Comparative Analysis of 1470 nm and 1940 nm Wavelengths in Endovenous Laser Ablation of Large Diameter Great Saphenous Vein

Analiza porównawcza długości fali 1470 nm i 1940 nm w wewnątrznaczyniowej ablacji laserowej żył odpiszczelowych o dużej średnicy

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SUMMARY

Aim: To compare pathomorphological changes in the venous wall of large diameter great saphenous veins (GSV) after endovenous laser ablation (EVLA) using wavelengths of 1470 nm and 1940 nm.

Materials and Methods: We studied 120 specimens of great saphenous veins from 30 patients with chronic venous disease with large-diameter (>1 cm). Patients were randomly divided into two groups. The 1st group received EVLA using wavelengths of 1470 nm, the 2nd group received EVLA using wavelengths of 1940 nm. Four specimens were taken at the level of the lower third of the thigh after laser coagulation in each patient. Vein specimens were processed for histological studies. Both qualitative and quantitative analyses were performed to assess the degree of wall changes.

Results: The share of satisfactory results when using 1470 nm laser wavelengths is 83.3%, while when using 1940 nm laser wavelengths this result is 93.3%. When using both wavelengths of laser irradiation with a GSV diameter of more than 1 cm, no unsatisfactory results are observed.

Conclusions: Obtained in our study data confirmed efficacy of the 1470 and 1940 nm endovenous laser ablation in the treatment of the large size GSV (more than 10 mm). Histological exams show preferability in the 1940 nm EVLA versa 1470 nm, considering the excellent result in the uniformity of distribution and safety in the deepness of the thermal injury.

Key words: endovenous laser ablation, chronic venous disease, large diameter great saphenous veins, 1470 and 1940 nm wavelengths, laser thermal injury

Słowa kluczowe: wewnątrzżylna ablacja laserowa, przewlekła choroba żylna, żyły odpiszczelowe o dużej średnicy, długość fali 1470 i 1940 nm, laserowe uszkodzenie termiczne

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INTRODUCTION

Introduction of the endovenous laser ablation (EVLA) in the surgery practice leads to improvement of the clinical outcomes in treatment of chronic venous disease [1-3]. During the COVID-19 pandemic mortality rates due to venous thrombosis tended to grow [4].

There are retrospective cohort studies reporting that the risk of developing deep vein thrombosis was significantly increased among adults with chronic venous disease [5]. Similarly, Wu N.C. et al. [6] population-based study showed that the presence of chronic venous disease is a risk factor for venous thromboembolism and correlates with an increased risk of mortality in patients. Venous thromboembolism is the main disease burden worldwide, with an estimated 10 000 000 cases per year [7].

Considering the existence of a direct relationship between thrombosis and great saphenous veins (GSV) morphology and sizes, accessibility for the non-invasive outpatients' surgery approach becomes more significant [8, 9].

The advantages of this technique include high efficiency, ease of execution, minimal surgical trauma, rapid medical and social rehabilitation [1-3]. The use of the EVLA on large diameter veins (more than 10 mm) is especially relevant. In the postoperative period of treatment of large diameter GSV, patients are disturbed by large painful cords along the coagulated veins, paravenous infiltrates, risks of recanalization of welded veins. Literary wavelengths indicate that EVLA is less effective in GSV with a diameter of more than 10 mm. There is no generally accepted standard, so randomized clinical trials and deeper analysis of the effects of different wavelengths in the treatment of large veins are needed [10, 11].

AIM

The aim of this study is to compare pathomorphological changes in the venous wall of large diameter GSV after endovenous laser ablation using wavelengths of 1470 and 1940 nm.

MATERIALS AND METHODS

All patients included in the study received informed consent to participate in accordance with the World Medical Association's Declaration of Helsinki (WMA Declaration of Helsinki – Ethical Principles for Medical Research Involving Human Subjects 2013). The study was approved by the Bioethics Commission of the Academic and Research Medical Institute of Sumy State University.

