EXPERIMENTAL STUDY

Laser-tissue interaction in endovenous laser treatment

Veverkova L, Kalac J, Capov I, Wechsler J, Pac L, Svizenska I, Pitr V

1st Department of Surgery, St. Anna's University Hospital, Masarykiensis University, Brno, Czech Republic. **lvever@med.muni.cz**

Abstract

The authors present the results of recorded changes in the endothelium in rabbit's veins following photocoagulation by laser diode. This study concentrates mainly on the detailed description of individual changes in the rabbit's venous system in the area of pelvis following laser therapy. The aim of our experiments was to reach the obliteration of rabbits' lateral saphenous vein using 980 nm laser diode with 200 micron fibre. The intensity of discharge was 3, 5, 6 and 7 watts. We examined the relationship between changes and the amount of joules that affect the endothelium of the rabbit's veins. The operation was conducted under general anaesthesia. All animals survived treatment and were returned to breeders. Within the time span of one, three, six and eight weeks the laser treated veins were removed. They were fixed in formaldehyde and sent for microscopic examination. We were interested in how long it will take for fibrous changes to occur in the endothelium of the vein and thus also the subsequent occlusion of the vein depending on the amount of joules applied per one centimetre of the vein *(Tab. 1, Fig. 4, Ref. 6)*.
Key words: venous system, endovenous laser, morphological changes in rabbit's veins.

Medical care in the 21st century is evolving into a minimally invasive speciality. This evolution has also entered the field of phlebology. Endovenous laser treatment allows the delivery of laser energy directly into the blood vessel lumen in order to produce endothelial and vein wall damage with subsequent fibrosis (1). Laser-induced indirect local heat injury of the inner vein wall by steam bubbles originating from boiling blood is proposed as the pathophysiological mechanism of the action of ELVT.

The aim of the study

The aim of our experiments was to reach the obliteration of the saphenous vein in rabbits using 980 nm endovenous laser diode with 200 and 600 micron fibre. The intensity of discharge was 3 watts with the length of discharge 1.5 seconds and one second pause. At the beginning the same amount of watts was applied and the fibre was pulled in a standard manner by 2 mm. During the experiment percutaneous application of laser without ultrasound control was used. The operation was done under general anaesthesia. All animals survived the operation and were returned back to breeders. Within the time span of one week,,four and eight weeks the laser treated veins were removed. They were fixed in formaldehyde and sent for microscopic examination to identify changes.

Materials and method

The experiment was conducted on rabbits under general anaesthesia using Xylazine, in dose of 4mg per kilogram of body weight and Ketamine, in dose of 50 mg per kilogram of body weight, the exact dose was calculated individually for each animal, based on its body weight (4). At the pullback of the fibre from the lateral saphenous vein the period of recovery depends on the time, wavelength and the use of laser together with the energy that is applied. The exact calculation of the amount of applied joules per one cm of vein was not done during the initial experiments. We applied the method gradually as we wanted to find out how quickly the rabbits veins obliterated when using 3 W without compressive therapy. The second phase of the experiment was based on the presumption that the higher the amount of joules applied per 1 cm of the vein the faster their occlusion.

1st Department of Surgery, St. Anna's University Hospital, Masarykiensis University, Brno, Department of Anatomy, Faculty of Medicine, Masarykiensis University, Brno, and Veterinary Clinic, Brno, Czech Republic

Address for correspondence: L. Veverkova, MD, PhD, 1st Dept of Surgery, St. Anna's University Hospital, Pekarska 53, CZ-602 00 Brno, Czech Republic
Phone: +420.5.3182328

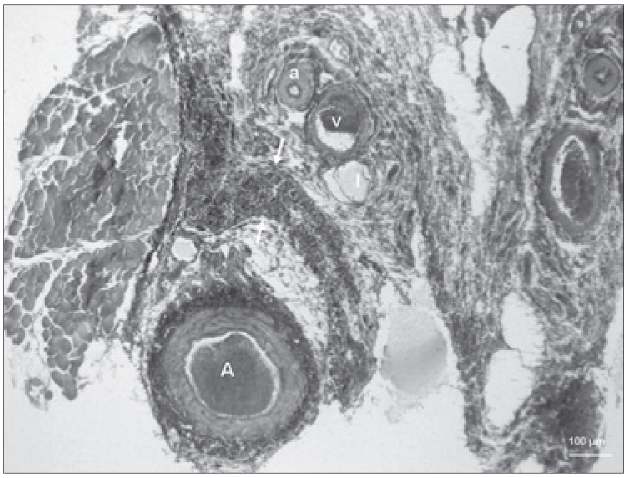

Fig. 1. The vein walls are fibrotic, stuck together (between the arrows) near the artery (A). There is a small artery (a), a vein (v) and a lymphatic vessel (l) near the artery (5x0.75).

