The Tohoku Journal of Experimental Medicine, Vol. 60, No. 2, 1954

Experimental Studies on the Mechanism of the Auricular Flutter

By

Eiichi Kimura, Kazuzo Kato, Satoru Murao, Hidero Ajisaka,
(木村 榮一) (加藤 和三) (村尾 覺) (鰺坂 秀朗)
Shintaro Koyama and **Zenkichi Omiya**
(小山 晋太郎) (大宮 善吉)

From the Medical Clinic of Prof. T. Nakamura, Faculty of Medicine, Tohoku University, Sendai and the Mikamo's Department of Internal Medicine, University of Tokyo, Medical School, Tokyo

(Received for publication, September 17, 1953)

It is a well known fact that there are two hypotheses on the nature of auricular flutter, namely, ectopic theory[1)-5)] and the circus movement theory[6)-15)]. Lively discussion is still being conducted between the said two theories. The Journal, " Circulation " of April 1953, has taken up this disputing issue[16)].

Most noteworthy research results obtained recently, with respect to this problem, are the experiments by Rosenblueth[12)13)] and the analysis of Prinzmetal[5)]. When auricular muscle is electrically stimulated, fibrillation easily occurs but flutter is difficult to be induced, as experienced by any persons who tried to produce an auricular flutter experimentally. However, Rosenblueth has discovered that the flutter can be easily induced by electrical stimulation after blocking the muscular bridge between the orfices of superior and inferior venae cavae. This phenomenon is explained by Rosenbleuth as follows: " It suggests that the infrequency of occurrence is due to the difficulty of initiating one-way flutter waves around the dual obstacle. Even though a one-way impulse may meet one of the cavae end-on, and thus propagate unidirectionally around it, the presence of a bridge of conducting tissue between the two vessels will usually lead to two-way conduction around the second cava, with a cancellation of the two wave fronts." After the blocking, the cancellation does not occur, therefore the flutter is easily induced. Accordingly, Rosenblueth advocates that the phenomenon in his experiments support the circus movement theory.

On the other hand, research of Prinzmetal[5)] is an observation on the auricular flutter induced mainly by aconitine, demonstrated by a high speed color film; according to this observation, the contraction wave started at the injected area spreading to whole auricular muscle. Of course, this supports the ectopic theory.

Which of these two opposite facts corresponds to an auricular flutter observed in the clinical cases is an interesting problem. Main object of our experiment has been directed to this point.

Experimental

Experiments to blook a Muscular Bridge between the Orfices of Superior and Inferior Venae Cavae

In the first place we attempted to ascertain whether the auricular flutter would occur easily after blocking the muscular bridge between the orifices of superior and inferior venae cavae as observed by Rosenblueth.

Animal used for experiments was dog weighing 5–10 kg., with the use of a narcosis by intravenous injection of pentothal or evipan. Chest has been opened, cutting pericardium, exposing heart. The muscular bridge has been compressed by 3–4 Pean's forceps, thus blocking the same. An electric stimulation has been employed by thyratron, 500–600 cycle per minute frequentcy of which has induced the auricular flutter. Flutter did not occur so easily by a frequency other than the said cycle. Frequency of flutter wave induced by this cycle was 450–550 cycle per minute, slightly less than the cycle at the stimulation.

By this stimulation in all cases where forceps we used, it was possible to induce an auricular flutter as shown in Table I. But in some cases where no forceps were employed, it was impossible. Moreover, although flutter occurred easily where forceps were used, while without forceps flutter occurred only when electric stimulation has been applied repeatedly. Flutter which occured without forceps usually stopped in a short period, but with forceps the flutter has sometimes continued as long as one hour. Above observation verifies the results of Rosenblueth. Furthermore, it was not recognized that flutter does not occur unless stimulation is applied to a special region. Flutter sometimes occurs even under stimulation of the appendage.

Table I

	Total number of experiments	Auricular flutter occurred	Auricular flutter did not occur
Without blockade	20	13	7
With blockade	24	24	0

Analysis of the Intra-auricular Conduction of the Excitation Wave

Since Lewis' investigation[6-9], analysis of intra-auricular conduction is being made by comparing the intrinsic deflections, same as in analysis of the intra-ventricular conduction.

However researches conducted heretofore have been made mainly with respect to right auricle and no detailed observation has been made with respect to left auricle. This is due to the fact that left auricle is hidden behind the heart and very difficult to be explored. However, we thought that one of the reasons for not clearly defining the nature of auricular flutter is because the propagation of excitation in left auricle is not well observed.

