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A single-center experience with a 1470 nm versus a 1940 nm diode laser

Ann. Ital. Chir., 2022 93, 5: 578-583
pii: S0003469X22037538

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The evolution of endovenous laser ablation (EVLA): A single-center experience with a 1470 nm versus a 1940 nm diode laser

AIM: *To evalue the short-term results obtained in endovenous laser ablation (EVLA) procedure of the varicose insufficiency of the lower limbs with Diode 1470 nm laser compared to Diode 1940 nm laser.*
MATERIALS OF STUDY: *A total of 55 patients were enrolled in the study. The patients were divided into two groups: those subjected to 1470 nm laser treatment in group A and those with 1940 nm laser treatment in group B. The endpoints were: Closure of the target vessel, complications and post-operative pain.*
RESULTS: *There are no intra-and post-operative complications. The occlusion rate of the target veins was 100% at 7- and 60-day controls. The pain perceived in the immediate post-operative and at the controls showed no statistically significant differences between the two groups. However in group B it was necessary to apply lower values of Power (W) and Linear Energy Density (LEED) with a statistically significant difference compared to group A.*
DISCUSSION: *Short-term results demonstrate closure rates comparable to those obtained with 1470 nm lasers. There were no statistically significant differences in the two groups in terms of primary and secondary endpoints. The advantage of using 1940 nm laser technology is that it is possible to dispense a lower linear energy density (LEED) at a lower power (Watt).*
CONCLUSIONS: *Endovenous laser ablation with Diode 1940 nm is particularly suitable and advantageous in the treatment of superficial and small vessels, as well as venous segment adjacent to nerve structures.*

KEY WORDS: Diode laser, Intravenous ablation, Varicose, Venous insufficiency, Veins.

Introduction

In the last few years, the surgical treatment of varicose veins has undergone to a progressive, but substantial, evolution towards minimally invasiveness, both in the primary treatment and in that of relapses [1-3]. Such changes of the techniques have allowed not so much the attainment of a greater radicality of the procedure, in the sense of abolition of the reflux, but, sure, an always more rapid post-operative recovery and a reduction of the perioperative-complications and post-procedurals. In consideration of this, current international guidelines recommend the percutaneous ablative techniques such as laser thermoablation (EVLA) or radio frequency (RFA) as the first-choice treatment of venous insufficiency [4,5,6,7]. However, the transition from traditional open surgery to percutaneous surgery did not represent the final goal of evolution: in fact, it has been possible to witness a progressive refinement of the methods through the use of materials with increasingly advanced technology. As for the laser thermoablation technique (EVLA), it exploits the effects that laser has on target tissues. An extremely important factor are the chromophores, that is the particles that absorb the light radiations and that make the laser an instrument with high selectivity and precision for the treatment of this pathology. In particular, the element that most affects this selectivity is the wave-

Pervenuto in Redazione Dicembre 2021. Accettato per la pubblicazione Gennaio 2021
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length. In fact the same energy administered at different wavelength, by virtue, will determine a different interaction with the chromophores present. The wavelength between 650 and 810 nm is predominantly absorbed by melanin, while between 975 nm and 1064 nm are predominantly recognized by hemoglobin. Hemoglobin has an uptake peak in the wavelength range from 900 to 1000 nm (especially around 975 nm). That absorption decreases progressively until near 1064 nm there is no more selectivity. Water from 975 nm onwards begins to have high affinity with laser light. Obviously the water is a chromophore with the highest concentration in biological tissue. For these reasons, today, lasers with higher frequencies (1320 nm and 1470 nm) are more used compared to the past (810 nm and 980 nm). The advantage of the new generation lasers is that allow to obtain a complete damage to the vein wall using a lower power (W) and a lower linear energy density (LEED, J/cm) [8-14].

In this article we report, the short-term results of the intravenous laser treatment (EVLA) for the treatment of the varicose pathology of the lower limbs performed in our Center obtained using laser 1470 nm and laser 1940 nm.

