

Low-Intensity Infrared Laser Therapy after Laparotomy Wound Repair with Polypropylene Hernia Mesh

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ABSTRACT

Aim: To establish the effects of low-intensity infrared laser radiation (LILR) after laparotomy wound repair with polypropylene hernia mesh in outbred rats.

Methods: The experiment was performed on 90 outbred white rats, which were divided into 3 groups of 30 animals each. The first group underwent surgical intervention with closure the surgical wound by typical technic without any additional materials. The closure of laparotomy wound in the second group carried out using polypropylene hernia mesh. In the third group, polypropylene hernia mesh was also implanted and after the surgery low-intensity infrared laser radiation (LILR) was applied to the surgical site. The animals were removed from the experiment on different terms. Then a morphometry of tissue sections from the operation area was performed.

Results: The experimental study demonstrated different effects of LILR on soft tissues around the surgical wound. Laser-tissue interactions consisted in acceleration of neutrophil infiltration decreasing, a relatively low eosinophilic leucocyte concentration in the tissues during the experiment, boost of the processes of neovascularisation and the appearance of fibroblasts. A rapid decrease in the intensity of edema in samples was presented.

Conclusion: Applying of low-intensity infrared laser radiation in case of ventral hernia treatment using mesh statistically significant ($p < 0,05$) accelerates the wound regeneration due to microcirculatory bloodstream intensification. At the same time, this method of postoperative treatment decreases leukocyte infiltration, which reduces the period of wound healing.

Keywords: Laser radiation, hernia, wound regeneration

INTRODUCTION

Today, the treatment of ventral hernias is a widespread problem in surgery. Operations with autoplasty methods are still used, but relapse rate could be from 5 to 60%, while using alloplasty methods, it averages up to 22%^{1,2}. According to different investigators, the most effective technic for the ventral hernia treatment is applying polypropylene mesh. Compared to autoplasty, using mesh reduces the percentage of relapse³. The number of postoperative complications reaches 30.5%, and among them 59–71% are seromas^{3,4,5}. The list of wound complications associated with the mesh implantation includes postoperative wound infiltrate, postoperative wound infection, abdominal wall abscess, subcutaneous fat infarction, granulomas, ligature fistulas, rejection of the mesh^{6,7}.

Management of the postoperative complications requires long hospitalization, which affects not only the patient's condition, but also the economic part of the task⁸. According to authors, the financial losses in case of treating patients with different wound complications after hernia mesh associated abdominal wall repair can amount to hundreds of thousands of dollars^{9,10}.

High morbidity rate, as well as a high number of wound complications after hernia treatment by using the mesh, indicate the necessity of surgical site complication prevention.

MATERIAL AND METHODS

The study was carried out in accordance with the European Convention for the Protection of Vertebrate Animals used

for experiments or for other scientific purposes (Strasbourg, 1986) and with the permission of Ryazan State Medical University local ethics committee. For the experiment, 90 outbred white rats weighing 150-200 g were used. All the animals were divided into 3 groups of 30 animals each.

Surgical intervention on animals was carried out in the operating room of the university vivarium. A section of hair was shaved along the white line in the region of the anterior abdominal wall. Then a midline laparotomy was performed. The incision length was 5-6cm, the section began at a distance of 0.5 cm from the xiphoid process and ended at 0.5 cm from the groin. At this stage, the further strategy varied depending on the group.

Group 1: after dissecting of all layers of the anterior abdominal wall and providing access to the abdominal cavity, the wound was closed with polypropylene non-absorbable monofilament sutures on an atraumatic needle.

Group 2 and 3: after performing a laparotomy, a defect zone of the muscle-aponeurotic layer was formed by excision of its area (2-2.5 cm). Then aponeurotic layer defect was sutured and a polypropylene mesh was applied on an outer surface. After suturing the skin, the wound was covered with an antiseptic dressing.

Group 3: Animals of this group underwent laser therapy sessions in the postoperative period. Laser therapy consisted of exposure to low-intensity infrared laser radiation (LILT) on the area of surgical intervention starting from 1 day after surgery every 2 days. The source of laser beams was a therapeutic infrared laser – semiconductor two-channel apparatus with a laser emitting head with a wavelength of 0.87-0.91 μ m, a maximum power of 5 W, and a pulse repetition frequency of 3000 Hz. The impact was

contact: the radiating head was located on the surface of the skin. The exposure time was 256 seconds; the diameter of the focused spot was 1 cm. During the one procedure the whole wound surface was covered. The number of sessions ranged from 2 (in animals removed from the experiment on day 3) to 10 (in animals removed on days 21 and 30).