So, electrodes of solder balls made of silver have been chained together by one insulated tape (Fig. 1), and the surface of left auricle has been explored by inserting this tape between both venae cavae and pulmonary veins. Leads from right auricle were made by needle electrodes. One of these leads or an intra-auricular cavity lead has been employed as a standard curve.

a) Sinus rhythm: The excitation process in the sinus rhythm analyzed by the method stated above is shown in Fig. 2 as a control.

Fig. 1

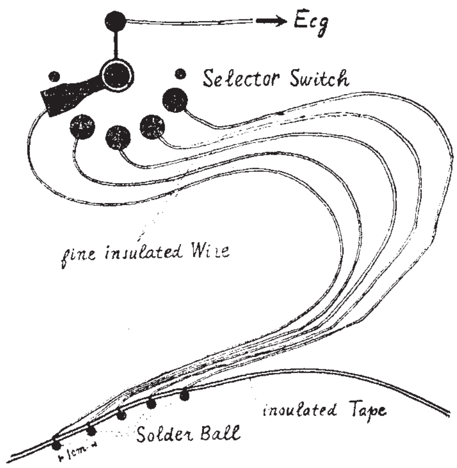

Fig. 2

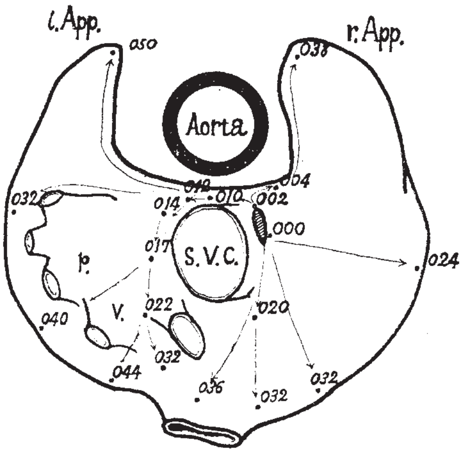

Fig. 1. A diagram of the electrodes used in direct leading from the left auricular surface.

Fig. 2. (No. 35, Exp. 1). Outline of the surface of a dog's auricle, showing readings for the arrival of the excitation wave during the sinus rhythm. The auricular cycle is 0.310 sec.

b) Aconitine flutter: Scherf[1)-4)] and Prinzmetal[5)] have studied the flutter which has been induced by injection of aconitine into auricular muscle as the object of their observation.

When 0.1–0.2 cc. of 0.05% water solution of aconitine is injected intramuscularly at any given region of an auricular muscle, a flutter-like condition occurs after a while. Fig. 3a shows the record of this condi-

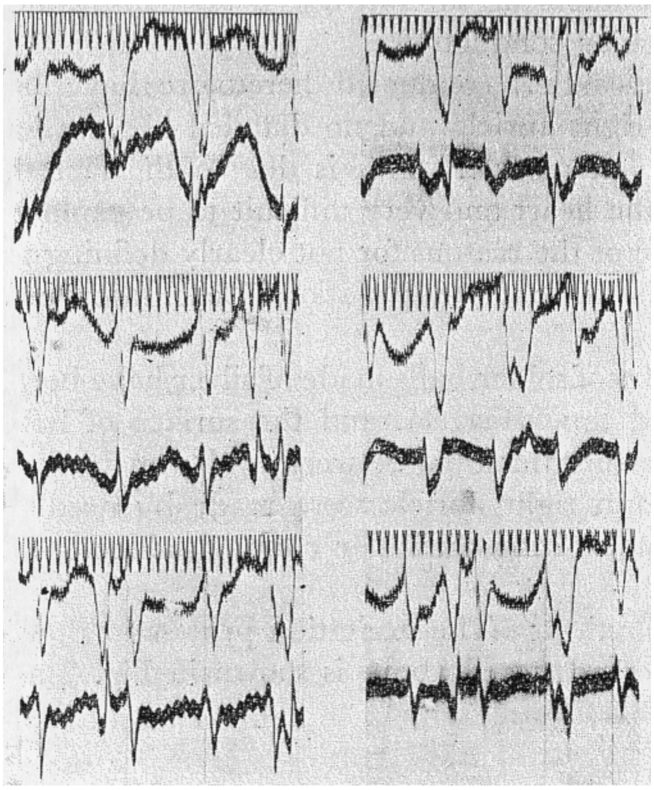

Fig. 3a (No. 35, Exp. 2). Curves taken by direct leads from the surface of an auricle during the flutter induced by injection of aconitine solution at right appendage. The curve taken simultaneously from left lower region is shown upper. The time figure shown at sides of the curves are the interval between the intrinsic deflections of the upper and lower curves. − and + indicate " before " and " after " the control intrinsic deflection.

