
Endovenous Treatment of the Great Saphenous Vein Using a 1,320 nm Nd:YAG Laser Causes Fewer Side Effects than Using a 940 nm Diode Laser

THOMAS M. PROEBSTLE, MD, MSc,*† THOMAS MOEHLER,† DOENDUE GÜL, MD,† AND SYLVIA HERDEMANN, MD*†

*Department of Dermatology, University of Heidelberg, Heidelberg, Germany; †Department of Dermatology, University of Mainz, Mainz, Germany

BACKGROUND. Limited data are available about treatment-related side effects with respect to laser wavelength in endovenous laser treatment (ELT) of the great saphenous vein (GSV).

OBJECTIVE. To compare the results and side effects of a 940 nm diode and a 1,320 nm neodymium:yttrium-aluminum-garnet (Nd:YAG) laser.

METHODS. Three patient cohorts (A, B, and C) received ELT of the GSV using a 940 nm diode laser at 15 W (group A) or 30 W (group B) or using a 1,320 nm laser at 8 W (group C). In all cases, energy was administered continuously with constant pull-back of the laser fiber under perivenous tumescent local anesthesia.

RESULTS. The GSVs of group A ($n = 113$), group B ($n = 136$), and group C ($n = 33$) received ELT. An average linear endovenous

energy density of 24, 63, and 62 J/cm and an average endovenous fluence equivalent of 12, 30, and 33 J/cm² were administered to the vein. Occlusion rates were 95% (group A), 100% (group B), and 100% (group C) at day 1 after ELT and 90.3% (group A), 100% (group B), and 97% (group C) at 3 months after ELT. With the 1,320 nm laser ELT (group C), treatment-related pain (50%) and the need for analgesics (36%) were significantly reduced ($p < .005$) in comparison with treatment-related pain (81%) and the need for analgesics (67%) after the 30 W 940 nm laser ELT (group B). Ecchymosis was also significantly reduced ($p < .05$) in group C (1,320 nm) compared with group B (30 W, 940 nm).

CONCLUSION. ELT of the GSV using a 1,320 nm Nd:YAG laser causes fewer side effects compared with 940 nm diode laser ELT.

THIS STUDY WAS FUNDED IN PART BY GRANTS FROM DORNIER MED TECH LASER GMBH AND COOLTOUCH CTEV. THOMAS M. PROEBSTLE, MD, MSc, IS A CONSULTANT TO BOTH COMPANIES.

DURING RECENT years, endoluminal treatment modalities have evolved for the thermal ablation of incompetent great saphenous veins (GSVs). Soon after the introduction of a bipolar endovenous radiofrequency (RF) closure technique,¹ endovenous laser treatment (ELT) of the GSV was presented, initially using diode lasers of 810 nm and 940 nm wavelength.² However, although RF closure came as a developed technique with a mode of action that was generally understood, the mode of action of ELT was not realized in its full depth in the first scientific reports. The treatment parameters of ELT and even the use of different laser wavelengths are still subject to a massive evolution. Interestingly, some treatment-related side effects, such as pain or ecchymosis, seemed to be less pronounced after RF closure³ than after ELT with laser wavelengths between 810 and 1,064 nm.⁴⁻⁶ This observation in particular might be caused by the fact that RF closure avoids vein perforation

during treatment, whereas perforation of the vein and direct impact to perivenous tissue generally cannot be avoided with ELT.^{7,8}

Recently, a 1,320 nm neodymium:yttrium-aluminum-garnet (Nd:YAG) laser device was introduced for ELT,^{9,10} avoiding treatment-related vein perforation because of its different absorption characteristics. Therefore, we were interested in whether this new ELT would lead to less pronounced treatment-related side effects. In a retrospective study, 3-month clinical follow-up data were compared from patients treated by a 940 nm diode laser with two different protocols or by a 1,320 nm Nd:YAG laser.

