EXPERIMENTAL DESTRUCTION OF THE ATRIOVENTRICULAR JUNCTION OF THE CONDUCTING SYSTEM OF THE HEART BY LASER ENDOSCOPY

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An urgent problem in modern heart surgery is the operative treatment of patients with cardiac arrhythmias and, in particular, with supraventricular tachyarrhythmias resistant to medical treatment. Operations to destroy the conducting pathways are performed as a rule on the open heart. Cryosurgical [1], ultrasonic [7], and laser [13] methods of destruction are used for this purpose. One way of inducing transverse heart block without thoracotomy is by the use of a defibrillating pulse [3, 9, 10], applied to the endocardium through an electrode introduced into the cavity of the atrium.

The aim of the investigation described below was to destroy the atrioventricular (AV) junction by means of an endoscopic laser device. For this purpose experiments were carried out on models of the isolated perfused dog's heart [6].

EXPERIMENTAL METHOD

Experiments were carried out on 18 isolated dogs' hearts. An endoscopic laser system [4] consisting of a cardiofibroscope, developed in conjunction with the Japanese firm "Olympus," and a "Fibrolaz 100" Ne-YAG laser with quartz light guide 600 μ in diameter (Fig. 1). The laser cardiofibroscope has an external diameter of 4 mm and consists of three channels, with a combined working channel 1200 μ in diameter, and is provided with a silicone rubber balloon tip to displace the blood locally. A pressurized system also is provided, so that the laser light guide can be introduced into the free channel of the endoscope with a T-shaped distributor and two-way cock to allow immersion fluid to be introduced into the same free channel in order to inflate the balloon tip and to cool the end of the laser light guide (Fig. 1). Distilled water was chosen as the immersion fluid, for the refractive index of water is identical to that of quartz fiber (n = 1.43). If the power of the laser radiation exceeds 40 W, the water boils with the formation of microbubbles and with an unpredictable direction of reflection of the laser beam from them, and this must be taken into account when the operating conditions of the laser are chosen.

The instrument was prepared for work as follows: the laser light guide was inserted into the endoscope channel until it projected by 1 mm from its end. Next, 1 ml of distilled water was injected through the T-shaped distributor, inflating the balloon tip to a diameter of 10 mm. The size of the homing spot was recorded using the red beam of an He-neon laser, mounted in the apparatus and combined with the infrared (invisible) beam of the Ne-YAG laser, and remained at 3-4 mm. The AV junction is about 1 mm thick and is located beneath the atrial endocardium in the zone of Koch's triangle [12]; it was therefore necessary that laser destruction of tissue should reach that depth [2, 5, 8, 11, 14, 15]. The laser cardiofibroscope was introduced into the working dog's heart through the auricle of the right atrium until the balloon tip touched the endocardium, and in the region of the apex of Koch's triangle, at the base of the commissure of the tricuspid valve, the laser beam was applied to the endocardium until complete transverse block was obtained. The ECG was recorded by means of an electrode introduced into the root of the aorta. The visible spot of the He-neon laser was used for hom-

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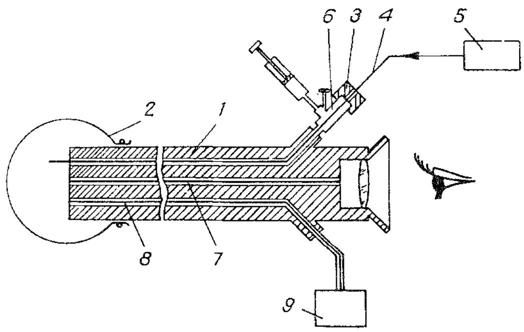

Fig. 1. Endoscopic laser system: 1) free working channel, 2) balloon tip, 3) pressurizing device, 4) laser light guide 5) laser, 6) T-shaped distributor, 7) observation channel, 8) illumination channel, 9) cold light source.

TABLE 1. Dependence of Depth of Tissue Destruction on Energy of Laser Pulse

Number of observations	Energy of laser pulse, J	Depth of destruction, mm	AV-block
3	19—53	0,7—0,72	Absence
3	65—77	0,8—0,84	Temporary
3	83—88	0,9—0,97	Permanent
6	97—121	1,0—1,12	»
3	126—131	1,2—1,3	»

ing. The distance from the end of the light guide to the object was kept constant at 12-13 mm. The depth of tissue destruction was studied macro- and microscopically.

EXPERIMENTAL RESULTS

The results are given in Table 1. If the energy of the laser pulse was 19-53 J (three applications) complete transverse block did not appear on the ECG (three observations). A temporary block was observed if the pulse energy was 65-77 J (four applications, three observations). Lasting total transverse block took place if the energy of the laser pulse was between 83 and 131 J (three or four applications, 12 observations); in the last two observations, moreover, a block appeared after one laser pulse. The zone of the atrial septum subjected to laser irradiation was visible microscopically from the side of the endocardium as a round spot 3-4 mm in diameter, which was paler than the surrounding unchanged tissue. These changes extended to a depth of 0.9-1.3 mm. Subsequently this zone will be called the "zone of destruction." Microscopic investigation showed that the zone of destruction was entirely or partly (in the form of foci) impregnated with blood and edema fluid (Fig. 2). Specific muscle cells of the AV junction and muscle cells and collagen fibers of the endocardium were separated by areas of extravasation and were thus arranged singly. Fibrin thrombi were present in the venules.