Materials and Methods

Was enrolled a total of 55 patients undergoing laser thermoablation surgery (EVLA) in the period between April and June 2021 at Our Center, Villa Salus Foundation, Villa Salus Hospital - equated and accredited with the SSN, Venice Mestre (VE). The typology of the study is retrospective observational. The procedures were carried out by expert operators in EVLA treatment with more than 100 EVLA interventions/year. The endpoints were: closure of the target vessel, complications and post-operative pain. The inclusion criteria were: venous reflux >1 sec, minimum venous diameter >3 mm, classification Clinical, Etiologic, Anatomic, Pathophysiologic (CEAP) >=C2. Treatments on greath saphenous vein, small saphenous vein and perforators veins were included. The exclusion criteria were: venous diameter > 20 mm and patients with flebostatic ulcer (CEAP C6). It was decided to exclude such patients to prevent interference in results (Bias) in post-treatment pain. The latter was evaluated by filling in a questionnaire NRS (Numerical Pain Rating Scale) with values from 0 to 10. Ultrasound checks were carried out at the end of the procedure, at 7 days and 2 months. The data obtained were discussed and evaluated with the Department of Clinical Medicine and Surgery of the University of Naples Federico II.

Statistical Analysis

The data were recorded in tables on Excel 2019, (Windows Microsoft, Redmond, WA, USA). The variables were expressed in absolute and relative values and included in tables. Statistical analysis was performed by using averages and standard deviations (SD). The differences between the two groups were evaluated by t-Student Test. The values of $p<0.05$ were considered statistically significant.

Description of the Procedure

Each procedure was preceded by the written acquisition of an accurate informed consent. The surgery were carried out in outpatient treatment. The day of the surgery was performed a preoperative ultrasound mapping, with the patient in orthostatism, using GE Logic ultrasound (General Elettric Company Scenectady, NY, USA). The procedures were conducted with percutaneous access, using a 6 Fr or 4 Fr introducers at operator's discretion and according to the size of the vessel to be treated. The entire procedure was performed under ultrasound guidance. The laser control units used are manufactured by Neolaser ltd. (Caesarea, Israel) and are the models: Neov1470 and Neov1940. The interventions were conducted with the administration of only local anesthesia by tumescence (500 ml of saline solution cooled at 4 ° C with 2 vials of 10 ml of Lidocaine 20 mg/ml), delivered with peristaltic pump under ultrasound guidance. The laser thermoablation procedure was performed with pullback technique, applying a linear energy density (LEED) from 25 to 60 Joule/cm, in accordance with the size of the target vessel. As usual in endovenous laser ablation, the tip of the laser fiber was positioned below the upper collaterals of the saphenous-femoral junction for the greath saphenous vein and about 2 cm from the saphenous-popliteal junction for the small saphenous vein. Such positioning not only reduce the risck from a possible thermal damage of the deep venous vessels, but, especially for the great saphenous vein, it allow to save the superficial epigastric vein, that is necessary to guarantee the "washing" of the safenic stump, preventing its thrombosis and reducing the incidence of relapses [15,16]. The procedures were completed with the treatment of the collateral varicose veins. In 6 cases with ultrasound guided foam sclerotherapy and in 40 cases with phlebectomies. At the end of the surgery an ultrasonographic closure check was performed and an elastic sock monocollant 35 nmhg was applied, with the indication to wear it h24 for 3 days and then only during daylight hours for a further 4 days. Then it was prescribed to wear a model elastic stocking and compression related to the class CEAP of belonging. The average duration of the surgery was 28 minutes. The postoperative therapy provided the administration of low molecular weight heparin (Enoxaparin 4000 IU/day) for 7 days and painkiller therapy to the need. After two hours of surgery, an evaluation of pain was carried out using an

NRS questionnaire. The first post-operative control was made 7 days after the surgery and included clinical and ultrasound examination as well as administration of a new NRS questionnaire for the evaluation of pain. Than, a new ultrasound control and a new NRS questionnaire was carried out two months after the procedure.