tion. Analysisng the time relation of the intrinic deflections thereof, then the result that the excitation starts at an injected area and propagates through the whole auricular muscle, was obtained, as shown in Fig. 3b. Experiments were repeated eight times and the results of all experiments were same. Intrinsic deflections in these experiments were grouped in a short period of an auricular cycle, differing from electrically induced flutter which is explained below.

c) Auricular flutter induced by electric stimulation: Figures 4b and 5b are the analysis of propagation of excitation in auricular flutter induced by electric stimulation.

Analysing a time relation of its intrinsic deflections, they are distributed in order around the orfices of both venae cavae. Moreover, they are scattered all over one auricular cycle. This is judged to be a circus movement of excitation wave along the pathway as shown in Fig. 4b and 5b. Zero (0) indicated in the Figures does not mean that the excitation wave starts at this point; it merely means that the intrinsic deflection of this region is used as a standard of time analysis.

a

b

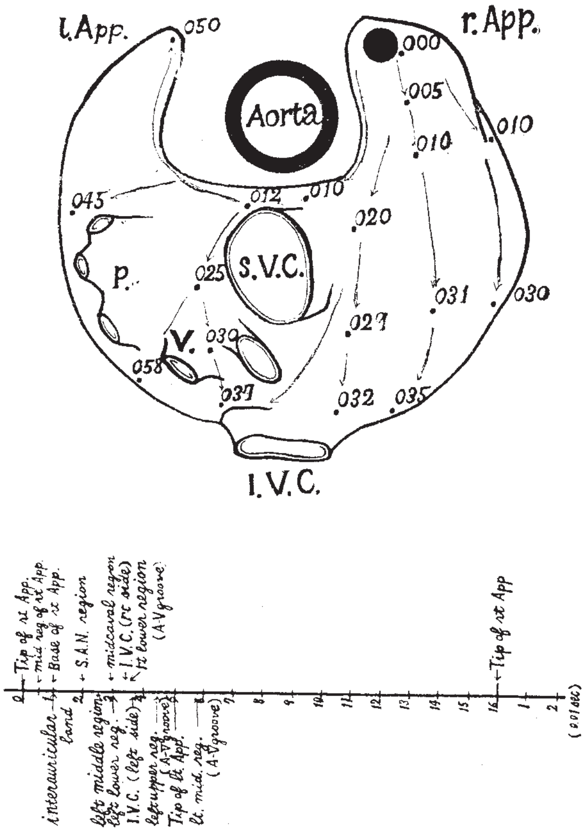

Fig. 3b (No. 35, Exp. 2). (a) Outline of the cephalic surface of a dog's auricle, showing the reading for the arrival of the excitation wave in the case of Fig. 3a. Aconitine solution was injected at the black shadowed portion. (b) A chart showing the time relation of readings from the surface of the auricle during the same flutter.

Twenty-six experiments were attempted and in each case the findings considered to be a circus motion has been obtained. Direction of circus motion is clockwise in some cases and counterclockwise in others, seeing from cranial side. Fig. 4 is a sample of a clockwise circus movement and Fig. 5 is that of a counterclockwise. No relation exists between the direction of circus movement and method of applying stimulation (seat of stimulated region, direction of the poles of stimulating electrodes, etc.). Of twenty-six experiments clockwise was eighteen and counterclockwise was eight. Also in the flutter induced without forcepts, it was possible to obtain a figure of circus movement (Fig. 6).

