TIME COURSE OF HEALING OF EXPERIMENTAL LASER AND SCALPEL WOUNDS OF THE SKIN

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The use of high-intensity laser radiation has achieved widespread popularity in various branches of surgery in recent years. Nevertheless, there is as yet no unanimity regarding the advantages and disadvantages of laser surgery, because of differences in the interpretation of the results when the course of wound healing is estimated in tissues exposed to the action of the laser beam. Most workers who have studied repair processes in experimental wounds inflicted by various surgical instruments have assessed the course of healing on the basis of the clinical and morphological picture. So far as planimetric and functional characteristics are concerned, such as the partial pressure of oxygen, the velocity of the blood flow in the tissue, making it possible to judge the quantitative aspect of wound healing and differences in its course, there have been too few comprehensive studies with determination of these characteristics, and this was the main reason for undertaking the present study.

EXPERIMENTAL METHOD

Experiments were carried out on 90 noninbred albino rats, male and female, weighing 250-300 g. The animals were divided into three equal groups. Surgical manipulations were carried out under hexobarbital anesthesia (40 μg/kg). A full-thickness circular wound 12 mm in diameter, 120 mm^2 in area, down to the muscle fascia, was inflicted on the animals of group 1 on the dorsal skin on the right side, after preliminary cutting of the hair and shaving, using a scalpel. The skin, excised around a stencil, was removed and the wound healed beneath a scab without a dressing or without the use of any medication. The animals of group 2 underwent a combined operation: the skin incision as described above was made with a scalpel, but excision was by the focused beam of a serially produced "Skal'pel'-1" surgical laser system, using photohydro-dissection. In animals of group 3, the skin incision and excision were both carried out by laser. The animals were killed under general anesthesia on the 3rd, 5th, 7th, 10th, and 15th days, and also when the course of wound healing was complicated by sepsis; in the latter case the data were not included with the experimental results. Planimetry of the wound was carried out by the method in [8] at the times indicated above. The partial pressure of oxygen (pO_2) was studied in the zone of the postoperative scar by the transcutaneous transducer of an instrument from the firm "Radiometer" after complete epithelization of the wound. Oxygen loading was applied by inhalation of pure O_2 for 1 min. Specimens for histologic investigation were stained with hematoxylin and eosin and with picrofuchsine (by Van Gieson's method). The results were subjected to statistical analysis by the "Statgraf" package of statistical programs.

EXPERIMENTAL RESULTS

Immediately after excision with a scalpel the wound consisted of a full thickness skin defect, the floor of which, after transient bleeding, was filled with blood clot. Compared with the stencil, the wound was enlarged due to the "false

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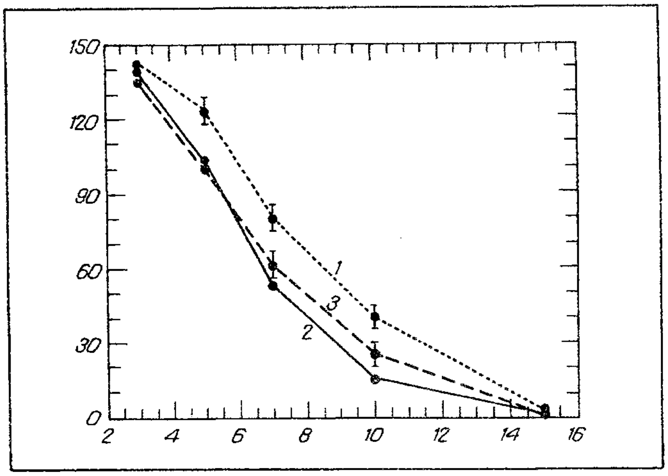

Fig. 1. Trend of rate of healing of wounds caused by laser (1), scalpel (2), and a combination of laser and scalpel (3). Ordinate, area of wound (in mm^2), abscissa, days of experiment.