Results

A total of 55 patients (38 women and 17 men), corresponding to 55 venous segments were treated with endovenous laser ablation (EVLA) technique. Patients were divided into two groups: those treated with 1470 nm laser in group A and those with 1940 nm laser in group B. Patients's demographic characteristics are shown in (Table I). The average diameter of the venous segments subjected to laser ablation was 9,25 ± 3,40 mm in group A and 9,54 ± 3,25 mm in group B. The power used was respectively 6,22 ± 0,81 Watt in the group treated with 1470 nm laser and 4,8 ± 0,85 Watts in the group treated with 1940 nm laser. The applied linear energy density (LEED) values used were respectively 35,60 ± 11,05 in group A and 31,17 ± 6,15 in group B (Table II). All patients showed improved symptoms related to venous disease (burning, swelling, itching and heaviness). None intra- and post-operative complications were observed. The occlusion rate of the target veins was 100% at 7- and 60-day controls. The pain perceived in the immediate post-operative and at the controls showed no statistically significant differences between the two groups. There were no differences even in the return to normal activities 7 days after the procedure. The post-operative controls, performed at 7 days and 2 months, carried out did not shown any recanalizations (complete or partial) of the treated vessels nor relapses. No cases of EHIT have been recorded (Table III).

Table I

	Laser 1470 NM (group A)	Laser 1940 NM (group B)
Patient	24 (gruppo A)	31 (gruppo B)
Average Age (years)	50,20	55,66
Gender	15 (62,5) F 9 (37,5%) M	23 (74,19%) F 8 (25,81%) M
Great Saphenous Vein	20 (83,33%)	23 (74,19%)
Small Saphenous Vein	2 (8,33%)	4 (12,90%)
Perforator Vein	2 (8,33%)	4 (12,90%)
CEAP C 3	9 (37,5%)	11 (35,48%)
CEAP C4	9 (37,5%)	14 (45,16%)
CEAP C5	6 (25%)	6 (19,35%)
Average Diameter at 2 cm from the Junction (mm)	7,23 ± 2,78	8,48 ± 3,08
Average Diameter (mm)	9,25 ± 3,40	9,54 ± 3,25
Medium Length (mm)	35,79 ± 14,67	27,53 ± 14,26

Table II

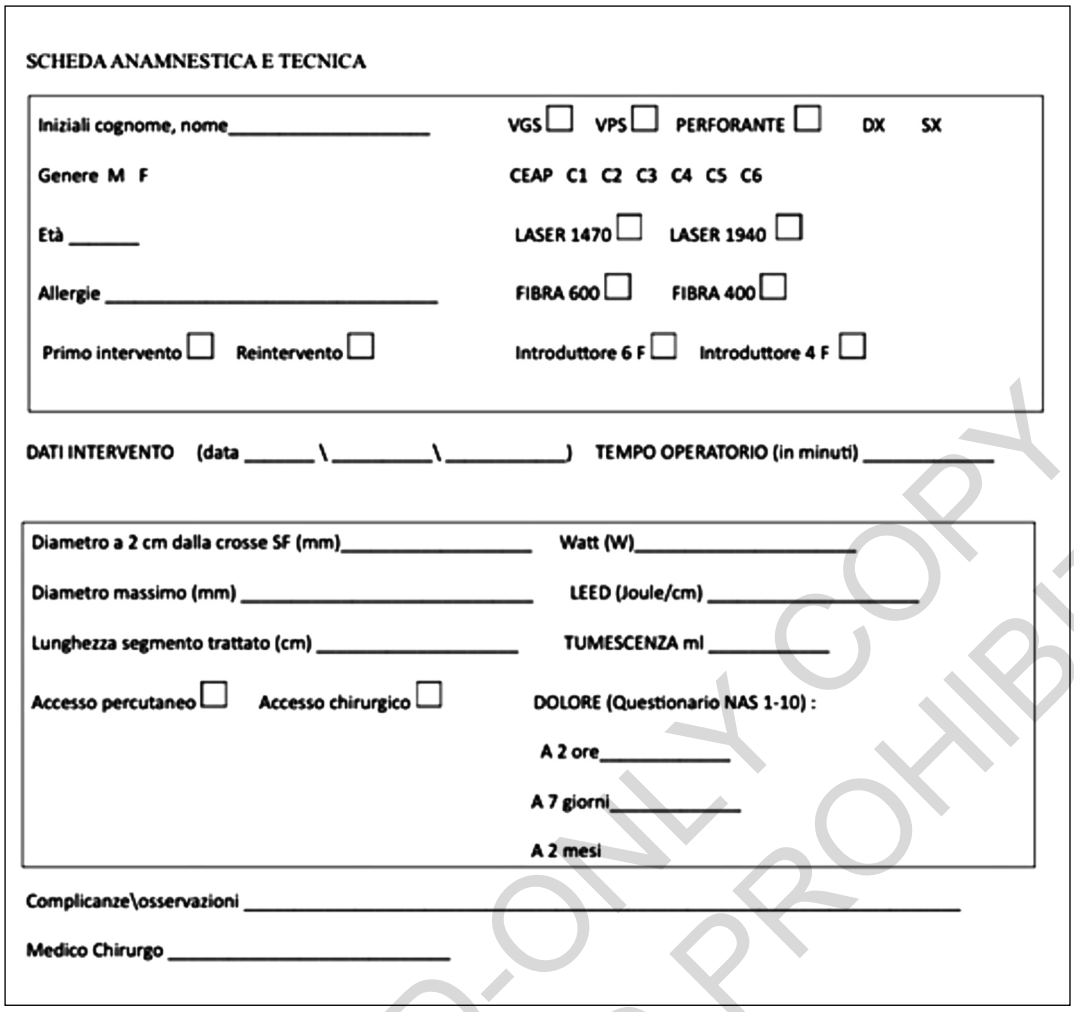
	Laser 1470 NM (group A)	Laser 1940 NM (group B)
Percutaneous Access	24 (100%)	31 (100%)
Fiber 600 Micron	18 (75%)	29 (93,54%)
Fiber 400 Micron	6 (25%)	2 (6,45%)
Total Tumescence (ml)	107,91 ± 63,72	118,06 ± 83,69
Watt	6,22 ± 0,81	4,8 ± 0,85 (p-Value 0,00004)
LEED (J/Cm)	35,60 ± 11,05	31,17 ± 6,15 (p-Value 0,00014)
Intervention Duration (Minutes)	27,45 ± 6,94	29,35 ± 7,71
Phlebectomies	16 (66,67%)	24 (77,42%)
Ultrasound Guided Foam Sclerotherapy	2 (8,33%)	4 (12,90%)