Patients and Methods

Patients

Patients with chronic venous insufficiency of all clinical stages presented for routine evaluation in our phlebology clinic. Functional testing, including duplex scanning, had to show an incompetent GSV, with reflux at Valsalva's maneuver lasting longer than 500 milliseconds. These

Address correspondence and reprint requests to: Thomas Proebstle, MD, MSc, Department of Dermatology, University of Heidelberg, Voss-Str. 2, 69115 Heidelberg, Germany; or e-mail: thomas.proebstle@med.uni-heidelberg.de.

patients were offered to undergo classic surgery or to receive ELT. Outpatients selecting ELT were treated with a 940 nm diode laser at 15 W laser power before March 2003 and with 30 W laser power thereafter. Starting in October 2003, in-hospital patients suitable for ELT were treated with a 1,320 nm Nd:YAG laser; there were no specific exclusion criteria, apart from concomitant acute disease preventing surgical or interventional treatment of varicose veins. Patients had to give written informed consent in accordance with the Declaration of Helsinki. The treated patients were representative of the patient population referred to a university clinic (Table 1).

Administration of Laser Energy

ELT was the only treatment. Additional treatment measures, such as sclerotherapy or miniphlebectomy, were performed 3 months after ELT if necessary. In the first cohort of patients (group A), 15 W of laser power of a 940 nm diode laser was administered continuously while the laser fiber was pulled back manually with a constant velocity of 4 to 5 mm/s. In the second cohort (group B), laser treatment was administered also with a 940 nm laser but with 30 W of power and a constant pullback velocity of approximately 3 mm/s. The third group of patients (group C) received ELT using a 1,320 nm Nd:YAG laser at a laser power of 8 W with continuous delivery of laser power and constant pullback of the laser fiber at a velocity of about 1 mm/s using a motorized pullback device. The length of the treated vein and total laser treatment time were measured additionally.

Otherwise, ELT was performed as already described.⁸ In brief, the GSV was punctured with duplex ultrasonography guidance at the distal point of reflux with an 18-gauge needle. With the help of a coated J-tip guidewire (0.035 in), a 5F angiocatheter was placed, duplex ultrasonography controlled, close to the saphenofemoral junction. The guidewire was then replaced by a 600 μ laser fiber connectable to a 940 nm diode laser (Medilas Compact, Dornier MedTech Laser GmbH, Germering, Germany) or to a 1,320 nm Nd:YAG (Cooltouch CTEV, Roseville, CA, USA). The desired position of the laser fiber tip was again ascertained by duplex scanning. After positioning of the fiber tip, tumescent local anesthesia (TLA) was infiltrated, duplex ultrasonography guided, with a motor pump into the perivenous intrafascial space. One liter of TLA was prepared with 1 L of physiologic saline (0.9%), prilocaine 700 mg, epinephrine 1 mg, and 10 mL of bicarbonate 8.4% as previously described.¹¹ Without further delay after infiltration, laser energy was administered as described above.

After complete removal of the fiber, an eccentric compression bandage was applied over the course of the treated vein for 24 to 48 hours. Additionally, the patient had to wear graduated compression stockings (30 mm Hg) continuously day and night for a period of 8 days. For the same period, patients had to administer low-molecular-weight heparin (2,500 IU dalteparin, subcutaneously) once daily. No sedation was applied; the patients had to walk immediately after the procedure. Diclofenac 75 mg was prescribed twice daily, and the patients were advised to use it for pain control if necessary.

Table 1. Patients' Characteristics and CEAP Classification of Treated Legs

	940 nm, 15 W	940 nm, 30 W	1,320 nm, 8 W
Number of patients	84	108	31
Age (yr), median (range)	61 (23–93)	55 (16–78)	59 (32–84)
BMI, median (range)	25.3 kg/m ² (16.8–48.8)	25.5 kg/m ² (17.4–47.3)	26.1 kg/m ² (17.7–36.7)
GSV diameter (mm), median (range)*	6.1 (2.0–17.3)	6.6 (2.8–16.1)	5.9 (3.0–13.1)
Female sex, n (%)	61 (73)	74 (69)	21 (68)
Number of treated legs (%)	113 (100)	136 (100)	33 (100)
C ₂	113 (100)	136 (100)	33 (100)
C ₃	60 (53)	78 (57)	12 (36)
C ₄	63 (56)	38 (28)	7 (21)
C ₅	2 (2)	4 (3)	2 (6)
C ₆	19 (17)	6 (4)	4 (12)
E _p	108 (96)	133 (98)	30 (91)
E _s	5 (4)	3 (2)	3 (9)
A _s	113 (100)	136 (100)	33 (100)
A _p	69 (61)	50 (37)	6 (19)
A _D	5 (4)	3 (2)	3 (9)
P _R	113 (100)	136 (100)	33 (100)
P _O	0 (0)	0 (0)	0 (0)

