Experimental Study of the Effects of Highly Intense Laser Exposure on Hepatic Tissue

I. Ya. Bondarevsky and L. V. Astahova*

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Irreversible changes in the liver tissue after high-intensity laser exposure develop at a depth of no more than 200 μ. Inflammatory reaction in the wounds does not depend on laser source and is characterized by predominance of proliferative processes leading by day 15 after surgery to the formation of a fine cicatrix. Hermetic sealing of the parenchymatous hepatic wound by laser welding to xenogenous peritoneum is no less effective than TahoComb and Beriplast P drugs and deserves further studies and clinical use.

Key Words: *laser welding; resection; liver; xenoperitoneum*

Despite highly technological support of surgery for hepatic tumors, the incidence of complications in resections remains at the level of 5-16% [1,6]. Approaches to reduction of complications consist in improvement of technological means providing hemostasis and methods for hermetic closure of the wound surface of the liver [5,7,9]. Problems of effective use of highly intense lasers in some surgical interventions on the liver have been discussed not once [3,4,8], but in general, the attitude of surgeons to this exposure remains sustained [5,7]. Presumably, this indicates good prospects and at the same time, insufficiently ample knowledge of the problem.

We studied the interactions of highly intense laser from various sources with hepatic tissue and tried to develop a method for hermetic closure of a parenchymatous wound by laser exposure in resections of the liver.

MATERIALS AND METHODS

A total of 62 experimental operations and 220 experiments on 20 mongrel dogs and 28 laboratory rabbits were carried out. Lancet 2 carbon dioxide laser (λ=10,600 nm), Raduga 1 Nd:YAG laser (λ=1064 nm), Sharplan 6020 diode laser (λ=805 nm), xenogenic preserved peritoneum (Biocomb), and drugs – TahoComb (Nycomed) and Beriplast (Aventis) – were used.

Resection of a standard (by size and location) fragment of the liver lobe and hemostasis with one of the above lasers were carried out in the dogs. Dynamic monitoring of the adjacent hepatic tissue temperature was carried out in 90 experiments during the first 300 sec in 5 points located at a distance of 0.5, 1.0, 1.5, 2.0, 2.5 cm from the focus of exposure and directly under it [2]. A similar resection with a surgical scalpel with suturing and electric coagulation of the hepatic wound was carried out in the control group.

Plastic repair and hermetic closure of the hepatic wound surface was attained by its laser welding to xenogenic preserved peritoneum.

Standard resection of a liver lobe fragment was carried out in 130 experiments on laboratory rabbits. In experimental group a xenoperitoneum sheet of a needed shape and size was applied onto diffusely bleeding parenchymatous wound. The xenoperitoneum was then exposed to a Sharplan 6020 diode laser (5 W), set perpendicularly to the liver wound, before fixation to the parenchymatous wound surface. The xenoperitoneum collagen fibrils melted during this manipulation and adhered to the wound surface. This provided hemostasis and hermetic closure of the liver

Chelyabinsk State Medical Academy, Russian Ministry of Health; *Chelyabinsk State Institute of Laser Surgery, Russia. ***Address for correspondence:*** bond_il@mail.ru. I. Ya. Bondarevsky

wound. In the controls the wounds were hermetically closed using drugs (TahoComb and Beriplast P) locally.

The animals were sacrificed on days 1-60. Liver sections from the focus of exposure and from the adjacent intact lobes were examined by histological methods. The significance of numerical data was evaluated by Student's and Mann–Whitney's tests.

RESULTS

Thermometry throughout laser coagulation showed elevation of surface temperature at a distance of 10 mm from the focus border only at 20 W, irrespective of the laser type. The maximum temperature elevation (by 1.3°C *vs.* the initial level) was observed in exposure to the diode laser. In case of Nd:YAG laser heating was negligible and did not differ ($p>0.05$) from that caused by diode laser (did not exceed 1.2°C). Heating of hepatic tissues caused by carbon dioxide laser was significantly lower (<0.9°C).