Further Observations on the Rosenblueth's Flutter

If the excitation is to move in circular way then the next problem will be where is the path of this movement. It is well known that the taenia terminalis was assumed by Lewis[6]. But according to Rosenblueth's experiments, even when the blocked area is widened beyond taenia ter-

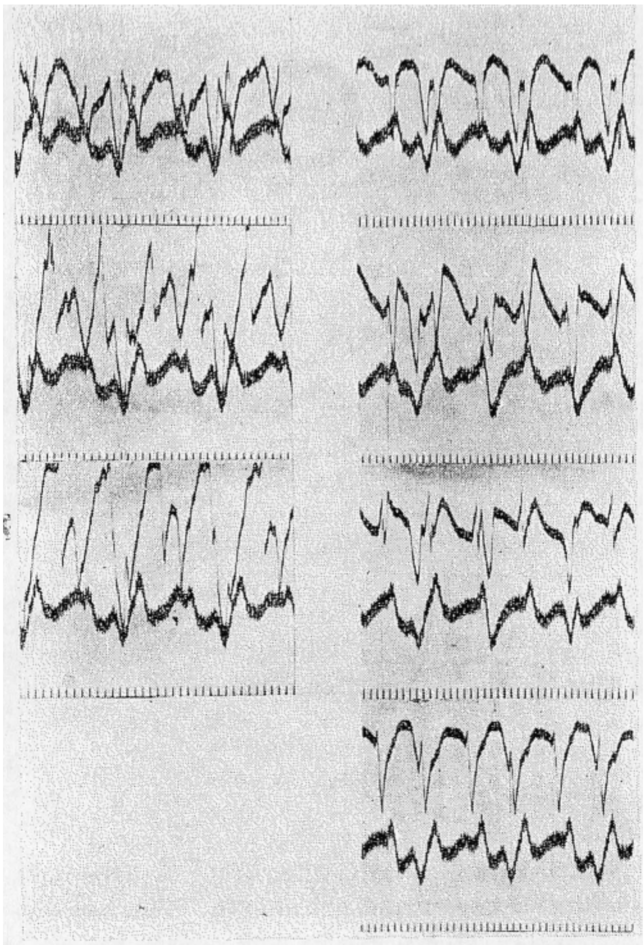

Fig. 4a (No. 12, Exp. 3). Curves taken by direct leads from the surface of a fluttering auricle, induced by electric stimulation at the caudal region of the right auricle. The curve shown lower was taken simultaniously from auricular cavity. The time shown at the sides of curves indicates the interval of the intrinsic deflection between those two curves. Auricular cycle is 0.130 sec.

minalis, flutter occurs. It stopped only when the injured area is enlarged to the auriculo-ventricular border.

The similar findings observed by us; the flutter does not stop by oppressing or cooling the stimulated place alone, while it stops when auricular body is oppressed or cooled from blocked area to auriculo-ventricular groove, as shown in Fig. 7. This fact indicates that circus way is not a limited path like taenia terminalis. Furthermore we observed the fact that, if an upper or lower part of the border between right and left auricle is cooled, the flutter stops easily. The reason therefore is thought to be due to the narrowing of muscle bundle in this region. From above facts we suppose that it is necessary for auricle muscle to be annular than the existance of a specific pathway in order that flutter occurs. Accordingly, if the length of this annular pathway is increased, frequency of flutter wave

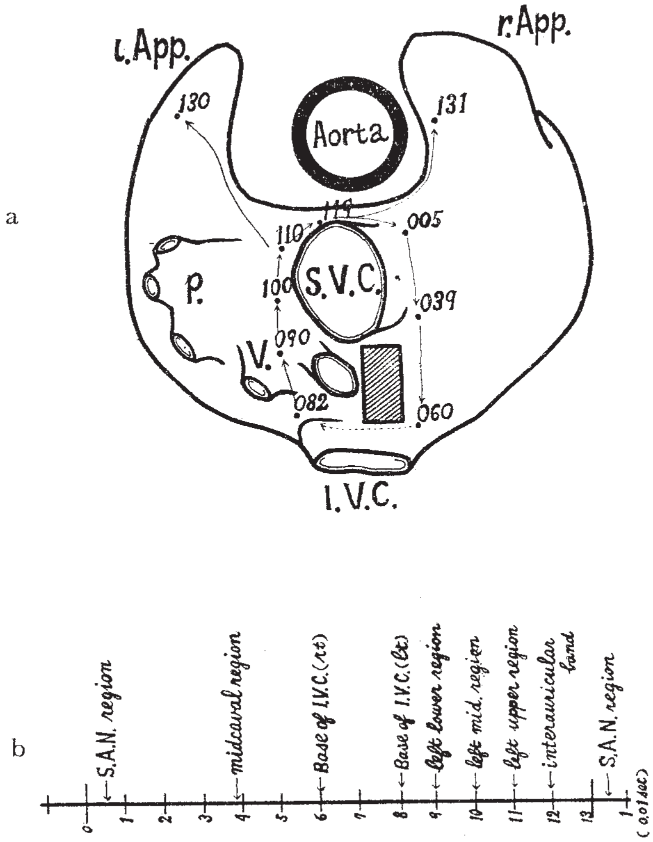

Fig. 4b (No. 12, Exp. 3). (a) Outline of the auricular surface constructed in the same fashion as Fig. 3b. The obliquely hatched area was injured by Pean's forceps. (b) A chart showing the time relation of readings from the surface of the auricle during the same flutter.