Table III

	Laser 1470 NM (group A)	Laser 1940 NM (group B)
Closure Rate at 7 Days	24 (100%)	31 (100%)
Closure Rate at 60 Days	24 (100%)	31 (100%)
E.I.T.H.	-	-
Neurological Complications	-	-
Pain (Nas Scale) at 2 Hours	4,21 ± 1,53	1,93 ± 1,82 (p-value 0,212)
Pain (Nas Scale) at 7 Days	1,58 ± 0,88	1,61 ± 1,23
Pain (Nas Scale) at 2 months	0,44 ± 0,25	0,47 ± 0,32

Discussion and Comments

The mechanism of action of laser photocoagulation is based on the absorption of photons, within a target tissue, by a substance called chromophore. The main chromophores at wavelengths between 500 nm and 1940 nm are hemoglobin and water. The local absorption of laser radiation by the chromophore generates heat within the irradiated tissue. Heat, at high temperatures, produces irreversible damage to the target structure. Specifically, the denaturation of collagen proteins present in the subendothelium of the venous wall occurs when temperatures between 70 C and 100 C are reached [17]. To reach such temperatures it is therefore necessary, not only to supply sufficient energy, but to do so in the presence of high concentrations of the target chromophore. Laser energy at frequencies of 1940 nm has an absorption coefficient in water more than 4 times higher than that of 1470 nm lasers and up to 200 times higher than the diodes at 980 nm of the previous generation [17,18,19]. Water certainly represents a chromophore present in very high concentration within biological tissues. With the LASER 1940 nm technology, precisely in view of that, the achievement of effective temperature requested to achive an effective damage of the vein wall, requires the



SCHEDA ANAMNESTICA E TECNICA

Iniziali cognome, nome_____ VGS ☐ VPS ☐ PERFORANTE ☐ DX SX

Genere M F CEAP C1 C2 C3 C4 C5 C6

Età _____ LASER 1470 ☐ LASER 1940 ☐

Allergie _____ FIBRA 600 ☐ FIBRA 400 ☐

Primo intervento ☐ Reintervento ☐ Introduttore 6 F ☐ Introduttore 4 F ☐

DATI INTERVENTO (data _______________) TEMPO OPERATORIO (in minuti) _____

Diametro a 2 cm dalla crosse SF (mm)_____ Watt (W)_____

Diametro massimo (mm) _____ LEED (Joule/cm) _____

Lunghezza segmento trattato (cm) _____ TUMESCENZA ml _____

Accesso percutaneo ☐ Accesso chirurgico ☐ DOLORE (Questionario NAS 1-10) :