The animals were removed from the experiment on days 3, 6, 9, 11, 21, and 30 after the surgery by general anesthetic drug overdosage. Then three sections of the anterior abdominal wall from the area of surgical intervention in each animal were excised. Samples were delicately freed from the elements of the mesh, fixed, and stained with hematoxylin-eosin. A morphometric study was carried out using a Leica DM1000 microscope (manufactured by Leica Microsystems GmbH, Germany). The samples were microscoped at the different layers of the abdominal wall: the epidermis, subcutaneous muscle and hypodermis. Morphometry consisted in the amount determination of the following elements: leukocytes, eosinophils (zoom x1000), fibroblasts (zoom x400), the number of vessels (zoom x400) and the distance between muscle elements (zoom x400). Calculation was carried out in 12 fields of view within the boundaries of each layer using the visualizing functions of the Image J 1.52 program. The distance between the muscle elements was also calculated in 12 fields of view using the Aperio Image Scope 12.3 program. The obtained results were entered into Excel 2013 program of the Microsoft Office 2013 package. Then the obtained data were processed using correlation analysis. The correlation strength was evaluated on the Cheddock scale. The significance of differences was determined using Student's t-test. Differences between the samples were considered statistically significant at $p < 0.05$.

RESULTS

On the 3rd day in all groups there was a typical pattern of exudative inflammation, characterized by leukocyte infiltration, a relatively large degree of edema in the tissues. The degree of neutrophilic infiltration in all observed layers was more extensive in group 3 compared with group 2. Over time, the degree of leukocyte infiltration varied, but in group 3 the quantitative curve was lower than the initial values in its group and below the corresponding curve in group 2. A drop in the curve was observed by 9 days in almost all groups, with the exception of group 1 in the layers of the subcutaneous muscle and hypodermis. Later, by 30 days, the degree of leukocyte infiltration either remained at the level of the initial values, or below.

As for edema, its degree was decreasing from days 6 to 30. The smallest distance between muscle fibers in the groups was observed on day 21. However, if in groups 1 and 2, the edema decreased only on day 9 with a non-intensified continuation of the process by day 11, then in group 3 the degree of edema was much lower by day 6 (~8 μm compared to group 1 and ~16 μm compared to group 2). By day 9, the distance between muscle fibers was 18 microns (in group 2 for the same period – 25 microns). By day 30, the average distance between the fibers in all groups was approximately the same and averaged 17.0541 microns.

When analyzing macroangiogenesis, there was a tendency to initially (on day 3) high rates in group 3 (at the level of the epidermis, subcutaneous muscle) in relation to other groups (1.493 times more than in group 2 and 2.157 times more, than in group 1). In the same group, the peak of vascular formation was observed on days 6–9, depending on the layer. In group 2 and control group 1, the peak value was reached on days 11–21.

On day 3, the number of fibroblasts in the field of view of group 3 was higher than in the other two groups. Increasing in fibroblast amount in groups 2 and 3 started from day 6 in all sections, however, in group 3, a significant increase was detected already by day 9. In this group, the highest values were achieved by day 30 and the number of fibroblasts was higher (on average at each level) compared with group 2 by 54.89%, and with the control group 1 by 87.5%.

The eosinophilic presence was brighter in group 2 at the level of all sections, especially on days 6–11. In group 3, the number of eosinophils was evenly decreasing by day 9 and then didn't not increase to statistically significant values $p < 0.05$). Comparing this indicator in groups 3 and 2, the fact that eosinophilic infiltration in group 3 did not exceed that in group 2.

DISCUSSION

The analysis of samples from the anterior abdominal wall clearly showed that the inflammatory response in all three groups had a phase course. This was reflected at all levels of the abdominal wall sections (epidermis, subcutaneous muscle, hypodermis). A decreasing of the edema degree indicated the normal course of the wound healing process. In the samples from the animals, exposed to the LILT, edema decreased faster and the effect was more stable compared to other groups.

The eosinophilic infiltration was higher in presence of polypropylene mesh, what was explained by the immune response to implantation of allogeneic material. Despite the presence of the mesh in both groups (2 and 3), the number of eosinophils in the layers was decreasing much faster in the group of animals underwent LILT and their total number didn't not exceed the same indicator in group 2 on any day.

In addition, the process of neovasculogenesis in the area of inflammation proceeded more intensively in group 3, what ensured the organization of the scar tissue. Along with the newly formed vessels, fibroblastic series cells play an integral role in the development of granulation tissue¹¹. The data obtained in the study indicated the acceleration of regeneration in the wound and predominance of the proliferative process under the influence of LILR.

CONCLUSION

The study demonstrates that low-intensity infrared laser therapy after abdominal wall repair using polypropylene hernia mesh leads not only to an acceleration of the subsidence of the leukocyte response, but also to a change in the quantitative indicators of neutrophilic infiltration. The increasing of local blood flow caused by LILR, along with an increasing in the number of fibroblasts, accelerates the proliferative process in the wound and ensures the fastest formation of granulation tissue.

The inflammation process after the applying the mesh and LILR therapy is characterized by the passage of the same stages as without laser therapy, but the differences are an acceleration of reparative processes in the wound, a decrease in the immune response to the mesh, which favorably affects the course of the wound healing process.

Declaration of author's competing interests: The authors declare no conflict of interest.

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