is expected to decrease. Rosenblueth recognized this fact. We have also observed a decrease in frequency when a blocked area is enlarged. But decrease of frequency of flutter was not so large as we have expected. Table II shows this fact. In this table the frequency of flutter wave computed from the enlarging rate of pathway is compared with the observed value.

The reason must be offered for such difference, but it seems to be difficult to give a definite answer. We suppose it as follows; although the excitation propagates through the auricular muscle annularly, it does not propagate perhaps around in a smooth ring. After all, it is necessary to consider an arrangement of each muscle bundle, therefore it is proper to assume that the excitation wave propagates along the ring in a zig-zag path. And if it is so assumed, frequency needs not necessarily to decrease so much as expected with an enlargement of the blocked area. This zig-zag propagation can be assumed from the fact that the intrinsic deflections are not distributed at regular intervals.

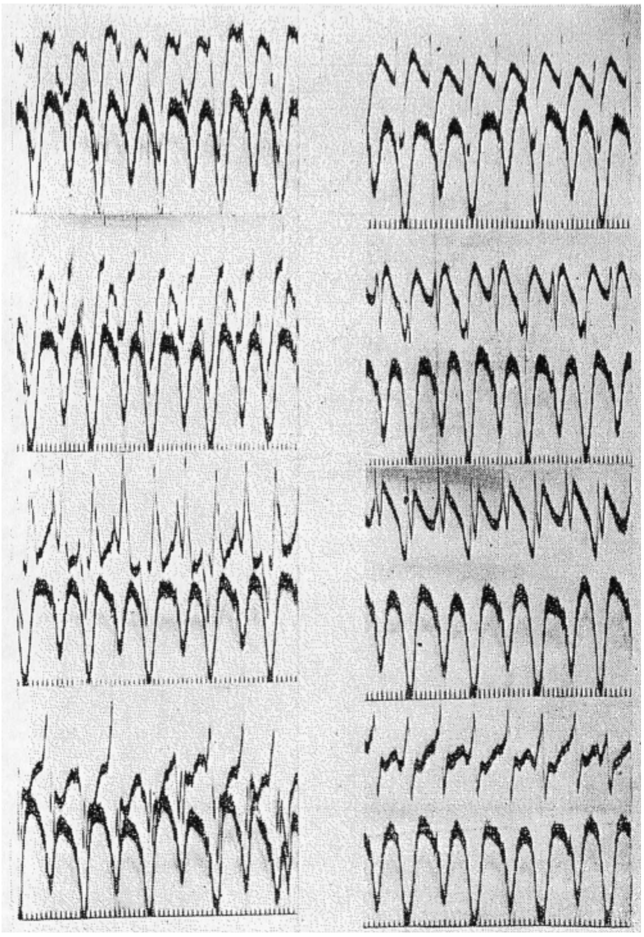

Fig. 5a (No. 12, Exp. 2). Curves taken by direct leads from the surface of an auricle during the flutter induced by electric stimulation at the caudal region of the right auricle. The lower curves were taken simultaneously from right auricular cavity. The time figures shown at the sides of curves indicate the intervals of the intrinsic deflections of the former from the bottom of the auricular complexes of the latter. The auricular cycle is 0.130 sec.

