9. P. N. Savitskii, Akush. Gin., No. 12, 40 (1969).
10. A. A. Smirnova, "Distribution of branches of the uterine arteries in man from the age aspect," Candidate's Dissertation, Tostov-on-Don (1956).
11. L. V. Timoshenko and M. O. Zhitskii, Pediatr. Akush. Gin., No. 4, 53 (1963).
12. D. R. Tsitsishvili, Ligation of the Uterine Vessels as a Method of Stopping Atonic Bleeding [in Russian], Tbilisi (1961).
13. M. S. Tsirul'nikov, Akush. Gin., No. 8, 59 (1970).
14. M. Glinsky and E. Stoktosa, Folia Morphol. (Warsaw), 25, 125 (1966).
15. E. G. Waters, Am. J. Obstet. Gynecol., 64, 1143 (1952).

RESPONSE OF MICROVESSELS OF THE SUBCUTANEOUS AREOLAR TISSUE TO ARGON LASER IRRADIATION

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The effect of argon laser irradiation on the microvessels of the subcutaneous areolar tissue of the rabbit ear, mounted in a transparent chamber by Clark's method, was studied. The capillaries and venules, in which dysfunctional changes were found in the microcirculation, were most sensitive to argon laser irradiation. Besides destruction of the vessel walls and perivascular inflammation, active reorganization of the microcirculatory system and a redistribution of the blood flow were observed under the influence of the laser beam.

KEY WORDS: laser; microcirculation; blood vessels.

Lasers are being used on an increasingly broad scale in clinical and experimental medicine. However, the action of laser radiation on biological objects and, in particular, on blood vessels has not yet been adequately studied, although tissue coagulation has been shown to result from exposure to the laser beam [5-8]. Argon lasers, giving the principal radiation at wavelengths of 488.0 and 514.5 nm [2], have been found to be very effective for coagulating blood vessels. The study of the effect of laser beams on microcirculatory systems is particularly interesting and its biological importance continues to be widely discussed in the literature [1, 3, 4, 7, 8, 10, 11].

The object of this investigation was an intravital study of structural changes in the vessels of the microcirculatory system in response to the action of an argon laser beam.

EXPERIMENTAL METHOD

Blood vessels of the subcutaneous areolar tissue of the rabbit's ear, mounted in a transparent chamber as in Clark's method [9], served as the test object. Experiments were carried out on eight rabbits with transparent chambers made of titanium or stainless steel previously implanted in their ear. The blood flow in the microcirculatory system was fully restored 5-6 days after implantation of the transparent chamber, so that a systematic microscopic analysis could be made of the movement of blood in the microvessels. Portions of the microcirculatory system were drawn under the microscope and photomicrographs taken so that a complete picture of the angioarchitectonics could be compiled.

The microvessels were irradiated with an argon laser giving radiation with a wavelength of 514.5 nm and with a power of between 300 and 500 mW; the duration of irradiation was 0.2-0.5 sec and the diameter of the beam 100 μ. Arterioles, capillaries, and venules were subjected to photocoagulation. For this purpose

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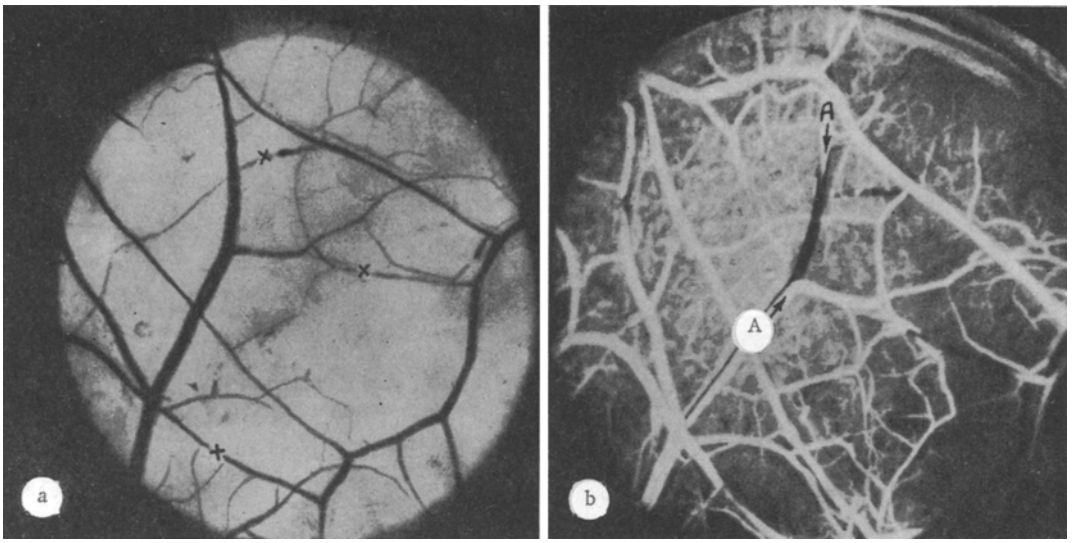

Fig. 1. Localization and blood volume in microvessels after irradiation with argon laser: a) intravital photomicrograph, 25×; b) intravital fluorescence microangiograph, 25×. A) Arteriole; V) venule. Arrows indicate direction of blood flow. X) Point of laser irradiation.

