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EXPERIMENTAL ANALYSIS OF MACROREENTRY FORMATION IN THE RABBIT RIGHT ATRIUM

F. Bukauskas, V. Valiunas, V. Mizeras, and A. Tamoševičius

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KEY WORDS: atrioventricular node, reentry, tachycardia, mapping

The commonest cardiac arrhythmias found in clinical practice are supraventricular disturbances of the cardiac rhythm, a large proportion of which consists of arrhythmias connected with the atrioventricular (AV) node [3, 8]. The hypothesis has been put forward that reentry formation within the AV node can be explained by assuming the existence of several pathways for the conduction of excitation in the AV node [12, 15]. On the other hand, the accumulation of clinical experience with the surgical treatment of cardiac arrhythmias has shown that several supraventricular arryhthmias can be effectively abolished by cryodestruction of the perinodal regions of the AV node [6, 11, 16]. This realistically describes the situation, for example, when macroreentry, intersecting the region of the AV node, is formed in the atria.

In the present study we concentrated our attention on arrythmias due to the formation of macroreentry in the atria, with a loop including the region of the AV node.

Kaunas Medical Academy. (Presented by Academician of the Academy of Medical Sciences of the USSR J. J. Bredikis.)

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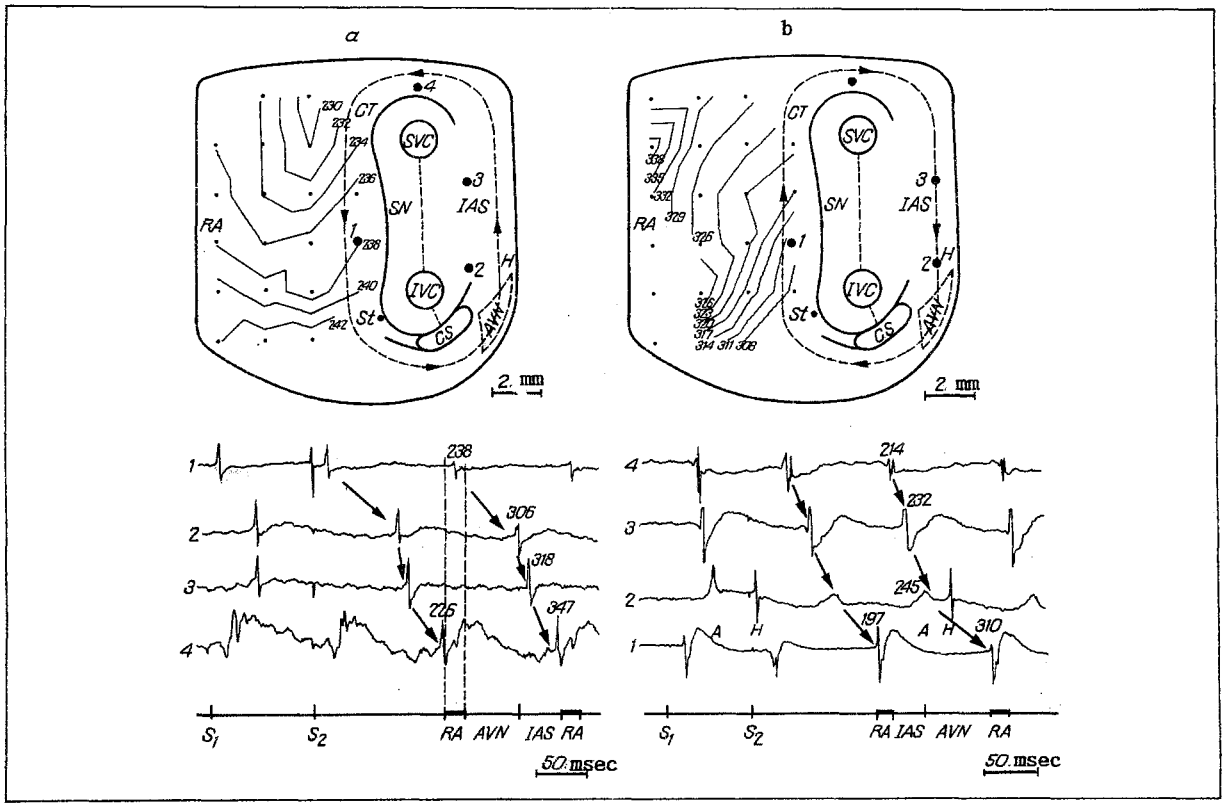

Fig. 1. Examples of circulation of excitation in two opposite directions (a and b). Broken line with arrows shows direction of spread of excitation wave. SVC) Superior vena cava, IVC) inferior vena cava, SN) sinus node, CS) coronary sinus. Electrograms recorded at points 1, 2, 3, and 4. Time intervals corresponding to spread of excitation along RA, through AVN, and along IAS, shown on time axis below electrograms. Order of circulation can be determined by numerical values of moments of excitation indicated by series of electrograms. On electrogram 2 (b): A) atrial complex, H) His bundle complex. Remainder of legend and explanation in text.