A 2 ore_____

A 7 giorni_____

A 2 mesi

Complicanze\osservazioni _____

Medico Chirurgo _____

Format used for the collection of clinical data during the study.

supply of lower power (W) in relation to the high concetration of the cromophorouse [19-24]. Therefore in order to avoid an excessive dispersion of energy during the treatment, it is necessary to reduce the presence of high amounts of hemoglobin, in particular in the vessels of large size. In fact, using minor energies one runs the risk of determining a thrombotic occlusion of the treated venous segment, without significant damage to the sub-endothelial structure of the vessel. Such an eventuality would lead to a greater possibility of relapses in the medium term [16]. Therefore, the reduction of hemoglobin levels in contact with the laser during the procedure is a crucial objective for the effectiveness, especially in the long term-results, of the method in place. For this purpose, during the procedure it is useful to position the limb treated in Trendelemburg's position and to exert an ab-extrinsic compression by the infusion of good level of tumescence, thus to reduce the vein size and then the quantity of blood present there, so as to maximize the endothelial damage [25].

A further consideration, linked to the standardization of the endovenous laser ablation procedure, is that to date have not been shared protocols that establish common parameters, in terms of power (Watt) and linear energy density (LEED). In the literature there are, on this matter, some papers that have tried to propose standard parameters. For example, Doganci et al [26] reported a number of 30 patients treated using both a 1470 nm laser and a 980 nm laser with identical Power and LEED parameters. Specifically, a fixed power of 15 W was used, with an average LEED of 90 J/cm. With both lasers, a closure rate of 100% was reported at six months. Certainly applying high values of linear energy density (LEED) produces an effective damage to the target structure but increases the risk of spreading the damage also to the neighbouring biological structures. It is possible to deduce, therefore, that the lower the energy applied to obtain the same result, that is, specifically, to denature the collagen proteins, the lower are the risks of perivasal tissue damage. This concept is even more important when we are faced with the treatment of a superficial venous segment, or of small size vessel or located near nerve structures, as in the case of the external saphenous vein. 1940 nm laser technology certainly has a significant advantage in this principle compared to 1470 nm lasers.

Conclusions

Short-term results demonstrate comparable closure rates obtained with both lasers. There were no statistically significant differences in the two groups in terms of primary and secondary endpoints. However, in view of the need to provide a lower linear energy density (LEED) at a lower power (Watt), use LASER 1940 nm is particularly suitable and advantageous on smaller sized vessels, more superficial and adjacent to nerve structures. The limitations of this study, however, are the small number of enlisted patients, non-randomization, and monocentricity of the study. Further studies with more patients and medium to long-term follow-up are required.

Riassunto

Introduzione: La termoablazione laser (EVLA) rappresenta oggi la tecnica di prima scelta nel trattamento dell'insufficienza venosa. In questo articolo riportiamo l'analisi retrospettiva dei risultati a breve termine ottenuti dal trattamento laser endovenoso (EVLA) della patologia varicosa degli arti inferiori con laser 1470 nm e laser 1940 nm.

Materiali e Metodi: Sono stati arruolati nello studio un totale di 55 Pazienti. I pazienti sono stati divisi in due gruppi: quelli sottoposti a trattamento con laser 1470 nm nel gruppo A e quelli con laser 1940 nm nel gruppo B. Gli endpoint sono stati: closure del vaso target, complicanze e dolore post-operatorio.

Risultati: Non si riportano complicanze intra e post-operatorie. Il tasso di occlusione delle vene target è stato del 100% ai controlli a 7 e 60 giorni. Il dolore percepito nell'immediato postoperatorio ed ai controlli non ha mostrato differenze statisticamente significative tra i due gruppi. Tuttavia nel gruppo B è stato necessario applicare minori valori di Potenza (W) e Densità di Energia Lineare (LEED) con una differenza statisticamente significativa rispetto al gruppo A.