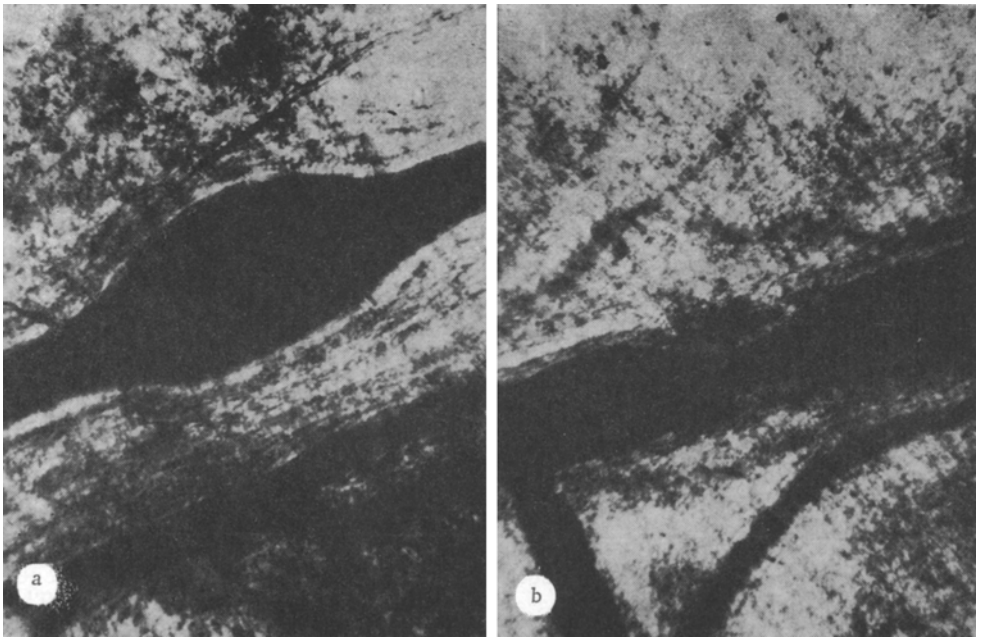

Fig. 2. Response of venule to laser irradiation of different power. a) Dilatation of lumen of venule after laser irradiation. Intravital photomicrograph, 90×; b) formation of juxtamural thrombus in venule after laser irradiation of higher power. Intravital photomicrograph, 90×.

the laser beam, under the control of a slit lamp, was focused on a particular vessel, after which it was irradiated. The accuracy of direction on the microvessel and the degree of patency of the vessel immediately after irradiation were determined by fluorescence microangiography, following intravenous injection of fluorescein (Fig. 1). Changes in the vessels and microcirculation of blood were recorded by microfilming with the MBB-1 microscope 2, 6, and 24 h and 2, 3, 4, and 5 days after irradiation with the laser beam.

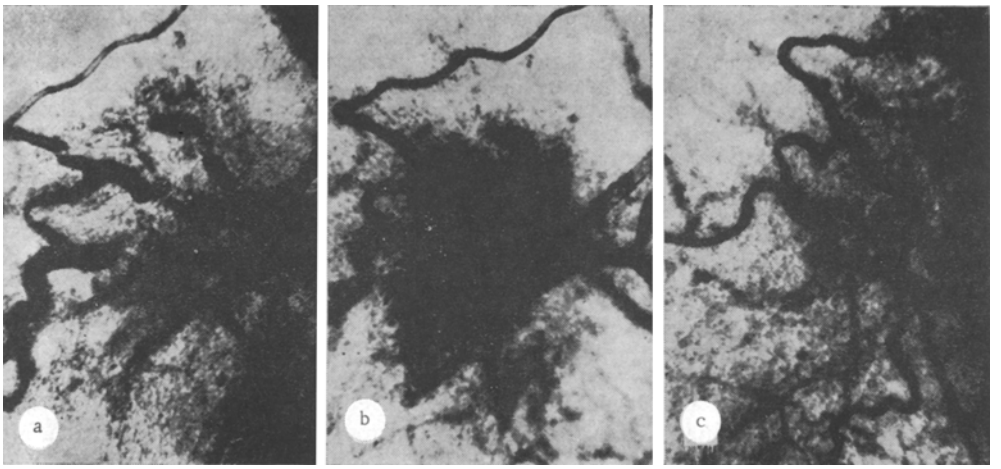

Fig. 3. Changes in capillaries and surrounding tissues after argon laser irradiation. Intravital photomicrograph, 60×. a) 30 min, b) 2.5 days, c) 4 days after irradiation.