The study included 30 patients with chronic veins disease. The criterion for inclusion in the study was that the diameter of GSV>10 mm. It was determined at the level of the lower third of thigh using ultrasound the SonoScape S6 apparatus with an L741 linear probe (frequency range of 7-13 MHz) in the gray-scale B-mode.

The exclusion criteria were pregnancy or lactation, deep vein thrombosis, connective tissue diseases, oncology, and severe concomitant diseases.

The age of the patients ranged from 30 to 65 years, in average 50 (50,65±11,08), women accounted for 86,7% (26). The duration of the disease varied from 7 to 20 years. Written consent was obtained from each patient after a full explanation of the purpose and nature of all procedures used. Patients were randomly divided into two groups according to the treatment options: the 1st group (n=15) – EVLA with 1470 nm wavelength; the 2nd group (n=15) – EVLA with 1940 nm. The groups were formed in parallel in time and matched by age, sex and clinical CEAP classes (Table 1).

For EVLA, universal laser coagulators "Lika-surgeon" manufactured by OOO "Photonica Plus" (Cherkasy, Ukraine) with λ=1470 nm and λ=1940 nm were used. The irradiation power of 10 W and the fluence of 50 J/cm^2 were the same in both groups.

Puncture of the GSV was performed with a Vasofix Braun 14 G needle distal to the lower reflux limit, which was determined by preliminary ultrasound mapping. Under ultrasound control a light fibre with radial optics was passed in the antegrade direction to saphenofemoral junction (SFJ) up to the point of the first tributary vein discharge into the GSV. Local tumescent anesthesia was applied with Klein's solution with a calculated dosage (0.1% solution of lidocaine and sodium bicarbonate 5-10 ml per 1 cm of a vein length). The fibre was tractioned mechanically at an average speed of 1 mm/s. After the operation, the patients underwent compression therapy of the 2nd class of compression around the clock for 5 days.

For histological analysis 3 cm segment was taken just after the laser ablation at the variable levels in the thigh after the output GSV from under the superficial fascia. The segments were fixed for 24 hours with a 10% buffered formalin solution (pH = 7.0-7.2). Subsequently, the standard histological processing of the material was carried out. After dehydration, a fragment of a vein was embedded in paraffin in a carousel type "AT 1010 M". Despite of decreasing in tissue volume during fixation, the integrity of the morphological structures remained unchanged.

Histological examination was carried out on dewaxed sections 5x10 mm, with a thickness of 4 to 7 microns. 120 samples (4 sample from each vein) were stained with hematoxylin and eosin according to the standard technique. For light microscopy, a Carl Zeiss Primo Star light microscope (Germany, ZEISS Microscopy) was used.

The state of the venous wall, the nature of morphological changes, which was determined by the severity of the prevailing

Table 1. Demographic characteristics of groups

Characteristic, units of measure	Groups		P-value
	1st group (n=15)	2nd group (n=15)	
Wavelength, nm	1470	1940	
Age, years	52.53±11.92	48.64±10.16	>0.05
Female, sex, n (%)	13(86.7)	13(86.7)	>0.05
CEAP clinical classification, n (%)			
C 3	11 (73.3)	10 (66,7)	>0.05
C 4	4 (26.7)	5 (33.3)	>0.05
GSV diameter, mm	13.53±2.23	13.21±2.69	0.348
Subtotal reflux type, n (%)	6(40.0)	5(33.3)	>0.05
Common reflux type, n (%)	9(60.0)	10(66.7)	>0.05

**Values are presented as mean ± standard deviation or number (%)*

***CEAP, Clinical, Etiology, Anatomy and Pathophysiology; GSV, great saphenous vein* pathological processes in the intima, media, adventitia, were assessed. The depth of pathomorphological changes in the venous wall and the length of the heat treatment perimeter were evaluated.

Statistical processing of the results was carried out using the standard package statistical programs "STATISTICA 10.0" and "MS Excel". For the obtained indicators the arithmetic mean (M) and standard error of the mean (m) were calculated. For rate the degree of significance of differences between the groups used a simple Student's t test (t).

RESULTS

Qualitative analysis of the 120 venous wall samples from both groups showed various pathomorphological signs of a thermal damage of the vein walls.

