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1940 NM ENDOVENOUS LASER IN CLINICAL PRACTICE: INITIAL RESULTS AND HISTOLOGICAL FINDINGS FROM A 1940 NM-TREATED GSV TRIBUTARY

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Abstract

Background: Endovenous laser treatment (EVLT) has evolved since its introduction in the late 1990s, with various wavelengths and fiber designs improving efficacy and patient safety. Lasers with wavelengths around 2 µm, including 1920 and 1940 nm, offer promising outcomes due to enhanced absorption by the venous wall and reduced energy requirements.

Objective: To evaluate the clinical effectiveness and histological impact of a 1940 nm laser generator for the treatment of varicose veins, including tributaries, and compare its outcomes with existing protocols.

Methods: From September 2023 to February 2025, 603 EVLA procedures were performed using a 1940 nm laser in 490 patients. Power settings ranged from 2.5 to 6 W, with a linear endovenous energy density (LEED) of 20–97 J/cm. Histological analysis was conducted on vein segments exposed to 0, 20, 40, 60, and 80 J/cm at 4 W pullback, including a large tributary vein and routine mini-phlebectomies under ultrasound guidance.

Results: At 1, 6, and 12 months, target vein occlusion was 100%, and complete vein resorption was observed in 87% of patients within 3–6 months. No incidences of deep vein thrombosis, EHIT, skin burns, or clinically significant hematomas occurred. Mild paresthesia was reported in 5.6% of cases, primarily at mini-phlebectomy sites. Histological findings indicated no significant thermal damage below 40 J/cm, while substantial asymmetrical damage was evident at 60 J/cm and higher.

Conclusions: The 1940 nm laser demonstrates high safety and efficacy profiles for both truncal and tributary varicose veins, allowing lower power and LEED than conventional 1.5 µm systems. These parameters reduce postoperative side effects and permit safe treatment near superficial nerves, lymphatic structures, and skin.

Keywords: Endovenous Laser Ablation (EVLA), Varicose Veins, 1940 nm Laser.

Introduction

The introduction of endovenous laser technologies in phlebology dates back to the late 1990s. One of the earliest reports was made by the Spanish phlebologist, Dr. Carlos Boné, at the Union International of Phlebology conference in Bremen in October 1999. His presentation was titled "Endoluminal treatment of varicose veins with diode laser." In it, he presented clinical data on the

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intravascular use of an 810-nm diode laser for treating varicose veins of the lower extremities. The method was termed EVLT (Endovenous Laser Treatment). The first publication on the endovenous use of a laser was also an article by Carlos Boné [1].

Widespread adoption of lasers in phlebology began in 2001 following the publication of what became a classic article by Navarro L., Min R. J., Boné C. in the journal *Dermatologic Surgery* [4]. This publication presented the results of endovenous laser treatment (EVLT) of varicose veins using an 810-nm diode laser in 33 patients with great saphenous vein (GSV) reflux and 80 patients with reflux in the Giacomini vein or the anterior lateral tributary. The article described the classic method, which, with minimal modifications, is still applied today: puncture of the target vein with catheter placement or venous incision in the distal segment, antegrade advancement and placement of the laser fiber 1–2 cm distal to the saphenofemoral junction, positioning of the fiber with ultrasound guidance and pilot light, tumescent anesthesia using a 0.5% lidocaine solution without adrenaline, and digital compression of the fiber during retraction. The results were excellent. One hundred percent of the target veins were occluded, and there were no complications typical of classical surgical procedures, such as hematomas, paresthesias, or infections. In addition to reducing the risk of complications associated with traditional procedures, the study demonstrated the safety of performing the procedure in an outpatient setting without the need for specialized anesthesia.

Further Development of Endovenous Laser Technologies

Subsequent development of endovenous laser technologies focused on studying and refining treatment outcomes. Researchers aimed to identify optimal laser emission wavelengths and power settings that would ensure reliable obliteration of the target vein on the one hand and minimize trauma to surrounding tissues on the other, thus reducing the risk of complications.