Dissimilarity between Aconitine Flutter and Electrically Induced Flutter

From the results of above mentioned experiments it is assumed that aconitine flutter and electrically induced flutter are different in nature. If so, then a problem arises as to the category to which a clinically observed flutter belongs.[10][15] If those two flutters are comparatively observed, difference can be noticed at the time of returning to sinus rhythm. Electrically induced flutter returns to sinus rhythm instantly, while in the aconitine flutter auricular rate gradually decreases, then changes to sinus rhythm. This difference can be observed when a flutter is eliminated by using procaine amide. Because it is an established fact for a clinical flutter to convert to sinus rhythm instantly, so in the light thereof it can be assumed that a clinical flutter is under the same condition as electrically a

b

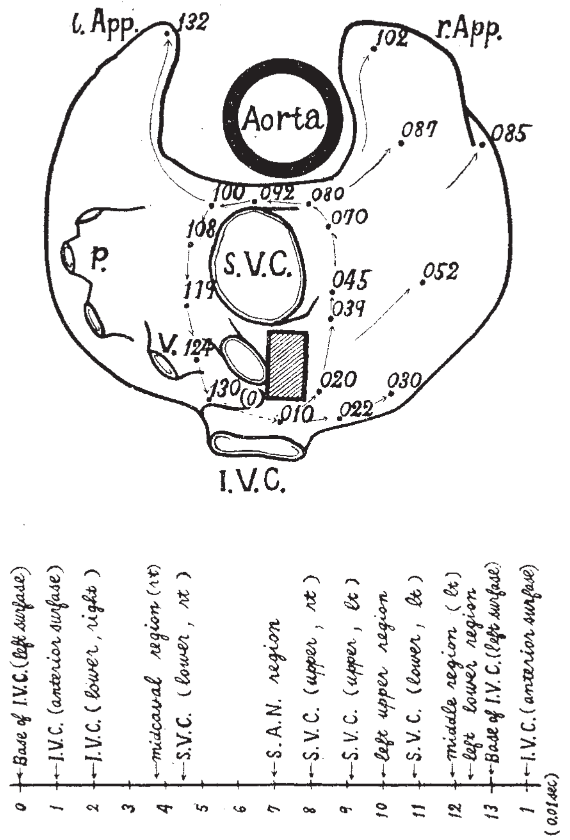

Fig. 5b (No. 12, Exp. 2). (a) Outline of the cephalic surface of a dog's auricle showing the arrival of the excitation wave, which have been obtained during the flutter same as Fig. 5a. The area plotted by oblique lines is injured. Auricular cycle is 0.130 sec. (b) A chart showing the time relation of readings from the surface of the auricle during the period of the same flutter.

TABLE II

Length of the Pathway has been Estimated from the Width of Injured Area

Experiment No.	Before widening of the blocked area			After widening of the blocked area		
	cycle length sec.	frequency per min.	length of pathway (estimated) cm.	length of pathway (estimated) cm.	calculated frequency per min.	observed frequency per min
1	0.130	461	12.0	14.9	370	414
2	0.120	500	12.0	13.0	461	480
3	0.125	480	14.0	15.5	401	428
4	0.130	461	13.0	15.0	393	414
5	0.115	522	12.0	14.0	447	454
6	0.122	492	14.0	16.0	430	423
7	0.110	545	12.0	15.0	467	545