BMI = body mass index; GSV = great saphenous vein.

*Measured in supine position.

Calculation of Energy Deposits

In both laser systems, the amount of delivered laser energy after each treatment was displayed in joules. For the energy amount in joules divided by the treated vein length in centimeters, we propose the term *linear endovenous energy density* (LEED). Such LEED reflects the average amount of energy in joules administered endovenously to a given length of treated vein in centimeters. The dynamic moment of this parameter, which actually allows calculation of a "linear energy density," comes from the continuous or stepwise pullback movement of the laser fiber tip.

To take into account different diameters of the GSV with respect to the administered laser energy, a cylindrical approximation of the inner vein surface area was calculated using the maximum vein diameter close to the saphenofemoral junction as already described.¹² For the quotient of delivered laser energy in joules against the approximated inner vessel surface, we propose the term *endovenous fluence equivalent* (EFE). This term seems necessary to us because EFE does not exactly resemble the definition of laser fluence. Unlike with transcutaneous laser treatment, in ELT, there is an inhomogeneity of the laser beam geometry with respect to the targeted inner vein surface area, and, furthermore, energy transfer to the inner vein wall surface is achieved not only by direct laser impact but also by steam bubble-mediated indirect heat transfer.^{8,13}

Follow-Up Examinations

Patients were reexamined at day 1 after the procedure and 3 months thereafter. Patients received duplex scanning and were reevaluated functionally and clinically. Treatment-related side effects and complications were recorded 3 months after ELT using a patient questionnaire, which was the same for all treatment cohorts. Symptoms of interest were the presence and duration of ecchymosis, palpable induration, phlebotic reaction, paresthesia, and pain. A pain score was not used. Pain was reported subjectively by the patients in the following three classes: not present, present but no analgesics necessary, and present with analgesics necessary. Additionally, the duration of all symptoms was recorded.

Statistical Evaluation

Statistical analysis was performed using the *StatXact*, version 3.0, software package (Cytel Software Corporation, Cambridge, MA, USA). The rates of side effects were compared using the Fisher exact test, and LEEDs and EFEs were compared using the Wilcoxon-Mann-Whitney test. All tests were performed two-sided.

Results

ELT of the GSV was performed on 84 patients (113 limbs, group A) using a 940 nm laser at 15 W, on 108 patients (136 limbs, group B) using a 940 nm laser at 30 W, and on 31 patients (33 limbs, group C) using a 1,320 nm laser at 8 W (see Table 1). The median (range) treated vein length was 60 cm (18–90), 55 cm (15–90), and 55 cm (12–70), respectively. The maximum diameters of the GSV, the age of the patients, body mass index, and distribution of gender were similar in the three groups (see Table 1). Clinical stages before treatment according to the CEAP classification were also comparable (see Table 1); however, the legs of patients receiving 940 nm, 15 W treatment showed a higher rate of skin alterations (C_4), whereas the legs of patients receiving 940 nm, 30 W treatment had a lower rate of ulcer disease (C_5 , C_6).