Superficial damage to the endothelium, coagulation necrosis extending to the subendothelial layer, thermal damage to the muscle layer of the vein, microperforation, perforation with extensive zones of coagulation necrosis were examined.

Typical signs of varicose lesions were founded in the both groups: blurring of the boundaries between the membranes, myoelastosis and myoelastophibrosis, focal petrification, phenomena of elastolysis and phlebosclerosis, interfascicular fibrosis of the media, atrophy of muscle fibers and dystrophic changes or a focal absence of subendotelium.

In the 1st group, after EVLA with a wavelength of 1470 nm, histological examination revealed more profound changes in the vessel wall, including thermal injury to all layers. Significant loosening, degenerative changes in elastic and collagen fibers of the subendotelium were observed in the 10% slices. Areas of endotelium carbonization (charring) at the point of contact with the laser fiber were detected in 10% patients. In 73,3% of the slices foci of coagulation necrosis reached the media were present. 16,7% of the slices were characterised deep pronounced dystrophic-necrotic changes of all the layers (Figure 1).

Histological examination of the slices after 1940 nm laser ablation in the 2nd group revealed signs of varicose vasodilation (myoelastosis and myoelastofibrosis) with continuous carbonization over the entire inner surface of the vein (Figure 2). Carbonization localized exclusively in the endothelial/subendothelial layers was detected in 8 slices (13.3%). Extension to the underlying tissues with moderate oedema, cells vacuolization, and a disorganization of elastic and collagen fibers were present in 48 slices (80.0%). Dystrophic-necrotic changes at the level of the adventitia were found in 4 slices (6.7%) (Figure 2).

No cases of tissue damages with extravasation were present in the both groups.

Quantitative histological analysis included assessment of the depth and perimeter of venous walls involving in the pathomorphological process.

The results were ranged based on injury depths and extension to evaluate the efficiency of EVLA with different wavelengths (1470 nm and 1940 nm):

Excellent, good, satisfactory, unsatisfactory – by the distribution of the pathological sings compare to the vessel perimeter (%);

Completely satisfactory, satisfactory, unsatisfactory – by the pathological sings extending into the layers of the vein wall.

The percentage of endothelium thermal injury compare to internal perimeter of the vein wall were categorized as following (Table 2):

- excellent result – the range of 0,75-1,0% – was founded in 60.0% of slices in the 1st group compare to 73.3% – in the 2nd group;
- good result – the range of 0,5-0,75% – 33.3% in the 1st group (1470 nm) compare to 20.0% in the 2nd group (1940 nm);
- satisfactory result – the range of 0,25-0,5% – 6.7% in the 1st group (1470 nm) and 6.7% in the 2nd group (1940 nm);
- unsatisfactory result – the range less than 0,25% – no cases in both groups.

The depth of injury level was classified as satisfactory result if the thermal lesion is localized within the endothelium/subendothelium, or endothelium/subendothelium and media.

Table 2. Results of the histological examinations of vein wall injures after 1470 nm and 1940 nm laser ablation

Distribution of histological signs	1st group	2nd group	P-value
Wavelength, nm	1470	1940	
Number of slices, n	60	60	
Diameter of the GSV, mm	13.53±2.23	13.21±2.69	0.348
Perimeter, n (%)			
0,75 – 1,0	36(60.0)	44(73.3)	<0.05
0,5 – 0,75	20 (33.3)	12(20.0)	<0.05
0,25 – 0,5	4 (6.7)	4(6.7)	>0.05
<0,25	0	0	
Deepness, n (%)			
Endothelium	6 (10.0%)	8 (13.3%)	<0.05
Endothelium + media	44 (73.3%)	48 (80.0%)	<0.05
Endothelium + media+adventitia	10 (16.7%)	4 (6.7%)	<0.05
Extravasation	0	0	

