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Research Article

Laser Remote Hemostasis of the Vessels of the Conjunctiva and Episclera in Eye Microsurgery

Kopayev SY[1], Kopayeva Valentina Grigorievna[1]* and Dryagyna OB[2]

[1]The S.N. Fyodorov Eye Microsurgery Complex, Moscow, Russia
[2]Ophthalmological clinic "Constellation", Kyrov, Russia

***Corresponding Author:** Kopayeva Valentina Grigorievna, Professor of the Federal State Autonomous Institution, "S.N. Fedorov National Medical Research Center, "MNTK "Eye Microsurgery", Moscow, Russia.

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Abstract

Morphological changes in the bulbar conjunctiva and episclera are presented in an experiment on rabbits after remote exposure to Nd:YAG laser radiation at a wavelength of 1.44 μm to achieve hemostasis in comparison with diathermic exposure. Morphologically substantiated the expediency of using Nd:YAG laser 1.44 μm in eye surgery for remote hemostasis. The delicacy of the impact of laser energy is expressed in the fact that the applications have a smaller area with non-contact directional exposure. The depth of energy penetration and tissue heating is strictly limited. There is no excessive repair, no scarring in the intervention area. The diathermic contact effect is characterized by the disordered nature of the spread of heat, manifested by burns and tissue necrosis with the formation of a deep and wide focus of exposure, followed by the formation of a soldered scar.

Keywords: *Nd:YAG Laser with a Wavelength of 1.44 μm; Photocoagulation; Remote Hemostasis; Plastic and Eye Microsurgery; Surgical Field Ischemia*

Abbreviations

Nd:YAG Laser, μm: Wavelength, Hz: Frequency, mJ: Pulse Energy

Introduction

The need for hemostasis to prevent bleeding during the incision of the conjunctiva and the preparation of the sclera arises during a number of surgical interventions on the eyeball. For this purpose, thermal exposure, cryoapplications, electrocoagulation, radio wave and laser exposure can be used [1,2].

The improvement of laser technology, the emergence of a wide range of lasers for various purposes allows them to be used in various fields of clinical medicine. In eye surgery, laser technologies are currently a serious alternative to ultrasound. For example, Nd-YAG laser radiation with a wavelength of 1.44 μm in the Rakot device, designed for cataract removal, can be successfully used not only for laser opening of the lens capsule and cataract destruction, but also very effective for influencing the conjunctival and episcleral vessels for stop bleeding when performing a number of operations on the eyeball [3,4]. The presence of the specified laser unit in the operating unit saves ophthalmologists from purchasing additional equipment.

Laser energy in the Rakot device, used to remove a cloudy lens, operates in the aquatic environment around the lens in the photodestruction mode with certain energy parameters [4]. To ensure the effect of non-contact hemostasis in the air, it is necessary to find the optimal parameters of laser applications in the projection of blood vessels [5].

Purpose of the Study

The purpose of this work: To determine the parameters and effectiveness of remote exposure of Nd:YAG laser radiation with a wavelength of 1.44 μm to achieve hemostasis in the conjunctiva of the eyeball and episclera in comparison with the method of diathermocoagulation based on morphological studies.

When developing the technology for hemostasis using a Nd:YAG laser with a wavelength of 1.44 μm, on the basis of experimental modeling, the optimal diameter of the optical fiber was determined, the design of the laser tip was created, the optimal combination of energy exposure parameters (pulse repetition rate and energy in impulse).

Materials and Methods

The experiment was performed on 16 eyeballs of Chinchilla rabbits. The vessels of the conjunctiva of one eye were subjected to laser exposure in 4 quadrants, the vessels of the fellow eye were exposed to diathermy with the average mode of operation of the Mira TR 4000 device. This is due to the fact that the conjunctiva of the rabbit eye has a poorly expressed vascular network, and the third eyelid contains large vessels. The eyeballs were enucleated together with the third eyelid after the animals were withdrawn from the experiment after 1, 3 and 8 days. The technique for preparing histological preparations was standard (Head of the laboratory of Candidate of Medical Sciences Shatskikh A.V.).

Results and Discussion

On the basis of experimental and morphological studies, the optimal parameters were determined, when using which the result of exposure to laser energy is the most gentle. 20 different laser energy modes were used, which were evaluated according to the following criteria: the number of pulses per one point of exposure; laser impact diameter (applicate); condition of the vessel in the affected area (visual occlusion); the state of the conjunctiva (the severity of the tissue defect, the presence of deformation, adhesion to the sclera). The following options for a possible combination of energy parameters were chosen to achieve effective remote hemostasis:

- At a pulse frequency of 5 Hz - the energy per pulse is from 150 to 200 mJ;
- At a pulse frequency of 10 Hz and 15 Hz - energy from 100 to 150 mJ;
- At a pulse frequency of 25 Hz - the energy is not more than 100 mJ.

With non-contact careful exposure, the energy level of 100 mJ with a pulse repetition rate of 5 Hz should be considered optimal. The laser beam was narrowly directed to one point of the bleeding vessel. Such a delicate remote laser effect on pinpoint areas of the conjunctiva can be used not only to achieve local hemostasis in the area of the bleeding vessel, but also to preliminarily anemize the area of the planned surgical incision.

The energy mode of operation was assessed by the sufficiency of the functional result on the fact of the most sparing response, in which the blood flow in the vessel stops and the smallest spot of exposure remains.