TLA Volumes

The use of TLA during ELT needs special consideration because higher TLA volumes may reduce treatment-related side effects, such as ecchymosis or paresthesia. Mean TLA volumes were comparable among the three treatment groups, ranging around 550 cc at each treatment (Table 2). Likewise, mean TLA per centimeter of treated vein was in the order of 10 cc/cm of vein in all three groups; however, pairwise Wilcoxon-Mann-Whitney testing revealed a statistically significant difference between the 940 nm, 15 W group and both remaining treatment groups ($p < .01$). Differences between the 940 nm, 30 W and the 1,320 nm, 8 W groups were not significant ($p > .8$). Even if TLA per centimeter of vein was divided by the individual body mass index of the treated patient, no significant difference was detectable between the 940 nm, 30 W and the 1,320 nm, 8 W groups. However, pairwise differences between the 940 nm, 15 W treatment group and the two other groups again showed statistical significance ($p < .01$).

Linear Endovenous Energy Density

ELT with a 940 nm laser at 15 W (group A) resulted in a LEED of a median of 24 (12–36) J/cm of vein. Using 940 nm at 30 W (group B) resulted in a nearly threefold LEED with a median of 63 (33–156) J/cm of vein. LEED was almost identical to the latter value using 1,320 nm laser treatment at 8 W (group C) with a median of 62 (38–86) J/cm. Statistically, the LEED of group A was significantly lower compared with group B or group C using the two-sided Wilcoxon-Mann-Whitney test ($p < .0001$). Group B and group C did not differ significantly from each other ($p > .05$).

Table 2. Clinical Results and Side Effects Related to Endovenous Laser Treatment during the First 3 Months after Treatment

Laser Protocol	Pulsed 15 W 1 s 940 nm	Continuous 15 W 940 nm	Continuous 30 W 940 nm	Continuous 8 W 1,320 nm
Number of treated legs	104	113	136	33
Longitudinal endovenous energy density (J/cm), median (range)	Approx. 30–45*	24 (12–36)	63 (33–156)	62 (38–86)
Endovenous fluence equivalent (J/cm ²), median (range)	ND	12 (3–37)	30 (13–94)	33 (13–83)
TLA volume (mL), mean ± SD	ND	530 ± 140	550 ± 160	560 ± 170
TLA volume per cm treated vein (mL/cm), mean ± SD	ND	9.5 ± 2.9	11.2 ± 3.9	12.0 ± 4.8
TLA volume per cm vein per BMI [(mL * m ²)/(cm * kg)], mean ± SD	ND	0.37 ± 0.11	0.44 ± 0.18	0.47 ± 0.26
Clinical results				
Recanalization rate (3 mo)				
Partial	2% (n = 2)	1% (n = 1)	0%	3% (n = 1)
Complete	4% (n = 4)	9% (n = 10)	0%	0%
Side effects: percentage of affected limbs, median (maximum) duration in weeks				
No side effects	ND	7	2	18
Ecchymosis	73, 2 (8)	78, 2 (8)	81, 2 (4)	61, 2 (4)
Pain	67, 1 (8)	72, 1 (4)	81, 1.2 (12+)	50, 1.5 (2)
Analgesics	51, 1 (4)	56, 1 (4)	67, 0.3 (4)	36, 1 (2)
Induration along vein	45, 3 (12)	62, 4 (12)	64, 4 (12+)	46, 2 (4)
Phlebitic reaction	10, 2 (4)	11, 1.5 (4)	13, 1 (2)	7, 1.4 (2)
Paresthesia	7, 4 (12+)	5, 2 (4)	12, 3 (12+)	14, 1 (3)

Data of pulsed treatment (940 nm 15 W, 1 s) are included as already published.⁵

BMI = body mass index; ND = not determined; TMA = tumescent local anesthesia.

*One precise measurement of laser energy per centimeter of vein was not done during that part of the study.

Endovenous Fluence Equivalent

Calculating the EFE as described above, the corresponding median values were 12 (3–37) J/cm² for 940 nm, 15 W (group A); 30 (13–94) J/cm² for 940 nm, 30 W (group B); and 33 (13–83) J/cm² for 1,320 nm, 8 W (group C). Again, statistical evaluation with two-sided Wilcoxon-Mann-Whitney testing showed that the EFE of group A differed significantly from group B or group C ($p < .0001$). Again, there was no statistical difference between groups B and C.

