STRUCTURE OF TISSUE ADJACENT TO THE ELECTRODE TIP AFTER EXTREMELY LOW-THRESHOLD CARDIAC PACING

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Continuous cardiac pacing (CP) is an effective method of treatment of patients with cardiac arrhythmias and conduction disturbances. One of the medico-biological problems of CP is regulating the response of the heart tissue to implantation of the electrode by means of which electrical pulses are transmitted from the pacer to the myocardium. An electrode applied to the endocardium or introduced into the myocardium in time becomes surrounded by a connective-tissue capsule, and under these circumstances structural changes in the myocardium are observed at distances of up to several millimeters from the electrode. A matter of practical importance is how the thickness of the capsule depends on the design of the electrode — the material from which it is made, treatment of its surface, and its size and shape [4]. To minimize loses of electrical energy, the development of a thick capsule must be prevented, but on the other hand, a very thin capsule may not be strong enought to ensure mechanical stability of the electrode. By the use of porous graphite electrodes the chronic threshold for CP has been reduced on average to 0.7-0.8 V [1, 2]. The structure of the cap-

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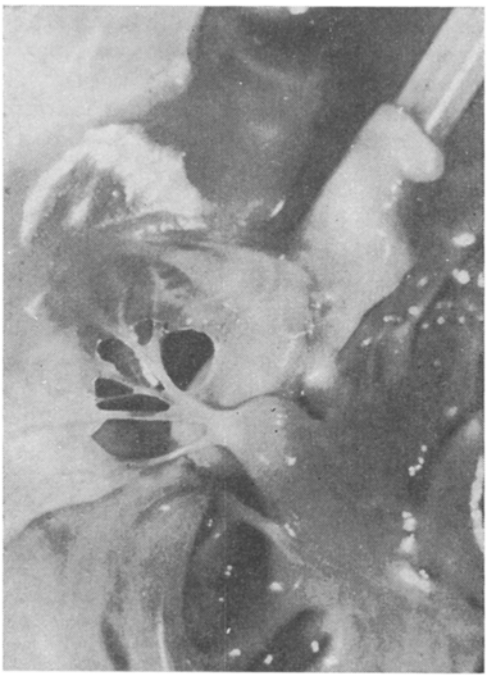

Fig. 1. Electrode in right ventricle of dog's heart after 9-month period of stimulation (magnification 3.7). Explanation in text.

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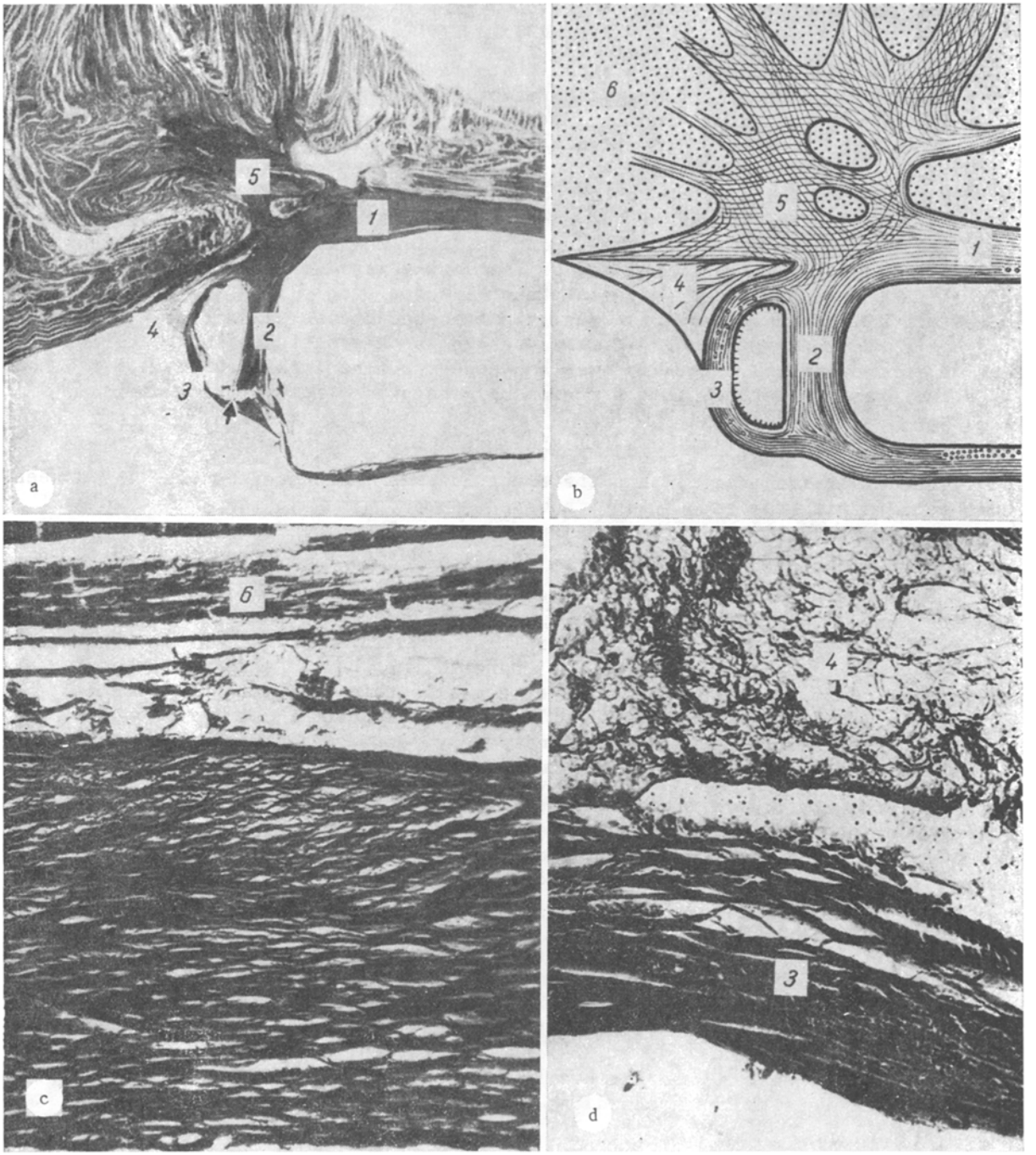