A significant contribution to the advancement of endovenous laser obliteration (EVLO) was made by the German phlebologist, Professor Thomas M. Proebstle. In the early 2000s, multiple articles devoted to EVLA (endovenous laser ablation) were published. One article focused on endovenous treatment of the small saphenous vein [5], and another examined the mechanism by which laser radiation affects the vein wall [6]. In that in vitro study, it was shown that one of the major mechanisms by which near-micron laser wavelengths (810, 940, and 980 nm) act on the vein wall is indirect, mediated by the generation of heated steam bubbles within the venous lumen. Notably, these bubbles form only in blood, not in aqueous solutions, and vein wall damage is more pronounced in the presence of these bubbles, owing to a combined destructive effect. Absorption of laser energy by blood components in the venous lumen leads to the formation of heated steam bubbles, and the volume of steam generation is almost linearly dependent on the power of the laser radiation delivered into the venous lumen. To achieve more reliable damage to the vein wall, some surgeons therefore began to use higher-power laser parameters—up to 30–40 W in some cases.

Although using such high-power settings provided more consistent venous obliteration, it also increased the incidence of side effects such as pain, ecchymosis, and thermal injury to surrounding tissues, even leading to skin scarring along the vein’s trajectory. One particularly significant issue associated with lasers that are absorbed by hemoglobin was the relatively frequent and problematic complication of vein wall rupture during laser exposure. A certain amount of blood would then leak into the subcutaneous tissue, aggravating ecchymosis and pain.

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In search of a solution, Thomas M. Proebstle proposed in 2005 the use of a 1320-nm laser [7]. That study analyzed three patient groups: in the first two, EVLO was performed at a 940-nm wavelength with laser powers of 15 and 30 W, respectively; in the third group, an Nd:YAG (1320 nm) laser was used at only 8 W. The target vein was occluded in 95% of patients in the first group and in 100% of patients in the second and third groups. At the same time, the patients who underwent EVLA with the 1320-nm laser experienced a statistically significant reduction in subjective pain and fewer ecchymoses.

Evolution of Laser Fibers

In parallel with improvements in laser devices, the fibers used for these procedures also evolved. In the early stages of developing endovenous techniques, end-firing (forward-firing) fibers were employed, transmitting radiation along the longitudinal axis. However, because the laser beam was focused at a single point, it had several significant disadvantages, particularly the inability to uniformly affect the entire inner surface of the vein wall. Increasing the laser power did lead to higher rates of successful occlusion (via indirect heat transfer and the creation of steam bubbles, along with direct heating and carbonization at the fiber tip). However, it also increased the incidence of complications such as perforation of the vein wall, heightened postoperative pain, and more frequent ecchymoses.

Fibers with radial emission, introduced in 2008, ensured better contact with the entire venous wall surface during the procedure. They emerged alongside the development of water-absorbing lasers with wavelengths of 1470 or 1560 nm. With these types of lasers, extensive heating of the fiber tip was unnecessary, and lower power levels were sufficient to achieve an effective outcome compared to hemoglobin-absorbing lasers. Later, fibers with two radial rings were introduced, as well as fibers with a reduced diameter for use in smaller veins, tributaries, and perforating veins.

Currently, laser generators with a wavelength of 2 µm (1920 nm or 1940 nm) are also available. This new generation of laser generators can provide equally effective endovenous laser coagulation with fewer undesirable side effects [3]. However, according to a meta-analysis by Malskat W. S. J. et al. [2], no significant differences have been identified in the efficacy of EVLA when comparing hemoglobin-absorbing versus water-absorbing lasers.

Mechanism of Laser Action

Laser radiation is high-energy, monochromatic, coherent electromagnetic radiation with a specific wavelength. Its effects on the body primarily depend on how it is absorbed by various biological tissues. Different tissues absorb laser energy differently depending on the wavelength. As the tissue absorbs (or “takes up”) the laser energy, the energy is transferred to the absorbing substance (chromophore). The main chromophores involved in energy transformation during EVLA are hemoglobin and water. Absorption of energy by blood and tissue leads to various effects and reactions, the most critical of which is photothermal—heating. Heating the absorbing tissue causes damage. Irreversible damage to venous wall tissues is typically attributed to the denaturation of protein structures. Most proteins denature at temperatures of 60–80 °C, when their tertiary structure is disrupted. Heating water within the cells and intercellular space of the venous wall leads to irreversible changes and permanent, nonthrombotic occlusion.