EXPERIMENTAL METHOD

Altogether 17 experiments were conducted on isolated preparations of the rabbit atrium. The atrial preparations were obtained by a method similar to that described in [4]. The preparations included the auricle of the right atrium (RA), the interatrial septum (IAS), and the region of the AV node (AVN) (Fig. 1). The isolated preparations were perfused by the standard method with Tyrode solution of the following composition (in mM) NaCl – 136, KCl – 2.7, $CaCl_2$ – 1.8, $MgCl_2$ – 0.5, NaH_2PO_2 – 4.6, $NaHCO_3$ – to pH 7.35, glucose 2 g/liter. The temperature of the solution was 37 ± 0.5°C. Against the background of periodic stimulation testing stimuli were applied with a delay after the periodic stimulus that could be regulated. Delay of the testing stimulus was changed so that it fell within the vulnerable phase of the cardiac cycle, i.e., to induce tachycardia. A multichannel electrode was used for recording. This electrode was placed on the auricle of the right atrium from the endocardial side. Signals recorded from the 32 electrodes were amplified and led into a measuring and calculating system based on the SM-1600 computer. By means of a special program, isochronous recorder charts (Fig. 1) of the spread of the excitation wave front were constructed from the data of the moments of excitation from all 32 monopolar electrograms. Three additional bipolar electrodes were placed in the region of IAS, on the crista terminalis (CT), and close to the bundle of His (H). Local cooling of the preparation by means of a metal tube, 1.5 mm in diameter, continuously perfused internally with water at 4°C, was used. The tip of the tube was applied to the surface of the preparation, so that the temperature in a local area could be lowered to 10°C.