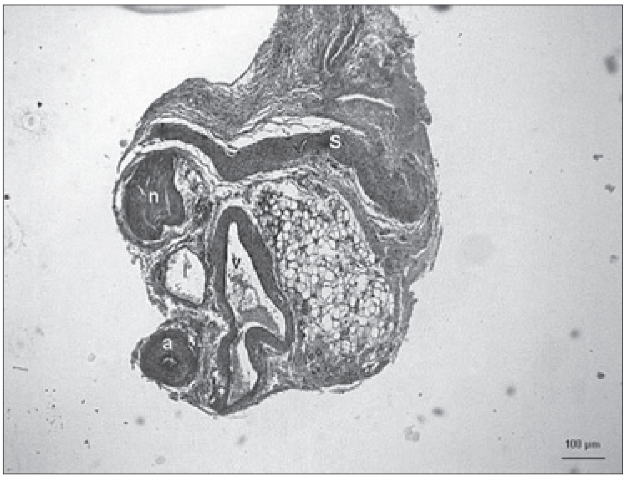

Fig. 3. The fibrotic altered and thickened vein wall, A – artery, l – lymphatic vessel, n – nerve, s – the fibre smoothly floats into the perivascular tissue, i.e. the laser influenced also the surroundings of the vein, v – vein (5x0.75).

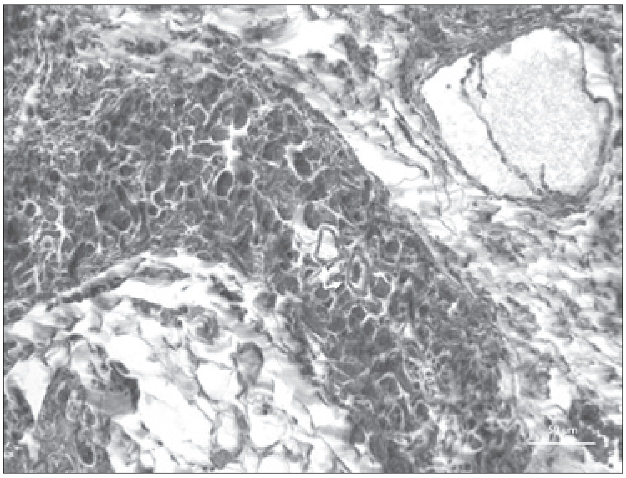

Fig. 2. A detail of the previous picture. There are remnants of endothelium (E) – perhaps, between the fibrotic vein walls (20x0.75).

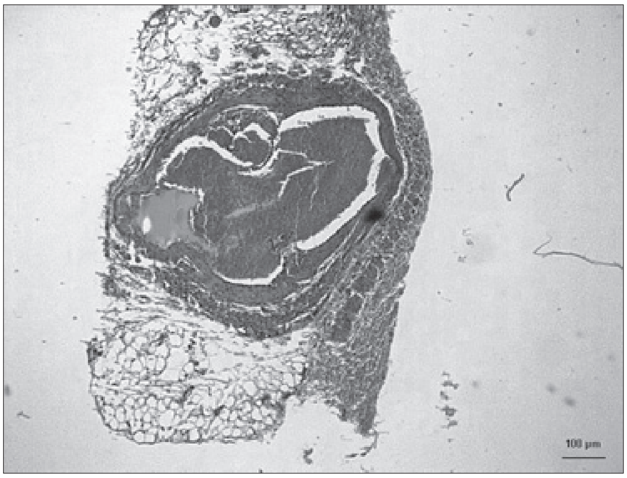

Fig. 4. Vein removed immediately after operation, i.e. basically intact – coloured with orcein which enables to distinguish the layers of the wall in detail (5x0.75).

Results

In total 30 rabbits underwent surgery, i.e. 60 lower limbs. In 14 cases we failed to apply the fibre well which resulted in a hematoma, we left 6 limbs as controls and in 4 cases a hematoma occurred during the laser treatment. These animals were excluded from the evaluation. In total, 36 limbs were evaluated.

The histological examination of the treated and excised veins demonstrates thermal damage along the entire treated vein with evidence of perforations at the site of laser application. This is described as an "explosive-like" photo-disruption of the vein wall. This produces a homogeneous thrombotic occlusion of the vessel. This situation is well-known in the literature.

In representative orcein stained sections of rabbit's saphenous veins, immediately after endovenous laser treatment the effect is not visible. The venous wall is not altered. The thrombus lies inside the venous lumen. Eight weeks after the endovenous laser treatment the rabbit's vessel segment is practically occluded. by an organized thrombus. Between the borders of the thrombus and the profusely injured part of the vessel wall a thin crack is preserved. Individual layers are not perceptible, above all the intimal layer is significantly altered (Figs 1–4).