A day after the first experiment, the conjunctiva in the area of laser exposure was not changed in color, not soldered to the underlying sclera. Macroscopically, it appeared as a white spot, 1 - 1.5 mm in size along the vessel. Surrounding this zone, a limited area with compaction of collagen fibers, as well as swelling of the underlying layers, was microscopically visible. At a higher magnification, the destruction of individual cellular elements in this area is visible, with a moderate amount of lymphocytes in the surrounding tissue adjacent to the intact conjunctiva. Nuclear polymorphism was observed in the layer of basal cells. The zone of the damaged epithelium abruptly breaks off at the border of the transition to the intact epithelium. Proliferation of the epithelium and its migration to the zone of laser exposure is outlined. The vessel is spasmodic.

In the second experiment, in the zone of diathermic effect, one day after the energy effect, the place of application was macroscopically manifested as a depression with tissue charring in the center, soldered to the underlying sclera within 2 - 3 mm. Microscopically, the zone of destruction of the epithelium was combined with a decrease in the volume of the underlying tissues. It occupied a significantly larger area in comparison with the laser exposure zone due to the extended transition zone between the area of the destroyed epithelium and the intact zone. There is no clear boundary between them. In the focus of the application, deep necrosis with partial charring was determined. The vessel is blocked.

3 days after the first experiment with laser exposure, complete epithelialization of the damaged area was noted. The restored epithelium was represented by a smaller number of layers. Under the laser exposure zone, the stroma had a limited compaction area, with a moderate amount of fibroblasts and lymphocytes. The lumen of the damaged vessel was restored, the macrophage phase of the reparative process was recorded. In the border areas there was a wide band of active fibroblast proliferation.

Three days after the diathermic treatment, a section of de-epithelialized conjunctiva was still preserved. An initial ingrowth of the epithelium into the damaged area was noted, more pronounced in the conjunctiva of the third eyelid. Edema remains in the underlying tissues, accompanied by inflammation with abundant infiltration by fibroblasts and macrophages, in the form of muffs. There is a perivascular accumulation of lymphocytes. The vessel is spasmodic.

After 8 days, the zones of laser applications are no longer distinguishable from the surrounding tissue, there were limited areas of tissue compaction. There was an active proliferation of epithelial cells capable of complete regeneration without scar formation both in the conjunctiva and in the third eyelid, as well as in the episclera.

After diathermic exposure, after 8 days, initial cicatricial changes were observed in the stroma of the conjunctiva with areas of proliferation of granulation tissue (an abundance of fibroblasts and cells of the histiocytic series). Folding of the tissue around the coagulation zone was noted. A scar with uneven edges is formed, sinking in a cone to the center. In some cases, the maturation of fibrous tissue and replacement of the defect led to deformation of the affected area, which was more pronounced in the conjunctiva of the third eyelid.

Conclusion

It should be noted that there is no information in the literature on the dynamics of the morphological pattern of the applicate in the conjunctiva after exposure to a 1.44 μm Nd:YAG laser, but there are data on the morphological state of coagulates after diathermic exposure.

The different morphological picture after laser and diathermic hemostasis in our experiment is explained by different mechanisms of heat transfer from the tip to the tissue [6,7].

The laser tip is cold. It does not touch the surface of the fabric, does not burn it. There is a radiative, remote mechanism of heat transfer. Laser (light) radiation is characterized by the rectilinear distribution of energy and heat, and the conjunctival tissue is a weakly scattering medium. This explains the delicacy of the impact on the depth and surface of the applicate. The radiation we used with a wavelength of 1.44 μm is capable of producing strictly directed (not scattered) internal heating of the tissue to a depth of no more than 0.5 mm. Therefore, after laser exposure, there is no scar and tissue deformation. Complete epithelialization of the defect ends 2 - 3 days after exposure.

In contrast, the diathermy tip is hot. In direct contact with the fabric, it burns it. Conductive mechanism of heat transfer is carried out. The diathermic effect is distinguished by the disordered (scattered) nature of the spread of heat, which is manifested by the formation of a deep and wide focus of exposure, followed by scarring. Diathermic contact action on the vessels of the conjunctiva captures a larger area (compared to laser), leaves a deep tissue defect with a necrosis area. The epithelialization of the defect ends not on the 2 - 3rd day, but only on the 8th day with the formation of a scar, soldered to the underlying tissue.

Morphological criteria for the expediency of choosing one of the compared methods of hemostasis for the clinic, namely laser, are: a smaller area of application with non-contact directional exposure, a strictly limited depth of energy penetration and tissue heating, the absence of necrosis of cellular elements and excessive repair with subsequent scarring in the intervention area, as well as rapid recanalization of the affected vessel. The de-epithelialization zone of the conjunctiva is significantly smaller. It is clearly limited to the place of impact. There is no inflammatory reaction roller, no areas of necrosis, complete epithelialization of the tissue defect is accelerated. After laser exposure to Nd-YAG 1.44 μm, there is no scar and tissue deformation, recanalization of individual vessels is possible.

Reversible changes in the walls of blood vessels in the zone of laser (Nd-YAG 1.44 μm) exposure can also be explained by the property of hemoglobin not to absorb incident light in a certain part of the light spectrum. Radiation in the near infrared range, including radiation at a wavelength of 1.44 μm, is not absorbed by hemoglobin. Therefore, there is no rough coagulate in the vessel. With the disappearance of edema of the walls of the blood vessel in the postoperative period, the spasm is eliminated and blood flow is restored.

The optimal parameters of laser action on the vessels of the conjunctiva and sclera, obtained in the experiment, were then confirmed in the clinic when used to stop bleeding, as well as for preliminary tissue anemization before performing an incision during operations for cataracts, glaucoma, and pterygium excision.

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Conflict of Interests

No conflict of interests.

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