Similar morphological changes not depending on the source of radiation were detected in the exposed zone at a depth of 10 mm. Exudative changes in the focus of laser exposure and adjacent hepatic parenchyma were observed during the first 3 days after surgery. The necrotic focus by this time was the largest and was clearly separated from the intact parenchyma by a narrow cell roll (Fig. 1). By day 21, the focus of laser exposure looked like a well-formed connective tissue cicatrix; by day 60, this cicatrix shrank in size due to reduction of blood vessels and decrease in cell count in comparison with the collagen matrix. After scalpel resection and electrocoagulation, massive leukocytic infiltration (on days 5-7) without clear-cut separation from the intact parenchyma was noted. Proliferative processes started only by days 7-10; they led to the formation of coarse cicatrices with focal lymphohistiocytic infiltration and few new vessels (Fig. 2).

Morphological studies of liver specimens from animals subjected to laser welding of the parenchymatous wound to xenogenic peritoneum showed that alteration and reparation processes, characteristic of laser exposure, differed significantly from the time course of wound healing after its hermetic closure by TahoComb and Beriplast B.

From the very first day the xenoperitoneum was fixed to resected surface by homogenous pink protein mass and fibrin threads, with loops filled by white blood conglomerations. Microscopically, the resected liver site was a multilamellar necrotic focus with few polygonal yellowish-brown particles on its surface. The upper layers of resection zone (103.22±4.84 μ deep) consisted of numerous small empty spaces and cavities formed by stretched cell fragments of the liver parenchyma. The shape of vascular adventitial cell

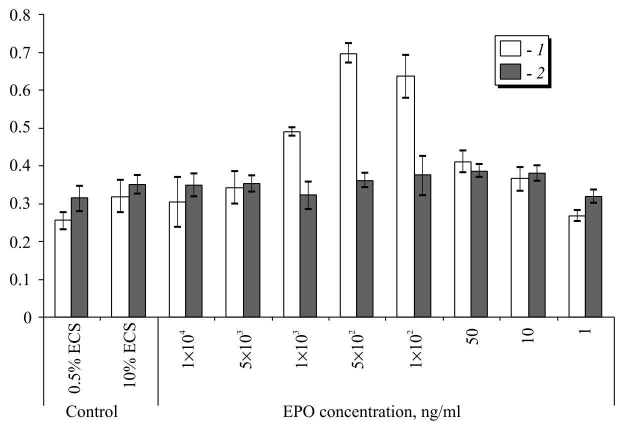

Fig. 1. Focus of exposure to a diode laser (λ=805 nm) 1 day postoperation. Hematoxylin and eosin staining, ×200. Border between coagulation necrotic focus (*1*) and intact parenchyma (*2*).

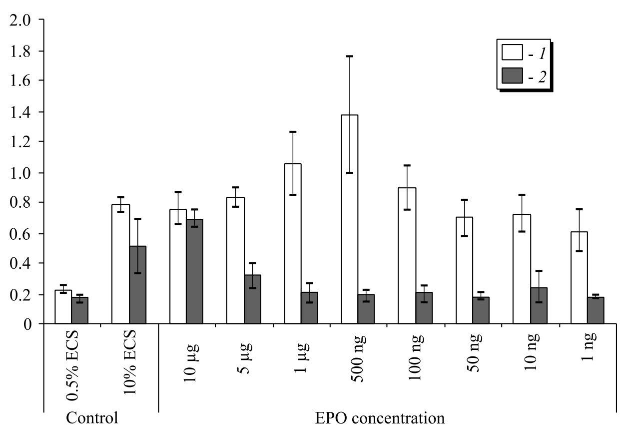

Fig. 2. Scalpel resection zone 30 days postoperation. Hematoxylin and eosin staining, ×200. Coarse fibrous connective tissue (*1*) against the background of lymphohistiocytic infiltration (*2*).