Perivascular structures were not affected in any of the cases, this documents Figure 3, which shows an intact nerve but a completely occluded vein.

Data are in the Table 1.

Discussion

During the last five years the treatment of varices has changed. Classic surgical treatment is on the retreat and endovascular therapy is preferred. The principle and method of treat-

Tab. 1. Data.

Rabbit No	Weight (kg)	(W)	(J)	(s)	vein length (cm)	Watts per 1 cm
1	1.6	5	62.0	19.70	4.00	15.50
			157.0	12.70	2.50	62.80
2	1.6	5	86.0	28.00	4.50	19.10
			76.0	16.40	2.50	30.40
3	1.6	5	99.0	21.00	3.50	28.28
			85.0	17.60	1.70	50.50
4	1.6	6	178.0	31.00	5.00	35.60
			94.0	16.70	3.50	26.86
5	1.6	6	86.0	15.00	5.50	15.63
			208.0	36.00	6.00	34.66
6	1.8	6	12.0	2.00	4.50	2.66
			168.0	29.00	5.50	30.54
7	1.8	7	142.0	21.00	6.00	23.66
			60.4	8.83	6.00	10.06
8	1.8	7	209.0	30.30	6.50	32.15
			92.0	13.00	1.50	61.33
9	1.8	7	65.0	9.90	2.00	32.50
			133.0	20.00	6.00	22.00
10	1.5	5	263.0	53.50	5.00	52.60
			406.0	82.50	5.00	81.20
11	1.2	5	56.8	11.90	3.00	18.90
			55.2	11.70	2.50	22.80
12	1.3	6	56.0	9.90	2.50	22.40
			94.0	16.70	3.50	26.85
13	2.8	6	76.8	24.00	2.50	30.72
			68.0	12.60	1.80	37.78
14	2.5	6	77.0	31.30	2.00	38.50
			64.0	30.00	2.00	32.00
15	2.5	7	113.0	17.80	4.00	28.25
			110.0	18.70	3.50	31.43
16	1.2	5	56.8	11.90	3.00	18.93
			55.2	11.70	2.50	22.08
17	1.3	6	56.0	9.90	2.50	22.40
			94.0	16.70	3.50	26.86
18	1.8	7	209.0	30.30	6.50	32.15
			92.0	13.00	1.50	61.33

ment of saphena incompetence using endovascular laser is to remove the reflux by destroying the endothelium of the inner vein walls without damage to perivascular tissue. In the case of humans the treatment is conducted under general anaesthesia (3). In the treatment a laser diode is used with 600 and 200 nm strong uncovered fibre. Perivascular structures that are 0.8 mm thick are spared thermal damage. But it is not known how far the heat spreads from the laser beam through the venous wall and what damage is caused to structures that are thinner than 0.8 mm. At the pullback of the fibre from the vein the period of recovery depends on the time, wavelength and the use of laser together with the energy that is applied (2). Generally known rules for the use of the equipment are provided by the equipment manufacturer. The experience of individual workplaces on how to use endovenous laser to obliterate GSM are also available. It is, however, not clearly stated how many joules must be applied per 1 cm of vein. Thus far no study has explored damage to tissues caused by the heat of the endovascular laser beam. Specialized literature comprises only the excellent article by R.A. Weiss that deserves further consideration. It is the first study using animals to determine the basic mechanisms of this novel technique. This situation then raises the question: should we not gain more theoretical information to optimize new techniques before applying them to patients? Thanks to R.A. Weiss' work and additional in vitro experiments, showing that laser-generated steam bubble formation might be an important mechanism of action, a new technique of endovenous laser treatment has evolved (6), The continuous delivery of laser energy during the continuous pull-back of the laser fibre, slow enough to keep the steam bubbles at the fibre tip, obviously minimizes the problem of vein perforation and even accelerates treatment.

We believe that the widespread use of laser is not possible without the mastery of the technique and a thorough knowledge and understanding of the equipment, J.L. Gerard recommends to apply the minimum energy of 40 J/cm of the treated vein. On the basis of our experience we recommend to measure the length of the treated part of the vein and calculate the energy, i.e. the minimum of joules that must be applied to the given part of the vein, before the surgery. Currently we use 50--70 J/cm. It is necessary to check the values on the equipment throughout the operation, this significantly accelerates operational drill and brings the desired benefits for the patients. The histological crosscuts of rabbits' veins proved that the higher the applied thermal energy per 1 cm the quicker the fibrotic change of the vein. Even though, it still remains questionable what maximum energy can be applied without damage to perivascular structures.

Conclusion

Initial reports have shown this technique to have excellent short-term efficacy in the treatment of incompetent GSV, with 96 % or greater occlusion at 9 months in human medicine. Rabbits' veins were occluded after 8 weeks with no major complication and compressing therapy was not used. These results are very auspicious for using ELVT in human medicine.

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