Conclusioni: I risultati a breve termine dimostrano tassi di closure sovrapponibili a quelli ottenuti con laser 1470 nm. Non si sono registrate differenze statisticamente significative nei 2 gruppi in termini di endpoint primari e secondari. Il vantaggio dell'utilizzo della tecnologia laser 1940 nm deriva dalla possibilità di erogare una minore densità di energia lineare (LEED) ad una minore potenza (Watt). Per tale motivo questa metodica risulta particolarmente indicata e vantaggiosa nel trattamento di vasi di calibro più piccolo, più superficiali e attigui a strutture nervose.

References

1. Quarto G, Amato B, Giani U, Benassai G, Gallinoro E, Apperti M, Furino E: *Comparison of traditional surgery and laser treatment of incontinengreat saphenous vein. Results of a meta-analysis.* Ann Ital Chir, 2016; 87(1), 61-67.

2. Turtulici G, Furino E, Dedone G, Sartoris S, Zawaideh J, Fischetti A, Silvestri E, Quarto G: *Percutaneous treatment with radiofrequency ablation of varicose veins recurring after vein stripping surgery. A preliminary study*. Ann Ital Chir, 2017; 88(5), 438-42

3. Ontas H, Yavuz T, Acar AN, Uysal D: *Comparison of ultrasound results following endovenous laser ablation and radiofrequency ablation in the treatment of varicose veins.* Ann Ital Chir, 2019; 90(5), 457-62.

4. National Clinical Guideline Centre *NICE Varicose Veins Full Guideline.* July 2013.

5. Stillo F, Ebner H, Agus GB, Apperti M, Bernardini E, Bianchini G, Camparini S, Crespi A, De Fiores A, Dorigo Emanuel G, Ferrara F, Genovese G, Giacomelli E, Giannasio B, Gossetti B, Musiani A, Quarto G, Sellitti A, Spinelli GM: *The 2016 guidelines of the italian society for vascular and endovascular surgery (SICVE) and italian society of phlebology (SIF) linee guida SICVE-SIF società italiana di chirurgia vascolare ed endovascolare e società italiana di flebologia.* Ital J Vasc Endovasc Surg, 2016; 23(4), 1-45.

6. Ebner H, Stillo F, Mangialardi N, Agus GB, Apperti M, Bernardini E, Bernardini M, Bernardo B, Bianchini G, Bisacci R, Camparini S, Chiulli N, Corda D, Crespi A, De Fiores A, Di Mitri R, Dorigo W, Ebner JA, Emanuelli G, Ferrara F, Genovese G, Giacomelli E, Giannasio B, Gossetti B, Guerra M, Mattaliano V, Musiani A, Pieroni O, Piccioli R, Pisacreta M, Pratesi C, Ronchey S, Quarto G, Sellitti A, Spinelli GM, Strati E, Tori A, Viani M, Zolesio P: *Linee guida flebo-linfologiche SIF-SICVE 2016 della società italiana di flebologia e della società italiana di chirurgia vascolare ed endovascolare.* Minerva Cardioangiol, 2016; 64(4), 1-80.

7. Nicolaides A, Kakkos S, Baekgaard N, Comerota A, De Maeseneer M, Eklof B, Giannouka A, Lugli M, Malòeti O, Mansilha A., Myers KA, Nelzen O, Partsch H, Perrin M: *Management of chronic: Management of chronic venous disorders of the lower limbs guidelines according to scientific evidence part II (chapters 9-18).* Int Ang, 2020; 39(3), 170-240.

8. Rasmussen LH, Lawaetz, Bjoern L, Vennits B, Blemings A and Eklof B: *Randomized clinical trial comparing endovenous laser ablation, radiofrequency ablation, foam sclerotherapy and surgical stripping for great saphenous varicose veins.* Br J Surg, 2011; 98:1079-87.

9. Navarro Min RJ and Boné C: *Endovenous laser: A new minimally invasive method of treatment for varicose veins-preliminary observations using an 810 nm diode laser.* Dermatol Surg, 2001; 27:117-22.

10. Min RJ, Zimmet SE, Isaacs MN and Forrestal MD: *Endovenous laser treatment of the incompetent greater saphenous vein.* J Vasc Interv Radiol, 2001; 12:1167-171.