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Additionally, several other thermal effects occur within the vessel during laser exposure. One of these is the carbonization of carbon-containing substances, resulting in the formation of a black carbon deposit at the fiber tip. The presence of carbon increases the temperature in the target zone (above 1000 °C). This intense heat causes vaporization of blood remnants inside the vein, burning them off and creating superheated steam bubbles. This phenomenon has been thoroughly examined in T. Proebstle's studies, which showed a direct correlation between the laser power and the volume of steam generated. Given that one theory of venous wall injury involves bubble formation and the bubbles' indirect effect on the endothelium, some authors have recommended performing EVLA at relatively high power settings (up to 30 W). These recommendations mainly applied to end-firing fibers and to lasers primarily absorbed by hemoglobin. While higher power settings do often improve vein occlusion, they also proportionally increase the number of complications. Thus, in the mid-2000s, the use of water-absorbing lasers (around 1.5 μm wavelength) was proposed, followed shortly thereafter by the introduction of radial emission fibers. These advances have allowed a reduction in the required laser power without sacrificing efficacy.

Experimental data indicate that laser light at approximately 1.5 μm is absorbed by blood and water several times more strongly than 1.0 μm wavelengths. The next absorption peak occurs at 2 μm, which is even more effective than 1.5 μm (Fig. 1). The trade-off for higher absorption is a shallower penetration depth into the tissue. For endovenous laser obliteration, the ideal scenario is to achieve maximal impact on the venous wall with minimal penetration beyond it (thus reducing damage to adjacent tissues).

Using radial emission fibers makes it possible to distribute the laser energy more evenly across the vascular wall, since the fiber tip contacts the vein wall circumferentially. This allows for reduced laser power settings without compromising effectiveness. According to some studies, achieving effective occlusion of the target vein may require direct damage only to the endothelial layer, which is physiologically justified because the endothelium is what prevents adhesion of blood coagulation elements and thrombus formation in a native vein.

For a long time, the formation of “gas bubbles” was considered an incidental side effect of laser energy rather than a factor in vein wall damage. However, modern experimental work involving lasers with wavelengths of 1.5 and 2 μm (Fedorov D. A., Minaev V. P. et al., 2019, in press) convincingly demonstrates that these “bubbles” are essential for proper delivery of laser energy to the vein wall (Figs. 2 and 3). This is because, during tumescent anesthesia—which aims to isolate the outer vein wall from surrounding tissues and expel blood from the vein—the vein itself may collapse around the fiber in unpredictable ways, given the excess capacity of venous wall tissue. Intuitively, one might think that the portion of the venous wall farthest from the fiber tip would remain undamaged, especially since in dense tissue, laser light penetration does not exceed roughly 1 mm (due to high absorption), suggesting a higher likelihood of the vein re-opening postoperatively. In reality, however, this almost never occurs. This is because superheated gas bubbles forming during laser operation effectively push the venous wall outward, allowing direct laser exposure of the endothelium and reducing the absorption of laser energy within the nontarget zone (the venous lumen). The absorption coefficient in the gaseous environment is much lower than in denser tissues or liquids.

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Thanks to their higher absorption coefficient, laser generators with longer wavelengths heat the surrounding fluid and tissues more quickly and thoroughly, ensuring uniform heating of the venous wall and causing irreversible endothelial damage.

Following EVLA, due to the laser's thermal effect and associated damage to the venous wall, a specific series of changes—primarily inflammatory—occurs in the vein, culminating in the complete cessation of blood flow. One key feature is that these changes develop along nearly the entire segment of the vein that was treated. Experimental removal of treated veins shows that if the vein is excised immediately after laser exposure, predominantly localized changes are observed; however, in veins removed later, the inflammatory process involves nearly the entire venous wall in a circumferential manner. As a result, the vein is excluded from circulation, effectively eliminating vertical reflux. Over a period of roughly 3 to 9 months, the vein is fully replaced by fibrous tissue, which is sonographically indistinguishable from its fibrous sheath. Differentiating the vein one year post-procedure is, in most cases, virtually impossible.

In experimental research examining microscopic changes in veins treated with a 1940-nm laser, complete coagulation of the venous endothelium and muscular layer was observed at an LEED of 40 J/cm (Bogachev V. Yu.).

