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Endovenous laser coagulation using two-micron laser radiation: mathematical modeling and in vivo experiments

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Endovenous laser coagulation (EVLC) is an effective treatment for varicose veins. This method combines low invasiveness and the almost complete absence of postoperative complications, which reduces the rehabilitation duration compared to, for example, phlebectomy. The occurrence of complications after EVLC is usually associated with thermal damage to perivenous tissues due to the use of high laser power levels (8–20 W for radiation with wavelengths of 810–980 nm [1-3]; 5–15 W for radiation with wavelengths of 1470–1550 nm [2-4]).

The task of identifying the optimal EVLC parameters that provide effective vein coagulation with minimal damage to the surrounding tissues is usually solved by conducting experiments with various parameters. Additional attraction of mathematical modeling methods will allow solving this problem more effectively. Since EVLC is a complex of phenomena, it is rather difficult to take into account the contribution of each of them to the final result, but even taking into account only the main processes allows us to establish the dependence of the procedure effectiveness on the treatment parameters and evaluate its possible complications.

This paper presents the results of an EVLC modeling using radiation of the solid-state laser based on an $LiYF_4$:Tm crystal with a wavelength of 1910 nm and a power of 1.5 to 4 W. The calculations were made in the COMSOL Multiphysics® Modeling Environment and were aimed at estimating the temperature distribution in the blood, vein wall and adjacent tissues when exposed to the indicated radiation. We also carried out in-vivo EVLC experiments on the sheep veins using the specified exposure parameters, the effectiveness of which was evaluated on the basis of histological studies, ultrasound studies, and clinical observations of animals during the postoperative period.

Values of the venous wall temperature, assessed as a result of modeling, correspond to the lesions character revealed by histological analysis of vein sections harvested immediately after EVLK and 40 days after it. Wherein, the damage caused by the use of 4 W radiation is irreversible, which ensures successful and permanent occlusion of the vessel. The use of 1.5 W radiation power does not contribute to the formation of a blood clot and leads to the vein wall damage, which is insufficient for vessel coagulation, and may lead to recanalization.

References

[1] MILON Group http://www.milon.ru/index.phtml?tid=1312.
[2] Sokolov A.L., Liadov K.V., Lutsenko M.M., Lavrenko S.V., Liubimova A.A., Verbitskaya G.O., Minaev V.P. (2009) Endovascular laser ablation with wavelength 1,560 nm for varicose veins. Angiol Sosud Khir 15:69–76.

[3] Malskat W.S.J., Giang G., De Maeseneer M.G.R., Nijsten T.E.C., Van der Bos R.R. (2016) Randomized clinical trial of 940- versus 1470-nm endovenous laser ablation for great saphenous vein incompetence. Br. J. Surg. 103:192-198.
[4] Almeida J., Mackay E., Javier J., Mauriello J., Raines J. (2009) Saphenous laser ablation at 1470 nm targets the vein wall, not blood. Vasc. Endovas. Surg. 43:467–472.