**Values are presented as mean ± standard deviation or number (%)*

*** GSV, great saphenous vein*

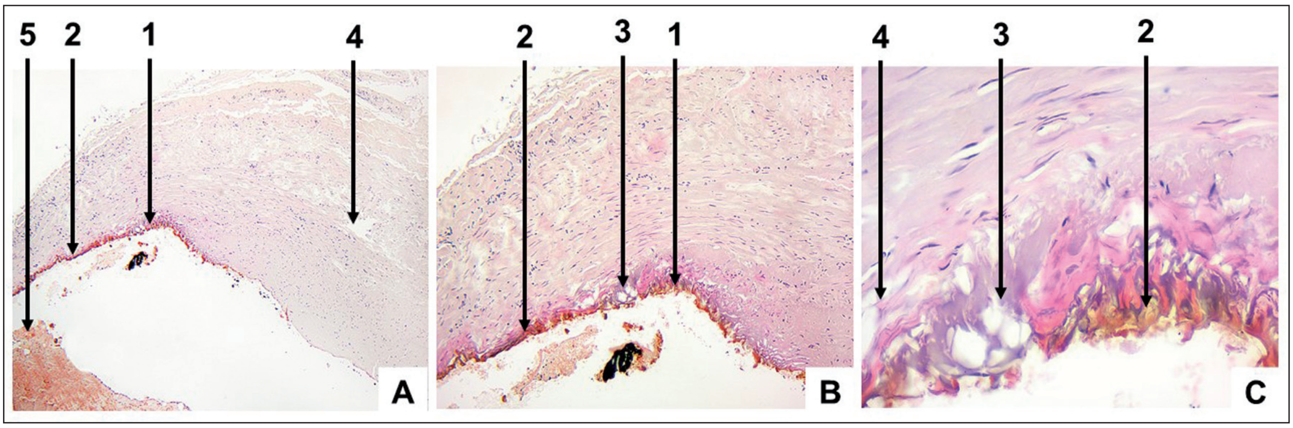

Figure 1. Histological examinations of the vein wall changes after 1470 nm laser ablation

1 – crater-like defect of the vessel wall, 2 – carbonization, 3 – focus of necrosis, 4 – edema, 5 – parietal thrombus. Staining with hematoxylin and eosin. Magnification: A×40, B×100, C× 400

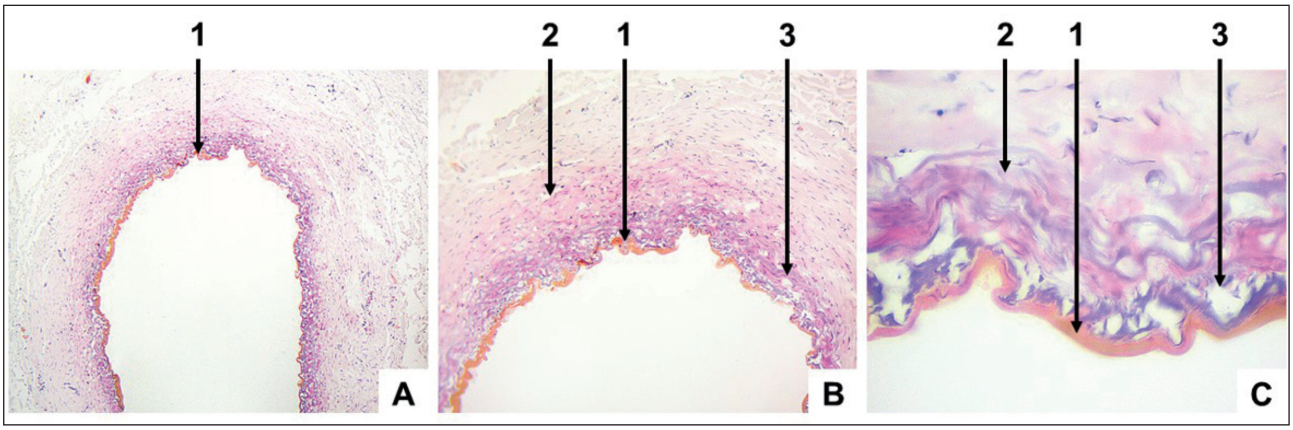

Figure 2. Histological examinations of the vein wall changes after 1940 nm laser ablation

1 – carbonation, 2 – edema, 3 – looseness of connective tissue fibers. Staining with hematoxylin and eosin. Magnification: A×40, B×100, C×400

If a thermal lesion was detected by all the venous layers, a result was considered as unsatisfactory.