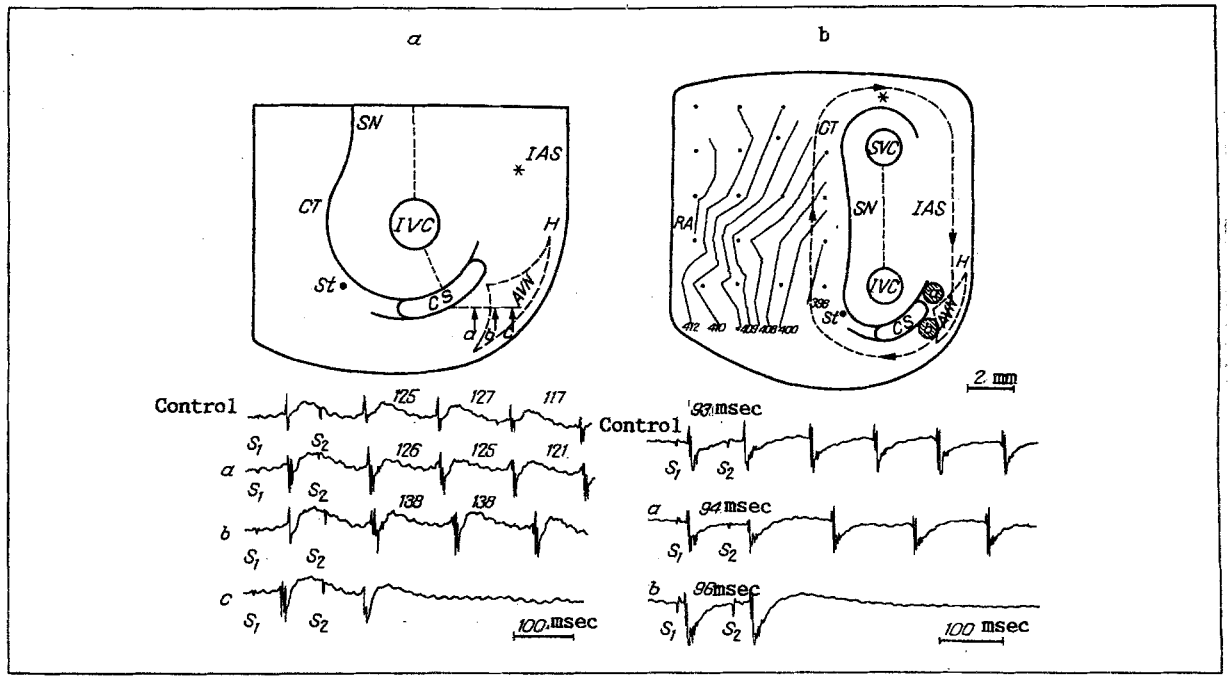

Fig. 2. Effect of incisions and cooling various regions of the AV node on tachycardia. a) Change in frequency of tachycardia during consecutive cuts from the coronary sinus into the zone of the AV node. Electrograms after each cut (a, b, c) shown in lower part of diagram. Cuts indicated by arrows and corresponding letters on topographic part of figure. Top electrogram (control) — before any incisions were made. Numbers between sets of electrograms denote period. b) Local cooling applied. Shaded zones a and b indicate sites of local cooling. Electrograms from top to bottom: first (control) — without cooling, second — cooling in zone a, third — cooling in zone b. Intervals S1-S2 were 93, 94, and 96 msec respectively. Site of recording of electrograms indicated by asterisk. Remainder of legend as to Fig. 1.

EXPERIMENTAL RESULTS

In nearly all (in 15 of 17) the experiments attacks of tachycardia could be induced by stimulating the preparation, if the stimulus was applied in the phase of relative refractoriness. The place of stimulation was located in the ST zone, as shown in Fig. 1.

Depending on the frequency of excitation the episodes of tachycardia could be conventionally divided into high-frequency (11-20 Hz) and low-frequency (7-10 Hz). Analysis of the spread of excitation in RA (mapping) and recording of three electrograms in IAS showed that with high-frequency tachycardia the source of excitation was located in RA, and was dual in nature: reentry or focal, whereas in the case of low-frequency tachycardia, reentry was formed around the superior and inferior venae cavae, and simultaneously spread to the region of the AV node. In the present study we concentrated on low-frequency tachycardias, for we studied high-frequency tachycardias previously [1].

Our task initially was to make absolutely sure that reentry did not involve one vena cava or the mouth of the coronary sinus separately, but all three together. For this purpose we made incisions initially between the superior and inferior venae cavae (broken lines in Fig. 1), and then continued the incision to the coronary sinus. After each incision there was no change in the character or frequency of induced tachycardia. Only after a complete incision as far as the atrio-ventricular fibrous ring did the tachycardia disappear. Analysis of the spread of excitation showed that the circulation of excitation can take place in two opposite directions (Fig. 1). We found no significant difference in the frequency of tachycardia depending on the direction of reentry. In Fig. 1 the bold segments (RA) on the axis denote time intervals which reflect the spread of excitation in the right atrium, where mapping was carried out.

The next series of experiments was aimed at discovering how deeply the reentry loop penetrates into the region of the AV node. For this purpose we made a series of cuts from the mouth of the coronary sinus toward the AV node. There were four experiments. One example is illustrated in Fig. 2a. Having made a successive series of cuts we observed a gradual decrease in the