11. Goldman MP: *Closure of the greater saphenous vein with endoluminal radiofrequency thermal heating of the vein wall in combination with ambulatory phlebectomy: Preliminary 6-month follow-up.* Dermatol Surg, 2000; 26:452-56.

12. Rass K, Frings N, Glowacki P, Hamsch C, Gräber S, Vogt T and Tilgen W: *Comparable effectiveness of endovenou laser ablation and high ligation with stripping of the great saphenous vein: Two-year results of a randomized clinical trial (RELACS study).* Arch Dermatol, 2012; 148:49-58.

13. Tesmann JP, Thierbach H, Dietrich A, Grimme H, Vogt T and Rass K: *Radiofrequency induced thermotherapy (RFITT) of varicose veins compared to endovenous laser treatment (EVLT): A non-randomized prospective study concentrating on occlusion rates, side-effects and clinical outcome*. Eur J Dermatol, 2011; 21:945-51.

14. Apperti M, Furino E, Sellitti A, Quarto G: *The use of transillumination as a rational approach to sclerotherapy and endovascular laser ablation of varices. Results in the use of an original instrument.* Ann Ital Chir, 2016; 87(4), 396-99.

15. Genovese G, Furino E, Quarto G: *Superficial epigastric vein sparing in the saphenous-femoral crossectomy or in the closure of the saphena magna.* Ann Ital Chir, 2015; 86(5):383385.

16. Cestaro G, Furino E, Solimeno G, Gentile M, Benassai G, Massa S, Quarto G: *The role of superficial epigastric vein sparing in the treatment of chronic venous disease: A retrospective study.* Acta Phlebologica, 2015; 15(3), 143-47.

17. Vuylsteke ME and Mordon SR: *Endovenous laser ablation: A review of mechanisms of action*. Ann Vasc Surg, 2012; 26:424-433.

18. Whiteley Mark S, Amy C, Cross Victoria, Whiteley C: *No significant difference between 1940 and 1470 nm in endovenous laser ablation using an in vitro porcine liver model*. Laser in Medical Science, 2021; https://doi.org/10.1007/s10103-021-03449-0.

19. Viarengo LM, Viarengo G, Martins AM, et al.: *Medium and long-term outcomes of endovenous treatment of varicose veins with a 1940nm diode laser: Critical analysis and technical considerations*. J Vasc Bras, 2017; 16:23-30.

20. Cowpland CA, Cleese AL and Whiteley MS: *Factors affecting optimal linear endovenous energy density for endovenous laser ablation in incompetent lower limb truncal veins: A review of the clinical evidence*. Phlebology, 2017; 32:299-306.

21. Malskat WS, Poluektova AA, van der Geld CW, et al.: *Endovenous laser ablation (EVLA): A review of mechanisms, modeling outcomes, and issues for debate*. Lasers Med Sci, 2014; 29:393-403.

22. Sroka R, Pongratz T, Esipova A, et al.: *Endovenous laser therapy for occlusion of incompetent saphenous veins using 1940 nm in: Lilge land sroka r (eds) medical laser applications and laser-tissue interactions.* 7th ed. SPIE Proceedings (Optical Society of America), 2015; paper 95420D.

23. Minwoo Ahn, Yu-gyeong Chae, Jieun Hwang, Yeh-chan Ahn and Hyun Wook Kang: *Endoluminal application of glass-capped diffuser for ex vivo endovenous photocoagulation*. J Biophotonics, 1-11:(2016).

24. Van Gia Truong, Van Nam Tran, Jieun Hwang and Hyun Wook Kang: *Effect of spatial light distribution on the thermal response of vascular tissue.* Biomedical Optics Express, 2018; 9(7), 1 Jul 2018.

25. Erzinger FL, Araujo WJB, Junior N, Seme C, Caron FC and Timi JRR: *Comparative study of great saphenous vein ablation in the thigh, with and without tumescence.* J Vasc Bras, 2016; 15:217-23.

26. Doganci S and Demirkilic U: *Comparison of 980 nm laser and bare-tip fibre with 1470 nm laser and radial fibre in the treatment of great saphenous vein varicosities: A prospective randomised clinical trial.* Eur J Vasc Endovasc Surg, 2010; 40:254-59.