MATERIALS AND METHODS

From September 1, 2023, to February 2025, 603 endovenous laser ablation (EVLA) procedures were performed on 490 patients in the VarikzoOFF clinics in Tashkent, using a 1940 nm laser generator. Among these, 456 procedures were carried out on the great saphenous vein (GSV), 78 on the small saphenous vein (SSV), and in 69 cases on other venous basins. In all cases, the EVLA of the main target vein was performed according to the classic, widely accepted technique. The fiber was inserted and advanced proximally through a 6F introducer from the most distal point of reflux. After positioning the fiber at the junction with the deep venous system, tumescent anesthesia was administered. When performing endovenous laser obliteration of main trunks, radial fiber emitters were used in all cases. The laser power ranged from 2.5 to 6 W (on average 4.3 W), with a LEED of 20–97 J/cm (average 43 + 9 J/cm). Fiber pullback was performed automatically at a speed of 0.7–1 mm/s. All stages of the operation were carried out under ultrasound guidance.

Combined mini-phlebectomy of varicose tributaries using the Varady technique through microincisions in the skin was performed in 393 patients. The tributaries were removed under tumescent anesthesia using Varady hooks without the placement of sutures. In 40 patients, a large GSV tributary was treated with a laser power of 4 W at different pullback speeds (5, 10, 15, and 20 s/cm). As a result, five fragments were subjected to five different linear endovenous energy density (LEED) values: 0, 20, 40, 60, and 80 J/cm. These segments were collected from a patient during a routine mini-phlebectomy for varicose veins, and 2-cm pieces were obtained for histological analysis.

In 181 patients, intraoperative or delayed sclerotherapy of tributaries was performed. EVLA of varicose tributaries (Total EVLA according to Ints Udris's method, modified by D. A. Fedorov) was done in 29 procedures. The choice of how to remove tributaries depended on the operating surgeon's preference. A distinctive feature of the 1940 nm laser radiation is the technical feasibility of performing EVLA on varicose tributaries. Due to the minimal absorption of the laser by non-target

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tissues, no thermal damage to the skin was noted in any case when treating tributaries with EVLA. For Total EVLA, after placing the fiber in the main trunk of the target vein, 16G or 18G cannulas (Braunüle) were inserted under ultrasound guidance into the pre-marked target tributaries. Considering the tortuous course of these tributaries, it is technically impossible to keep the entire cannula strictly within the vein; therefore, the aim during the puncture was to "thread" as much venous tissue as possible onto the cannula (Fig. 4). After placing the cannula, the puncture needle was not removed, to avoid thrombosis in the Braunüle lumen. EVLA of the tributaries was performed immediately after the main trunk EVLA. For this, the needle was removed from the outermost Braunüle, and an end-firing laser fiber was introduced into the lumen. An end-firing fiber was chosen in this situation due to the small diameter of the fiber (400 µm) and the limited diameter of the Braunüle, which reduces pain from the cannula insertion. Once the fiber was in place, the Braunüle was removed, tumescent anesthesia around the tributary was carried out, and the laser exposure was delivered. Pullback was done manually at 1–2 mm/s with a power setting of 5 W (Fig. 5).

RESULTS

Long-term follow-up was up to 1.5 years (mean 9.2 + 3 months). Occlusion of the target vein was noted in 100% of cases at 1, 6, and 12 months. Complete resorption of the target vein 3–6 months post-intervention was observed in 87% of patients. There were no cases of deep vein thrombosis, EHIT, skin burns, clinically significant hematomas, or lymph leakage. Mild paresthesia was noted in 5.6% of cases (mostly in the mini-phlebectomy area). Mild hyperpigmentation in superficial areas was seen in 3 patients (0.85%). Histological analysis showed no significant damage at 0, 20, and 40 J/cm. However, at 60 J/cm, pronounced asymmetric thermal damage was observed throughout the intima and media, and at 80 J/cm there was extensive damage affecting the entire thickness of the venous wall (Fig. 1).

CONCLUSIONS

Postoperative observations indicate a high level of effectiveness and safety when using the 1940 nm laser generator. In this case, both the laser power and LEED can be lower than those recommended for 1.5 µm generators. Reducing the amount of delivered energy and ensuring higher absorption by the target tissue of the vein wall decreases the number of side effects following endovenous laser coagulation. Moreover, it allows the safe application of laser treatment near the superficial nerves of the lower leg, lymphatic capillaries, and the skin when performing EVLA on varicose tributaries.