Signs of stable endothelium carbonization, disorganization and necrotization of collagen and elastic fibers along the entire perimeter within the endothelium or endothelium + media, categorized as completely satisfactory, were presented by 93.3% in the 2nd group and 83.3% in the 1st group.

The above characteristics, spreading into all the layers without extravasation, were categorized as unsatisfactory: in the 1st group, satisfactory results were detected by 16.7 %, in the 2nd group – 6.7 %. There were no unsatisfactory results in both groups – no cases of tissue damage with extravasation (Table 2).

Endolumenal thermal trauma led to the representing of the mixed blood clots, loose fibers of the subendothelial layer and necrotic-desquamative masses into the lumen. Postablation deformity of the inner surfaces and adhesion of the parietal parts of vessels were founded in slices of the both groups. In some slices of the 2nd group, the lumen of the vessels was not determined, due to adhesion of the opposite wall's intima.

DISCUSSION

The purpose of EVLA is to cause irreversible damage to the vessel wall, which will ensure permanent occlusion of the incompetent vein. Laser energy, which is transmitted through a flexible light guide to the operating area, causes thermal ablation, vaporization and carbonization of the lumen compound (plasma, blood cells) and vein vessel wall, leads to a photothermal burn of the endothelium and adhesion of the vessel walls, and its degeneration over time into a fibrous cord. Laser devices with predominant liquid water absorption are more efficient than those targeting haemoglobin as a chromophore target. The non-invasive chronic vein disease treatment recently focuses on using the longest wavelengths lasers, including 1940 nm and 1470 nm [12, 13].

Now-days debates include discussion of the upper limit GSV to provide complete obliteration after EVLA. It was accepted by a number of clinicians a value of 10, 12, 14,15 mm [14-16] as the upper limit for GSV diameter in endovenous thermal ablation.

Araujo WJB, Timi JRR, Kotze LR, Vieira da Costa CR [11] compared histological and immunohistochemical changes in GSV>10 mm after EVLA and LET (50 versus 100 J/cm). They demonstrated achieving of GSV occlusion with less thermal damage to the intima, media, adventitia and perivasal tissues using 1940 nm versus 1470 nm diode laser.

To carry out a comparative assessment of efficiency of 1470 nm and 1940 nm EVLA in large diameter GSV treatment, we considered the development of uniform stable carbonization of the endothelium, disorganization and necrotization of collagen and elastic fibers as the basis for the subsequent development of persistent fibrosis at the next stages postablative inflammation.

We analysed deepness of morphological changes in the venous wall after EVLA using the following criteria: no thermal lesion, thermal lesion within the endothelium/subendothelium, thermal lesion within the endothelium and media, thermal lesion of all the venous layers.

We determined the uniformity of carbonization by the distribution of pathohistological signs of endothelium in percentage (%) of the total intima perimeter ranged as: 0,75-1,0%; 0,5 - 0,75%; 0,25-0,5%; less than 0,25% of the perimeter.

Results of our study demonstrate significant differences in histological picture of the GSV wall after laser ablation between the groups: the excellent result in the uniformity of a distribution of the thermal injury sings compare to the vessel perimeter were obtained in 73.3% in the 2nd group (1940 nm) compare to 60% in the 1st groups (1470 nm) ($p<0,05$). Completely satisfactory results in a thermal injury within the endothelium/subendothelium and media layers were obtained by 93.3% after 1940 nm laser ablation in the 2nd group and 83.3% – in the 1st group with 1470 nm laser ablation.

CONCLUSIONS

Obtained in our study data confirmed efficacy of the 1470 and 1940 nm endovenous laser ablation in the treatment of the large size GSV (more than 10 mm). Histological exams show preferability in the 1940 nm EVLA versa 1470 nm, considering the excellent result in the uniformity of distribution and safety in the deepness of the thermal injury.

ETHICAL ASPECTS

The study was approved by the Bioethics Commission of the Medical Institute of Sumy State University.

