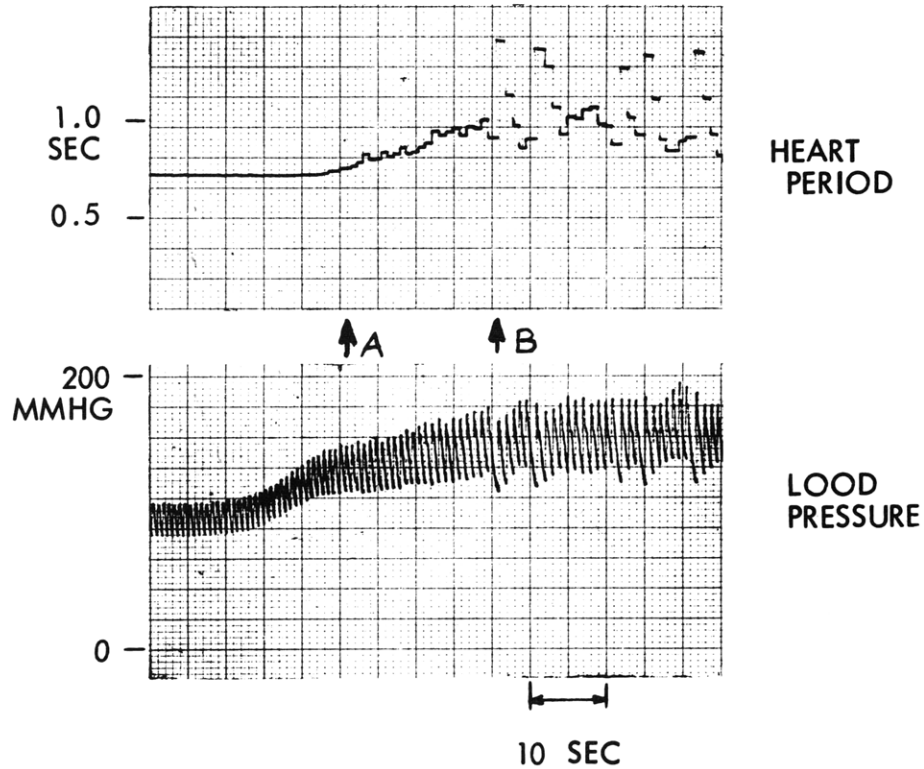

Fig. XXIII-1. Development of irregular heart rate at a high level of
blood pressure and heart period. The pressure was
raised by the infusion of Levophed.

in the form of a histogram, while Fig. XXIII-2b displays dependence between successive heart beats in the form of a joint interval histogram.[5] Figure XXIII-2c and 2d shows conditional histograms. The first one gives the distribution of heart periods of those beats that follow a short beat (shorter than the average), and the second gives the distribution of heart periods of those beats that follow a long beat (longer than the average). Figure XXIII-2e is a plot of the average heart period as a function of the duration of the preceding beat. These values of the "conditional mean" can be obtained by the averaging of vertical slices of the joint interval histogram.[5] Finally, Fig. XXIII-2f is a stretch of the original record, showing heart period as a function of time. Each jump corresponds to one heart beat.