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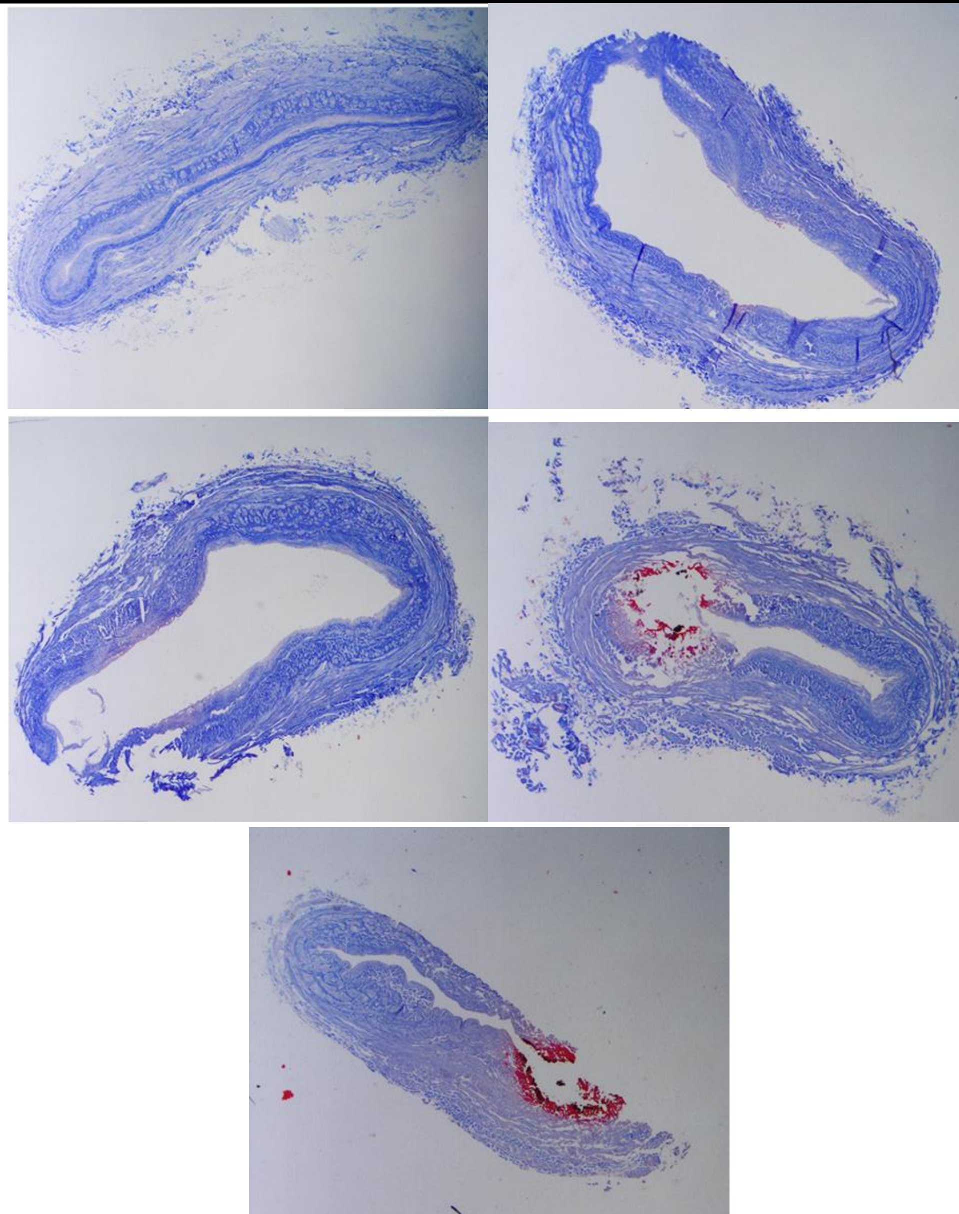

Fig.1. Histological analysis of a large extra-fascial tributary bypassing a hypoplastic segment of the great saphenous vein (GSV) treated with varying LEEDs by a 1920 nm endovenous laser. Stained with Martius Scarlet Blue. Connective tissue appears blue and fibrin red. 0 J/cm, 20 J/cm, 40 J/cm, 60 J/cm, 80 J/cm. Pictures taken at 40 magnification.

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