TABLE 1. Trend of Change in Area of Wound Surface (M ± m)

Group	Time of investigation, days				
	3	5	7	10	15
	Area of wound, mm^2				
1-	138,9±4,46	102,8±5,03	53,0±4,36	15,5±2,07	1,6±0,8
2-	133,7±5,62	100,4±1,9	61,1±3,21	25,3±1,79	1,5±0,4
3-	142,0±4,5	123,9±5,99	80,0±5,23	39,9±3,68	3,5±1,3

tissue defect" [1]. Later, the wound healed under a scab. In group 2, immediately after the operation, the differences from group 1 were as follows: the floor of the wound was filled with a pale brown coagulation film, and the source of bleeding was the wound edges, which had been cut by a scalpel. Later, the defect also healed under a scab. Wounds inflicted by the laser beam differed from those of the previous series immediately after the operation in the absence of bleeding during and after the procedure. Due to coagulation of the epidermis and dermis the area of the wound did not increase due to the "false defect," and charred tissue particles were found on the wound edges. A few hours later, a moderate quantity of serous exudate appeared on the surface of the wound. The subsequent of wound healing in this group was distinguished by the slowness of contraction of the wounds on the 5th, 7th, and 10th days. Slowing of contraction of the laser wound compared with data for combined wounds was observed on the 5th and 10th days. There were no significant differences in the course of healing of the scalpel and combined wounds. However, wound healing in all series was mainly complete by the 15th day after the operation (Fig. 1). Postoperative scars in the different groups did not differ significantly. The data given in Table 1 correspond to values within the limits of the confidence interval at $p = 0.05$. The number of parameters lying outside the limits of significance was about equal in all groups. These parameters were disregarded and were attributed to individual differences between the animais.

Within the zone of scar tissue the values of pO_2 were identical in all the groups, but in the region of the laser scar the initial value was 23 ± 2.5 mm Hg, compared with 37 ± 3.7 mm Hg during oxygen in the region of the scar of the scalpel wound the corresponding values were 22.5 ± 2.4 and 36.8 ± 5.7 mm Hg respectively. The histologic picture of wound healing in the experimental animals did not differ qualitatively from that of the classical course of wound healing, which has been studied and described sufficiently well [3]. The main difference in preparations from wounds for which the laser was used was the almost complete absence of polymorphonuclear leukocytes and the early proliferation of cells of the macrophage and fibroblast series during the first 5 days after the operation.

To discuss the results we used as the basis data obtained by other workers who compared healing of wounds inflicted by different instruments and by a CO_2 laser. Fidler [7] excised the burned skin of rats by means of different lasers, an electric knife, and an ordinary scalpel. He noted that toward the end of the 4th week epithelization of the wound surface amounted to 83% in the case of scalpel wounds, but only 40-44% in the case of thermoscalpel wounds.

In a review of laser techniques in general surgery, Dixon [6] associates delayed epithelial migration and lengthening of the period of phagocytosis in laser wounds to thermal injury to the tissues. However, in our view this explanation is incomplete and calls for an answer to the question of interaction of energy (high temperature, photic flux) at the molecular as well as the tissue level. The tensometric characteristics of laser wounds are significantly lower than those of scalpel wounds, especially in the initial stages of observation [5], which can be explained by the inadequate collagen production. Intensive fibrosis and lengthening of healing are linked by Tichy [9] with the formation of resorptive granulomas around charred tissue remains in wounds made by a CO_2 laser.

The stereotyped nature of the exudative inflammatory-reparative reaction of laser wounds is modified and is characterized by early activation of proliferation of cells on the boundary between damaged and intact tissues. Cells of the mononuclear phagocyte system (macrophages) play an important role in the healing of laser wounds. Their functional role is to program the course of healing of laser wounds [2].

Our data on the time course of healing of laser, scalpel, and combined wounds confirm conclusions drawn by others [1, 8], who explained the delayed healing of laser wounds by the more extensive thermal injuries of the epidermis and the formation of a dense scab on the wound surface, preventing contraction and epithelization. Delay in the healing of laser wounds, in our opinion, can be explained by inhibition of the phase of exudative inflammation, as a result of which the migration of microphages into the zone of damage is reduced; the latter, as we know, secrete factors involved in cel lular reactions in the course of the repair process [4].

High-intensity laser radiation thus has a complex action on tissue. Besides its positive effect (absence of bleeding, sterility of the wound) moderate delay of wound healing is observed. The polarographic data for tissue formed after procedures involving the laser and traditional scalpel show that laser thermal damage does not affect restoration of the microcirculatory system.

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