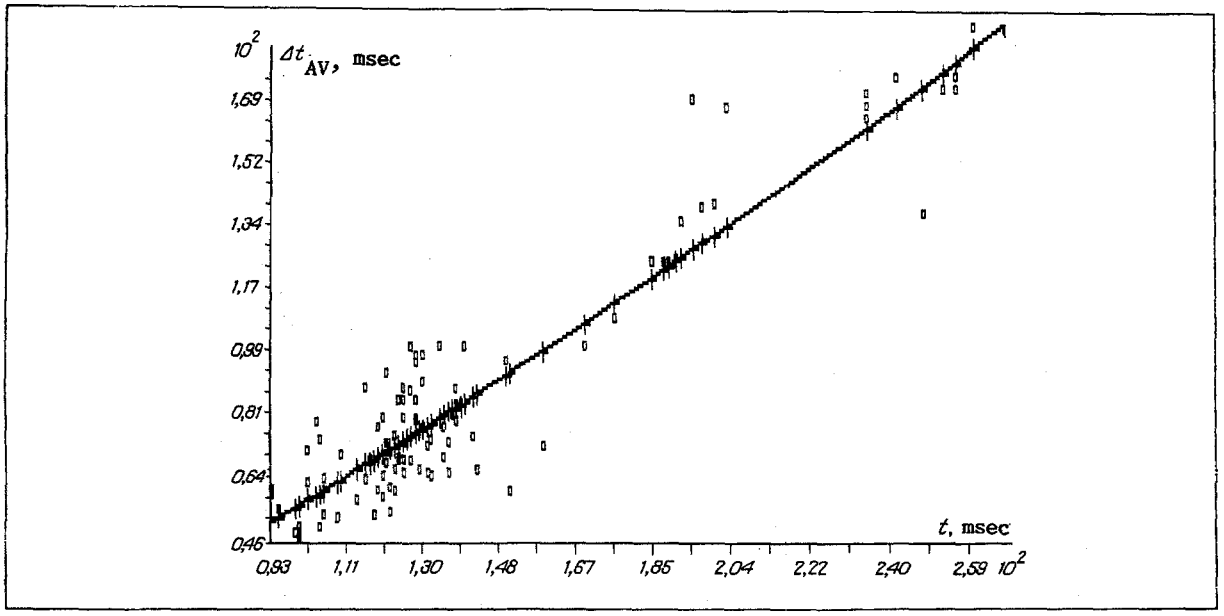

Fig. 3. Dependence of delay of impulse in zone of AV node (Δt AV) on period of tachycardia (t).

frequency of tachycardia. When the incision reached the central (N) zone of the AV node, the tachycardia disappeared and AV conduction was preserved.

The experiment showed that the main loop does not penetrate very deeply into the AV node, but mainly spreads to the perinodal AH zone (in accordance with the classification given in [7]).

How the bundle of His is excited during tachycardia is a very interesting problem. Continuous recording of the His bundle electrogram during tachycardia shows that it is excited after every 2nd, 3rd, or 4th excitation of the atrium. This indicates that the main reentry loop does not extend to the His bundle or, evidently, the NH zone.

During selective local cooling of different regions of the AV node, an attempt was made to determine zones where some kind of influence on the process of tachycardia could be observed. When the central N zone of the AV node was cooled, excitation of the His bundle ceased but the tachycardia continued. During cooling at point b tachycardia stopped, and it was impossible to induce it again (Fig. 2b). During cooling at point a tachycardia did not stop, but its frequency was reduced.

The frequency of excitation in the case of reentry is known to be determined by the duration of spread of excitation around the loop [13, 14]. Clearly in the present case part of the time was needed to conduct excitation through the region of the AV node. We analyzed the relationship between the period of tachycardia and the delay of excitation in the region of the AV node on the basis of the results of all the experiments. A line of dependence between the parameters studied is shown in Fig. 3. Delay in the region of the AV node varied from 50 to 180 msec, or 55-75% of the period of tachycardia. The change in the period of tachycardia took place mainly through a change in the delay in the region of the AV node.

In this study we examined one possible variant of atrial tachycardia, which is interesting because the reentry circle includes the AV node, and this greatly simplifies conditions for circulation of excitation in the circle.

Let us now attempt to analyze the situation in the simple scheme illustrated in Fig. 4a. Communication between the posterior input of CT into the AV node from IAS takes place through the conventional pathways a, b, c, and d. Let us assume that the fastest pathway of conduction of excitation is path a, and that each subsequent path enters ever more deeply into the structure of the AV node, and is therefore slower. In other words, a situation is possible when, to satisfy the conditions of reentry, the congenitally determined absence of, or functional damage to, the fast pathways, such as a or a and b, is necessary. It is clear that if the perinodal zone, located between the coronary sinus and the AV node, is damaged the reentry loop will penetrate deeper into the structure of the AV node. This must increase delay of the impulse, reduce the frequency of tachycardia, and facilitate the conditions of reentry.

Indirect confirmation that the situation we have analyzed really exists in clinical practice may be given by studies which showed effective termination of atrial paroxysms of tachycardia through surgical destruction of the anterior or posterior pathways of entry into the AV node in such patients [5, 6, 11, 16].

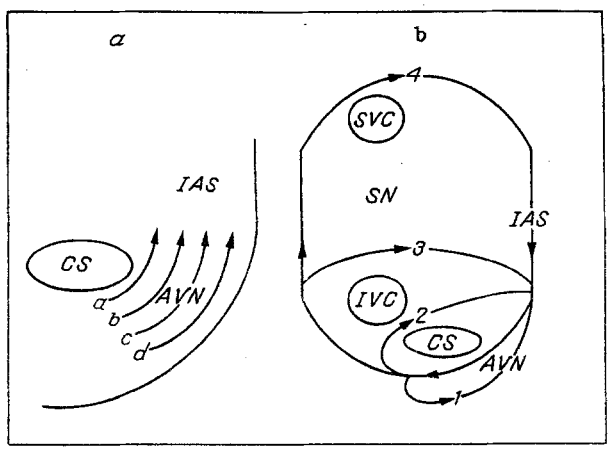

Fig. 4. Variants of reentry formation in the AV node. a) Conventional paths of conduction (a, b, c, d) through zone of AV node; b) possible variants of realization of circulation of excitation wave. Remainder of legend as to Fig. 1.