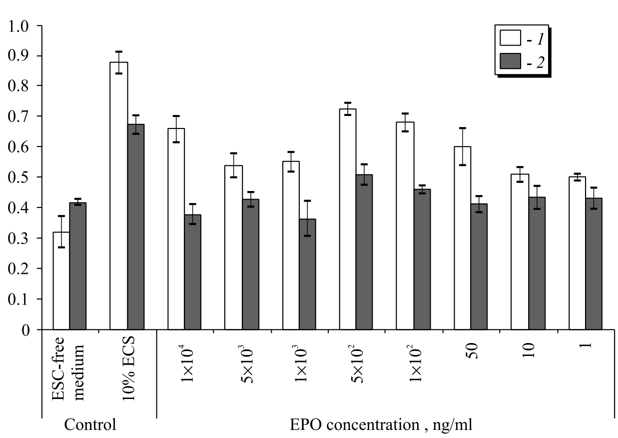

Fig. 3. Zone of laser welding of xenogenic peritoneum 7 days postoperation. Hematoxylin and eosin staining, ×100. A sheet of xenogenic peritoneum well fixed to the focus of liver parenchyma necrosis (*1*). Focal neutrophilic infiltration in the zone of contact with hepatic parenchyma (*2*).

TABLE 1. Damage to Liver Parenchyma after Exposure to Energy of Different Types

Device	Depth of tissue lesions, μ	
	necrosis	necrobiosis
Sharplan 6020 diode laser (λ=805)	103.22±4.84	77.46±3.88
Erbe-APC-300 argon plasma coagulator	164.36±6.21*	94.87±2.43*
Erbe electrocoagulator	242.16±6,91*	109.24±5.81*

Note. *Significant differences.

nuclei at a depth of 77.46±3.88 μ from the previous zone was modified; these cells were elongated and re-oriented perpendicularly to the organ surface. The entire necrotic and necrobiotic zone was clearly separated from the intact parenchyma with a moderately manifest perifocal leukocytic roll. By the end of day 14 the number of cellular and fibrous conglomerations of the xenomaterial with resected surface of the liver increased in experimental animals in comparison with the previous period. A parenchymatous necrotic focus was still seen in the resection zone; its linear size shrank significantly in comparison with days 3, 5, and 7 postoperation. A narrow roll of young granulation tissue with numerous cells, new connective tissue fibrils, and plethoric vessels was seen at the interphase with intact tissue (Fig. 3).

Microscopic changes in the liver parenchyma resection zone were similar in both control groups. Necrotic focus after resection was not clearly separated from intact liver parenchyma, as was the case in experimental group. Neutrophilic leukocytes migrated in the pericapillary spaces, forming a rather wide perifocal leukocytic roll with a trend to involve the deeper layers of the hepatic parenchyma. After 14 days the hepatic parenchyma necrotic focus was almost completely replaced by immature granulation tissue. Young fibroblasts and macrophages predominated in its cellular composition; small foci of neutrophilic lymphocytic infiltration were seen.

Resection of the liver without argon plasma coagulator is now assumed to be a risky venture. A previous experimental study [1] evaluated the extent of liver parenchyma lesions under the effects of modern coagulation means. Comparison of the depth of necrosis and necrobiosis of the parenchyma after laser welding with these data [1] clearly demonstrated a significantly lesser depth of thermal injury to hepatic tissue in our experiments (Table 1).

The experiments have shown that changes in the surface temperature of hepatic tissue under the effect of highly intense laser at 20 W took place at a distance of no more than 10 mm from the focus of exposure. The maximum temperature was no higher than 39°C (observed in response to diode laser, λ=805 nm). No irreversible changes developed in the cells; on the contrary, the biochemical reactions were stimulated [9]. In addition, reduction of bacterial contamination of the wounds below the critical level promoted a favorable course of the wound process.

Hence, morphological changes in liver tissue indicated that the wound process did not depend on the laser device. Exudative changes after laser exposure developed at a depth of no more than 200 μ within the first 3 days after the operation, the proliferative reactions predominating in the course of healing. Early fibroplastic reaction in the wounds led to the formation of a rather fine cicatrix by day 15 postoperation. Our experiments demonstrated good prospects of highly intense laser exposure and laser welding in surgery of the liver.

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