EXPERIMENTAL RESULTS

The results showed that during irradiation by a low-energy beam (pulse power 300 mW, duration 0.2 sec) mainly dysfunctional changes were observed in the vessels, namely atony of the wall and dilatation of their lumen (Fig. 2a). With an increase in the power and duration of exposure (500 mW, 0.5 sec) coagulatory destruction of the vessel wall accompanied by the formation of a juxtamural thrombus, narrowing the lumen of the vessel, was observed (Fig. 2b). Often microhemorrhages developed within a few hours around the vessel. Intravital microscopic observations showed that the arterioles were more resistant to laser irradiation than venules. However, with an increase in the power of irradiation thrombus formation also took place in the arterioles, with subsequent occlusion of their lumen and blocking of the blood flow.

Closure of the lumen of the arterioles and venules was reflected in the general microcirculatory hemodynamics, with changes in the functional angioarchitectonics of the microcirculation.

During the first day the direction and intensity of the blood flow in the capillary networks changed, reflecting adaptive changes in the microcirculatory system due to blocking of the afferent and efferent pathways of the blood.

From 3 to 4 days after laser irradiation the thrombi formed in the vessels were absorbed, the stasis disappeared, and the natural passage of blood along the microvessels was gradually resumed, slowly at first, but later at the normal intensity. In the case of complete injury to a vessel by the laser beam, parallel collaterals for the inflow and outflow of blood formed in the course of 2 or 3 days. Fragments of the capillary system were usually used as these collaterals. The capillaries under these circumstances were dilated by the pressure of blood and their diameter reached 10-15 μ.

During laser irradiation of the capillaries, destruction of their walls and the surrounding tissue structures took place, as a result of which local microhemorrhages formed and stasis developed in the adjacent capillaries (Fig. 3a). These changes were usually accompanied by edema and neutrophilic infiltration, and after 2.5-3 days gradual disappearance of the stasis and resumption of the blood flow were observed in individual capillaries in the zone of irradiation (Fig. 3b); the tissue edema was considerably reduced. The transcapillary passage of blood was restored next day (Fig. 3c).

On the first day after irradiation in vessels close to the site of application of the laser beam, increased adhesion of the cells to the vessel wall and increased permeability of the wall, especially in the postcapillary section, were observed. Blocking of the blood flow in individual parts of the microcirculatory system as a result of laser irradiation led to functional redistribution of the blood in the capillary networks, with subsequent structural changes in the vessel walls.

The results agree with those obtained by other workers [5, 6] who showed destructive changes in tissues irradiated by lasers. At the same time, analysis of responses of the different parts of the microcirculatory system to laser irradiation showed that the capillaries are the most sensitive section. It is in the capillaries

that dysfunctional changes in the microcirculation are most clearly revealed, as atony of the vessel walls and increased juxtamural and adhesive effects.

The comparatively rapid recovery of the blood flow in the capillary networks, which was back to its initial level after 3-4 days, demonstrates the relatively high powers of compensation and adaptation of the microcirculatory system in response to the action of the laser beam.

The biological effect of laser irradiation on microvessels thus is not merely one of destructive changes followed by perifocal inflammation. Its action is also largely determined by the fact that it causes structural changes in the microcirculatory system with a corresponding redistribution of the capillary blood flow in the tissue.

LITERATURE CITED

1. V. I. Kozlov, "Experimental morphological study of the microcirculation and structural organization of the blood flow channels on the basis of intravital microscopy," Doctoral Dissertation, Moscow (1972).
2. M. M. Krasnov, Vest. Oftal'mol., No. 1, 3 (1973).
3. V. V. Kupriyanov, Pathways of the Microcirculation [in Russian], Kishinev (1969).
4. V. V. Kupriyanov, Arkh. Anat., No. 3, 14 (1972).
5. B. V. Ognev, in: Proceedings of the 6th Volga Conference of Physiologists with the Participation of Biochemists, Pharmacologists, and Morphologists [in Russian], Vol. 2, Cheboksary (1973), pp. 305-306.
6. B. V. Ognev, A. A. Vishnevskii, R. L. Troitskii, et al., in: Proceedings of the 6th Volga Conference of Physiologists with the Participation of Biochemists, Pharmacologists, and Morphologists [in Russian], Vol. 2, Cheboksary (1973), pp. 306-307.
7. A. M. Chernukh, Vest. Akad. Med. Nauk SSSR, No. 5, 47 (1970).
8. P. G. Branemark and J. Lindstrom, J. Anat., 97, 323 (1963).
9. E. R. Clark et al., Anat. Rec., 47, 187 (1930).
10. B. Kovacs, Experientia, 30, 341 (1974).
11. E. Mester, Stud. Biophys., 35, 227 (1973).