Many models examining reentry formation in the AV node explain it by the existence of alpha- and beta-paths of conduction in the nodal structure [12, 15]. Other workers have found even three tracts [10]. It is evidently more correct in this case not to accept the existence of separate tracts for the conduction of excitation, for which there is no morphological confirmation, but to take into account the high degree of anisotropy characteristic of the AV node [2]. It is this which determines dissociation of the AV node into several functionally determined tracts.

In the present study the variant of reentry chosen for analysis is essentially similar to those based on the dual nature of conduction in the AV node. Incidentally, that part of reentry which emerges from the AV node into the atrial structure was not analyzed in these studies [12]. Only in one study [9] is the question of the role of atrial structure in reentry formation in the AV node examined very logically.

It can be concluded on the basis of our data obtained on rabbits that reentry within the node only (see variant 1 in Fig. 4b) is difficult to realize or, at least, we never recorded any such variants. On the basis of our results we put forward in schematic form some possible variants (Fig. 4b). We observed in our experiments and we accept that variant 4 of reentry is the case which fully satisfies the conditions of circulation of excitation.

Thus macro reentry, formed within the atrium, conjecturally includes the region of the AV node because of the slow spread of excitation in that structure. Irrespective of the spread of this type of macro reentry, therefore, they are all attached to the AV node at one end always. Surgical termination of macro reentry will be performed preferably in the future in the perinodal region of the AV node, for elsewhere (CT, perinodal region, etc.) will always find alternative pathways of spread of the excitation wave.

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REDISTRIBUTION OF THE BLOOD FLOW IN HEART MUSCLE DURING CHRONIC ISCHEMIA UNDER THE INFLUENCE OF DRUGS

G. G. Chichkanov, D. D. Matsievskii, E. A. Tolmacheva, and E. K. Grigor'eva

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Redistribution of the blood flow in the ischemic heart muscle under the influence of drugs plays an important, and at times decisive, role in the mechanism of their antiischemic (antianginal) action [3, 7, 8]. However, until very recently this problem still remained inadequately studied.

The aim of this investigation was to study the effect of certain drugs with antiischemic action, namely the β-adrenoblocker propranolol, the calcium antagonist diltiazem, the antihypoxic agents sodium and lithium hydroxybutyrate — on the redistribution of the blood flow in the ischemic heart muscle in the presence of a developed collateral circulation.

EXPERIMENTAL METHOD

Experiments were carried out on mongrel male and female dogs weighing 12-17 kg, in two stages. In Stage 1, under general anesthesia (pentobarbital sodium 40 mg/kg, intravenously) and artificial respiration, thoracotomy was performed on the first animal in the fourth left intercostal space, and the anterior descending branch of the left coronary artery was ligated in its upper third. At the second stage, 2 months later, the animals were used in an acute experiment. By means of an ultrasonic doppler technique, the blood flow in the coronary vein (CV), draining blood directly from the ischemic focus [1], and in the great cardiac vein (GCV), collecting blood from the whole of the left ventricle, was recorded simultaneously. Ultrasonic transducers, in the form of a bandage 2.0-2.5 mm long, with an internal diameter of 1.0-3.0 mm, and calibrated in units of volume velocity of blood flow, were placed on the veins. The redistribution of blood flow in the ischemic myocardium of the left ventricle was estimated by means of an analog computer, as the quotient obtained by dividing the mean values of the blood flow in the coronary and great cardiac veins (CV/GCV).

The pressure in the left ventricle and carotid artery, and in some experiments the retrograde arterial pressure in the basin of the occluded coronary artery, were recorded by means of a micromanometer. The N3031 instrument was used as recorder.

*Deceased.

Laboratory of Pharmacology of Antianginal Agents, Research Institute of Pharmacology, Academy of Medical Sciences of the USSR. Bioengineering Laboratory, Research Institute of General Pathology and Pathological Physiology, Academy of Medical Sciences of the USSR, Moscow. (Presented by Academician of the Academy of Medical Sciences of the USSR A. V. Val'dman*.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 111, No. 4, pp. 359-361, April, 1991. Original article submitted July 9, 1990.

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