Fig. 2. Tissue in vicinity of electrode: a) general view (arrow indicates site of rupture of capsule following removal of electrode). 13 ×; b) scheme of tissue in vicinity of electrode; c) capsule covering body of electrode. 70 ×; d) capsule covering electrode tip. 140 ×. Van Gieson's stain. Capsule covering: 1) body of electrode; 2) neck of electrode; 3) tip of electrode; 4) zone in vicinity of electrode; 5) root of capsule; 6) myocardium.

sule of these electrodes has been investigated [1]. More recently the present writers have recorded an extremely low chronic threshold for CP, only half of the average. With a view to development of a method of continuous CP it is necessary to determine the factors which brought about such a significant lowering of its chronic threshold.

This paper describes a histological investigation of the structure of tissue in the neighborhood of the electrode tip in one concrete case of an extremely low threshold of CP.

EXPERIMENTAL METHOD

Continuous CP was carried out in experiments on two dogs weighing 18 and 20 kg respectively. A porous graphite electrode with area of stimulating surface of 8-10 mm^2, whose properties were investigated previously [1, 2], was implanted into the apex of the right ventricle through the auricle of the right atrium. An implantable pacer, designed and made by ourselves, was used; it produced alternating pulses of opposite polarity at uniform time intervals [3]. The duration of the pulses was 1.2 msec and their frequency 120-130 pulses/min. The amplitude of the pulses of the pacer implanted in the first dog was 3 V and into the second dog 2 V. After 9 months the threshold of CP was measured, after which the dogs were killed by induction of ventricular fibrillation by very high frequency CP. The chronic threshold of CP in the first dog, using a cathodal pulse with a duration of 1 msec, was 0.8 V, compared with 0.35 V for the second dog. In the second case an extremely low chronic threshold of CP was thus recorded. For this reason the heart tissue in the vicinity of the tip of the electrode in the second dog was subjected to histological study. Sections were stained by Van Gieson's method. Light microscopy (magnification 13-140) was used.

EXPERIMENTAL RESULTS

It will be clear from Fig. 1 that the electrode was introduced between the trabeculae and was in contact with the endocardium; however, part of the tip faced the lumen of the ventricle and was covered only by a thin transparent capsule. The intracardiac part of the body of the electrode was covered with a thick capsule, adherent to the heart wall.

The general characteristics of the structure of the electrode capsule (Fig. 2a) are as follows. The capsule was composed of dense, shaped fibrous connective tissue. Its main element was collagen fibers, grouped in bundles in several layers. On the side facing the chamber of the heart the capsule was lined with endocardium, whereas immediately on the surface of the electrode there was an amorphous layer equal in thickness to the endocardium, resembling collagen in its structure, but without a fibrous structure. To correspond to the structural details of the electrode, with their different functions, it is useful to distinguish between the capsule of the body 1, of the neck 2, and of the tip 3 of the electrode.