The interesting feature of this record is that the heart period is mainly clustered about three values. This is shown by the three peaks in the histograms, the three clusters of points in the joint interval histogram, and the three horizontal bands of density in the original recording. The plot of conditional means indicates that, on the average, long beats tend to follow short ones, and short beats to follow long ones.
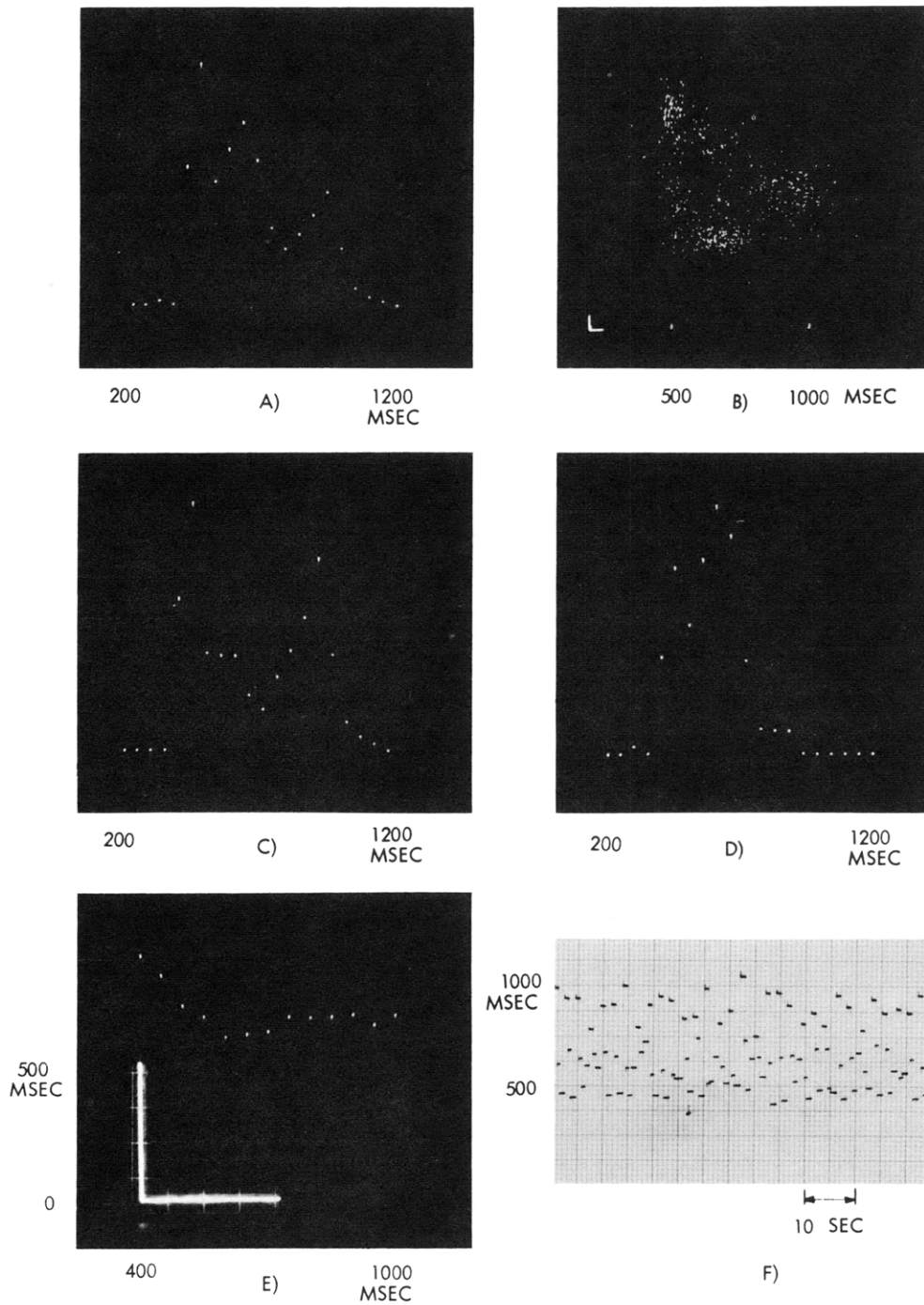
Fig. XXIII-2. Distribution of lengths of irregular heart periods. (a) Histogram. (b) Joint interval histogram. (c) Conditional histogram of beats following a short beat. (d) Conditional histogram of beats following a long beat. (e) Conditional mean vs length of previous heart beat. (f) Heart period vs time.

2. Nerve Firing Patterns of Cardio-Inhibitory Vagus Nerve Fibers

It is well known that the heart rate is influenced by the sympathetic (accelerator) and vagus (decelerator or cardio-inhibitory) nerves. It is also known that short, transient changes of blood pressure affect the speed of the heart primarily through the vagus nerves. As part of the pressure regulatory reflex, a rise in the pressure reflexly increases the vagal firing frequency, thereby slowing the heart, while a drop in the pressure inhibits vagal firing and causes an increase in heart rate.

Recently, several characteristics of the control loop which changes heart rate as a result of a change in blood pressure have been described.[1] The system was shown to be nonlinear, but the physiological mechanism responsible for the nonlinearity was not determined. In order to characterize the system more completely, it is desirable to record the neural activity both on the afferent (pressure receptor) and efferent (vagal) side. This work is concerned with the recording and analysis of the efferent cardio-inhibitory vagal activity.

Reports of successful recordings from the efferent vagal fibers have appeared quite recently. Weidinger, Hetzel and Schaefer[6] have reported that, in the cat, small vagal fibers in the vicinity of the heart show discharges with a cardiac rhythm. Calaresu and Pearce,[7] however, failed to see any activity with a cardiac rhythm in the cervical vagus of the cat, and questioned the accuracy of the findings of Weidinger. Shortly before this, Jewett[8] reported recording from cardiovascular fibers of the cervical vagus of the dog. These fibers showed cardiac synchronization, although the initial burst of activity shortly following the systolic rise of the blood pressure was not nearly as conspicuous as is the well-known, sudden increase in the activity of the pressure receptors during the steep rise in the pressure.

Thus far, we have recorded efferent vagal activity from the cervical vagus of three anaesthetized dogs and one cat. Computer analysis has shown that out of the 37 firing patterns examined, 22 exhibited a cardiac rhythm. Three of these recordings were obtained from the cat. For several preparations it was demonstrated that a slowing of the heart was preceded by an increase in vagal firing frequency.

Further work is being done on the quantitative characterization of the relationships between blood pressure and efferent vagal firing frequency, and between efferent vagal firing frequency and heart rate.

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