Fig. 6

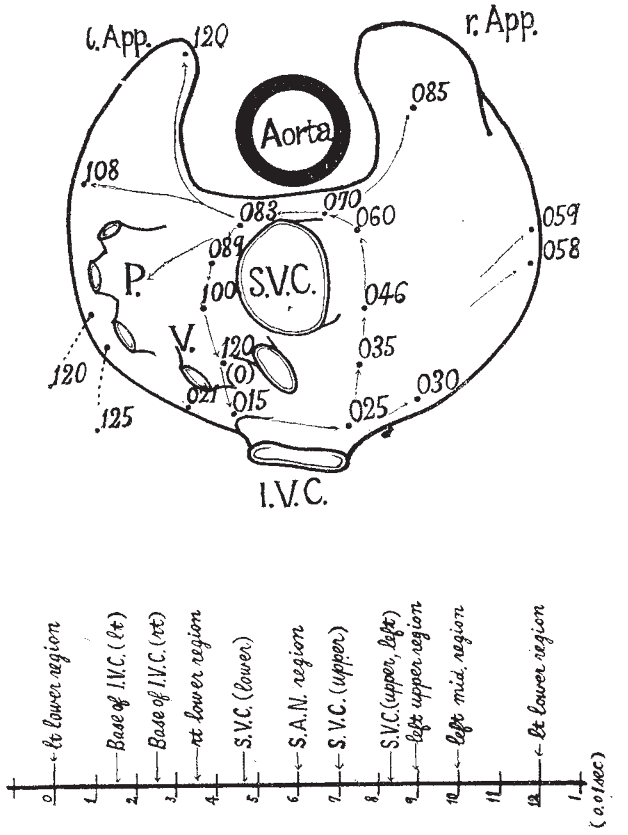

Fig. 7

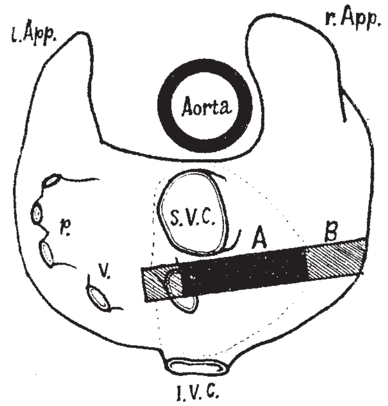

Fig. 6 (No. 29, Exp. 3). (a) Outline of the cephalic surface of a dog's auricle, showing the readings for the arrival of the excitation wave, which have been obtained during the flutter induced by stimulating at left appendage, without forceps. Auricular cycle is 0.120 sec. (b) A chart constructed in the same fashion as in Fig. 3b.

Fig. 7. A diagram showing enlargement of the blocked area. The flutter persists by the blocking of the area (A) alone, while it returns instantly to sinus rhythm when the blocked area is widened to the area plotted by oblique lines (B).

induced flutter, that is, flutter which occurs by circus movement of the excitation wave. This opinion was advanced by Brown and Acheson in 1952[14] upon the observation by the use of procaine amide. We agree with them.

Conclusion and Summary

1. As advocated by Rosenblueth auricular flutter easily and certainly occurs and continues for a long period, when a muscular bridge between the orifices of superior and inferior venae cavae is blocked.

2. 500–600 cycle per minute electric stimulation of auricular surface easily produces a flutter.

3. In inducing auricular flutter by electric stimulation it is not

necessary to stimulate a certain designated region.

4. In the aconitine flutter excitation wave starts at an injected area and spreads over whole auricle.

5. In the electrically induced flutter excitation wave surrounds and circulates around the orfices of both venae cavae. Direction of circus movement has no specific relation to method of stimulation.

6. Flutter stops when auricular muscle is oppressed or cooled so as to reach the auriculo-ventricular border from the blocked area. It does not stop when only a stimulated area or a neighbourhood of taenia terminalis is oppressed or cooled. Accordingly, circus way is not limited to taenia terminalis. Rather, it can be assumed that auricular muscle must be annular for inducing flutter.

7. Frequency of flutter wave decreases when a blocked area is enlarged, but not so much as expected. This indicates that the circus pathway is zig-zag ring.

8. Therefore, we concluded that electrically induced flutter and aconitine flutter are different in nature. And due to the fact that elimination of flutter in the former is instant while in the latter gradual, it can be assumed that an electrically induced flutter corresponds to the flutter observed in a clinical case.

References

1) Schrf, Proc. Soc. Exper. Biol. & Med., 1947, **64**, 233.
2) Scherf & Terranova, Am. J. Physiol., 1949, **159**, 137.
3) Scherf, Romano & Terranova, Am. Heart J., 1948, **36**, 241.
4) Scherf, Morgenbesser, Nightingale & Schaeffeler, Proc. Soc. Exper. Biol. & Med., 1950, **73**, 650.
5) Prinzmetal, Gorday, Oblath, Kruger, Brill, Fields, Kennamer, Osborne, Smith, Sellers, Frieg & Finston, Am. J. Med., 1951, **11**, 410.
6) Lewis, Heart, 1918–1920, **7**, 127.
7) Lewis, Feil & Stroud, Heart, 1918–1920, **7**, 191.
8) Lewis, Heart, 1918–1920, **7**, 293.
9) Lewis, Drury & Bulger, Heart, 1921, **8**, 83.
10) Lewis, Drury & Liescu, Heart, 1921, **8**, 361.
11) Brams & Katz, Am. Heart J., 1931, **7**, 249.
12) Rosenblueth & Ramos, Am. Heart J., 1947, **33**, 677.
13) Rosenblueth & Garcia Ramos, Arch. Inst. Cardiol. Mexico, 1947, **17**, 441.
14) Brown & Acheson, Circulation, 1952, **6**, 529.
15) Wenger & Hofman-Credner, Circulation, 1952, **5**, 870.
16) Hecht, Katz, Pick, Prinzmetal & Rosenblueth, Circulation, 1953, **7**, 591.