The capsule of the body of the electrode (Fig. 2a-c) consisted of two layers of collagen fibers — longitudinal and circular. The longitudinal layer was located mainly externally, i.e., further from the electrode surface. The bundles of collagen fibers forming it lay parallel to the long axis of the electrode. The circular layer of collagen fibers was closer to the surface of the electrode body. The ratio of the thicknesses of the longitudinal and circular layers varied in different parts of the capsule from 1:1 to 5:1. However, the circular layer tapered toward the tip of the electrode, and near its neck it disappeared completely. The density of distribution of the bundles of collagen fibers decreased in the direction from the tip to the body of the electrode. In some places besides longitudinal and circular fibers, other fibers with a spiral course appeared. The thickness of the capsule of the electrode body differed around its circumference. It was much greater where the body of the electrode was near the heart wall and was adherent to it (375-750 μ). Where the capsule was adherent to the myocardium, in some places bands of adipose tissue were found.

The capsule of the electrode neck was 312-375 μ thick and consisted entirely of circular bundles of collagen fibers, which merged without interruption into the capsule of the tip and body of the electrode (Fig. 2a, b).

The capsule of the tip was the thinnest part (60-150 μ) of the connective-tissue membrane covering the electrode (Fig. 2d). The collagen fibers composing it interwove around the tip in the form of short bundles in different directions. The capsule also contained outgrowths of amorphous substances, filling the pores in the electrode tip. The electrode capsule 2, 3 was connected to the myocardium 6 by means of a strong "root" 5, which formed a single entity with the capsule (Fig. 2a, b). Ramifications of this root penetrated into the substance of the myocardium to a depth of up to 3-4 mm. The electrode tip, like its capsule 3, did not directly make contact with the myocardium 6. A juxtaelectrode zone 4, differing sharply in its structure from the capsule (Fig. 2d), was located between the heart wall 6 and the capsule of the tip 3. The juxtaelectrode zone contained few fibers, but was richly supplied with the liquid component of the ground substance. Bundles of collagen fibers penetrating into it from the electrode capsule unwound into first-order bundles, then to individual fibers, forming a dense network.

The following distinguishing features of the structure of the juxtaelectrode tissue in this case can be recognized: first, a reduction in thickness of the capsule covering the electrode tip by 2-3 times, second, the presence of a juxtaelectrode zone, rich in the liquid component of the ground substance, and third, the formation of a powerfully developed root of the capsule, penetrating into the substance of the myocardium. The reduction in thickness of the capsule covering the tip, and the formation of a juxtaelectrode zone with a marked trophic function are factors lowering the threshold of CP. Meanwhile a developed capsule of the neck and body determined the mechanical stability of the electrode.

It can be concluded that juxtaelectrode zone and the powerful root, penetrating into the myocardium, constitute a kind of artificial conducting system, permitting generalized spreading of excitation.

The conditions of this experiment and the results of the histological investigation indicate a practical way of reducing energy consumption during continuous CP: the use of porous carbon electrodes with a small area of stimulating surface and the use of stimulating pulses of alternating polarity, with the lowest possible (i.e., threshold) level of energy. These recommendations are in agreement with the conclusions of other researchers.

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ULTRASTRUCTURAL CHANGES IN RED MUSCLE FIBERS OF THE RAT QUADRICEPS FEMORIS MUSCLE DURING INCREASED MOTOR ACTIVITY

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When a muscle contracts it undergoes partial destruction. So that this destruction is not total as a result of prolonged working efforts, a repair mechanism must operate in it [10-13]. It has been shown experimentally that under conditions of acute physical strain, marked destructive changes are present at the ultrastructural level in skeletal muscle fibers [4, 7, 15]. The aim of this investigation was to examine, in experiments on animals, the action of prolonged and increasing physical exertion on the ultrastructural organization of muscle fibers of one type, namely red muscle fibers (RMF).

EXPERIMENTAL METHOD

Experiments were carried out an adult male Wistar albino rats aged 17 weeks, subjected to training exercises in the form of running on a treadmill, the track of which moved at a speed of 35 m/min. The animals were trained for 6 weeks in accordance with a definite scheme [14]. At the beginning of the experiment the duration of running was 10 min, and at its end, 60 min. Under general anesthesia 24 h after the end of the experiment pieces of muscle were removed from the red portion of the quadriceps femoris. Material was fixed by Palade's method in OsO_4. Ultrathin sections were stained with uranyl acetate and lead citrate and examined in the IEM-100C electron microscope.

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