References

1. Wittens C, Davies AH, Bækgaard N et al. Editor's Choice - Management of Chronic Venous Disease: Clinical Practice Guidelines of the European Society for Vascular Surgery (ESVS). Eur J Vasc Endovasc Surg. 2015;49(6):678-737. doi: 10.1016/j.ejvs.2015.02.007.
2. Raetz J, Wilson M, Collins K. Varicose Veins: Diagnosis and Treatment. Am Fam Physician. 2019;99(11):682-688.
3. Nesbitt C, Bedenis R, Bhattacharya V, Stansby G. Endovenous ablation (radiofrequency and laser) and foam sclerotherapy versus open surgery for great saphenous vein varices. Cochrane Database Syst Rev. 2014;(7):CD005624. doi: 10.1002/14651858.
4. Akhter MS, Hamali HA, Mobarki AA et al. SARS-CoV-2 Infection: Modulator of Pulmonary Embolism Paradigm. J Clin Med. 2021;10(5):1064. doi: 10.3390/jcm10051064.
5. Chang SL, Huang YL, Lee MC et al. Association of Varicose Veins With Incident Venous Thromboembolism and Peripheral Artery Disease. JAMA. 2018;319(8):807-817. doi: 10.1001/jama.2018.0246.
6. Wu NC, Chen ZC, Feng IJ et al. Severe varicose veins and the risk of mortality: a nationwide population-based cohort study. BMJ Open. 2020;10(6):e034245. doi: 10.1136/bmjopen-2019-034245.
7. Turetz M, Sideris AT, Friedman OA et al. Epidemiology, Pathophysiology, and Natural History of Pulmonary Embolism. Semin Intervent Radiol. 2018;35(2):92-98. doi: 10.1055/s-0038-1642036.
8. Lawrence PF, Chandra A, Wu M et al. Classification of proximal endovenous closure levels and treatment algorithm. J Vas Sur. 2010; 52(2): 388-393. doi:10.1016/j.jvs.2010.02.263.
9. Bosson JL, Riachi M, Pichot O et al. Diameters of acute proximal and distal deep venous thrombosis of the lower limbs. Inter Union Angiol. 1998;17(4):260-267.
10. Mendes-Pinto D, Bastianetto P, Cavalcanti Braga Lyra L. et al. Endovenous laser ablation of the great saphenous vein comparing 1920-nm and 1470-nm diode laser. Int Angiol. 2016;35(6):599-604.
11. de Araujo WJB, Timi JRR, Kotze LR, Vieira da Costa CR. Comparison of the effects of endovenous laser ablation at 1470 nm versus 1940 nm and different energy densities. Phlebology. 2019;34(3):162-170. doi: 10.1177/0268355518778488.
12. Sroka R, Pongratz T, Esipova A et al. Endovenous laser therapy for occlusion of incompetent saphenous veins using 1940nm. In: European Conference on Biomedical Optics, Munich, Germany. 2015. doi:10.1117/12.2183777.
13. Yamamoto T, Sakata M. Influence of fibers and wavelengths on the mechanism of action of endovenous laser ablation. J Vasc Surg Venous Lymphat Disord. 2014;2(1):61. doi: 10.1016/j.jvsv.2013.05.009.
14. Dabbs EB, Mainsiouw LE, Holdstock JM et al. A description of the 'smile sign' and multi-pass technique for endovenous laser ablation of large diameter great saphenous veins. Phlebology. 2018; 33(8):534-539. doi:10.1177/0268355517734480.
15. Woo HY, Kim SM, Kim D et al. Outcome of ClosureFAST radiofrequency ablation for large-diameter incompetent great saphenous vein. Ann Surg Treat Res. 2019;96(6):313-318. doi:10.4174/astr.2019.96.6.313.
16. Malskat WSJ, Poluektova AA, van der Geld CWM et al. Endovenous laser ablation (EVLA): a review of mechanisms, modeling outcomes, and issues for debate. Lasers Med Sci. 2014; 29: 393–403. doi:10.1007/s10103-013-1480-5.

Conflicts of interest:
The Authors declare no conflict of interest

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