The depth of the zone of destruction with hemorrhagic or sero-hemorrhagic impregnation differed depending on the dose of laser irradiation. If loose connective tissue or fatty areolar tissue was present in the zone of irradiation, hemorrhages extended over a short distance outside the zone of destruction. The greatest degree of tissue damage in the atrial septum was observed, not at the surface of the zone of laser irradiation, but in the depth, evidently because of the greater quantity of energy absorbed at this level.

Specific muscle cells of the AV junction and working cardiomyocytes at sites of greatest damage were rather pycnotic, and this was true of both their cytoplasm and their nuclei. Their cytoplasm in some places stained more intensely with acid dyes. The collagen fibers of the endocardium were mainly swollen. Small foci of necrosis of muscle cells of the AV junction and working myocardium, infiltrated by polymorphonuclear leukocytes, also were found.

In most cases, because of the short time elapsing after laser irradiation until fixation of the material, it was impossible to state with certainty whether necrosis of the muscle cells

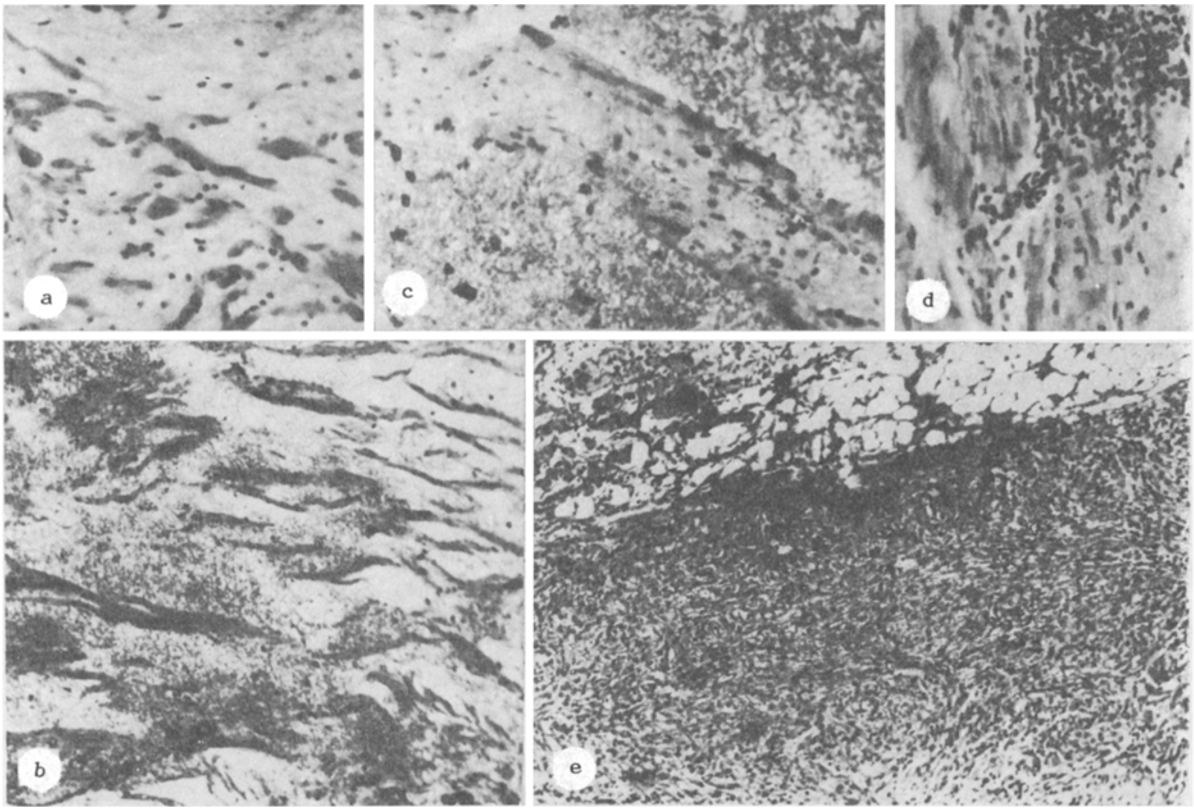

Fig. 2. Histologic changes in zone of destruction: a) single arrangement of muscle cells due to sero-hemorrhagic impregnation of its tissue. 160 ×; b) Hemorrhagic impregnation of tissue in zone of destruction, single arrangement and pycnosis of muscle cells. 63 ×; c) bundle of pycnotic muscle cells of working myocardium among mass of erythrocytes. 160 ×; d) infiltration of polymorphonuclear leukocytes in focus of myocardial necrosis in zone of destruction. 160 ×; e) tissue of unchanged AV junction on boundary with zone of destruction; single muscle cells (thicker) of working myocardium visible among adipose tissue, top right. 63 ×. a, b, d, e) Stained with hematoxylin and eosin, c) stained by Van Gieson's method.

of the AV junction and working myocardium was present. For the same reason the question of the degree of reversibility of changes noted in the zone of destruction cannot be answered. A transverse block was obtained in individual animals also when the boundary of the zone of destruction, as shown by the presence of hemorrhagic or sero-hemorrhagic infiltration, passed in the immediate proximity of the AV node, and when the latter appeared on microscopic examination to be unchanged. Just how permanent is the transverse block observed in such cases can also be established only by chronic experiments, and these will be undertaken in the future.

The method of measured endoscopic laser irradiation, developed by the writers on an experimental scale, can thus produce local destruction of the AV junction under the conditions of a nontransparent medium (blood). The energy of the laser pulse causing destruction of the AV junction without perforating the atrial septum is between 83 and 131 J, as was confirmed by the production of total transverse block on the ECG. The method thus developed experimentally by the writers may be promising for use in transvenous surgical operations on the conducting system of the heart in patients with tachycardias refractory to medical treatment.

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