Occlusion Rates

At day 1 after ELT in both cohorts with high LEED (groups B and C), all treated GSVs (100%) were completely occluded without flow, whereas in group A (940 nm, 15 W), 6 of 113 vessels (5%) remained open. The Fisher exact test showed that the differences between group A and group B or group C were statistically significant ($p < .01$). Three months after ELT, in group A (940 nm, 15 W) 11 of 113 treated limbs (9.7%) showed pathologic reflux by duplex scanning. No recanalization event (0%) was noted among 136 limbs of group B (940 nm, 30 W). In group C

(1,320 nm, 8 W), 1 of 32 limbs (3%) showed partial recanalization (see Table 2). Statistical analysis using the two-sided Fisher exact test revealed significant differences only between group A and group B ($p < .001$).

Side Effects

Side effects could be recorded from 106 limbs in group A, 129 limbs in group B, and 29 limbs in group C. No side effects were recorded any time after ELT in 7% (group A), 2% (group B), and 18% (group C) of treated limbs. The most frequent side effects were ecchymosis and treatment-related pain, regardless of which protocol for delivery of laser energy was used (see Table 2).

Ecchymosis was visible in 78% (group A, 15 W) and 81% (group B, 30 W) of treated limbs after 940 nm ELT and in 61% after 1,320 nm ELT (group C). The difference between group B (30 W, 940 nm) and group C (1,320 nm) was statistically significant according to the Fisher exact test ($p < .05$). The median duration of ecchymosis was 2 weeks in all groups.

The percentages of patients complaining of any treatment-related pain along the treated vein were 72% in

group A (15 W, 940 nm), 81% in group B (30 W, 940 nm), and 50% in group C (1,320 nm). The Fisher exact test proved significant differences between groups A and C ($p < .05$) and even stronger differences between groups B and C ($p < .005$). Differences between groups A and B were not significant. Pain was treated with analgesics (diclofenac 75 mg twice daily) in group A (15 W, 940 nm) in 56%, in group B (30 W, 940 nm) in 67%, and in group C (1,320 nm) in 36%. Statistically significant differences were detected with the Fisher exact test between groups A and B ($p < .05$) and between groups B and C ($p < .005$). Differences between groups A and C were not significant. The median duration of pain and the demand for analgesics lasted about 1 week in all three groups; however, the maximum duration in group C (1,320 nm) with 2 weeks was markedly shorter compared with 4 weeks in groups A (15 W, 940 nm) and B (30 W, 940 nm).

Subcutaneous indurations along the treated vein after ELT resembling either a palpable chord or the feeling of a shortened tendon at the inner thigh were noticed in 62% of limbs in group A (15 W, 940 nm), 64% in group B (30 W, 940 nm), and 46% in group C (1,320 nm). Interestingly, no correlation between this symptom and a low body mass index could be found. The maximum duration of this symptom was 12 weeks in group A, more than 12 weeks in group B, and only 4 weeks in group C. Corresponding median durations were 4, 4, and 2 weeks, respectively. All observed differences among the three groups did not reach the level of statistical significance.

Phlebotic reactions, which were defined by painful indurations with erythema at any location on the treated leg, were observed in about 10% of treated limbs. The median duration varied between 7 and 10 days, and the maximum duration was observed from 2 to 4 weeks. Differences between groups A, B, or C were statistically insignificant.

Paresthesia and dysesthesia were complained about by patients in 5 to 14% of treated legs, with a median duration between 1 and 3 weeks in all three groups. Symptoms were mainly of minor severity, and the maximum duration generally did not exceed 4 weeks. Only in four cases of group B (30 W, 940 nm) did the maximum duration reach 12 weeks, and it was still present thereafter. Differences between the three groups were not statistically significant.

Discussion

The comparison of three patient cohorts demonstrated that side effects such as pain and ecchymosis were significantly reduced when using the new 1,320 nm Nd:YAG laser wavelength¹⁰ for endovenous treatment of the GSV (see Table 2). For example, diclofenac for pain control was necessary after ELT in 67% of patients treated with the 940 nm laser (30 W) but in only 31% of patients treated with the 1,320 nm laser. This fact might be connected to

the different absorption characteristics of the 1,320 nm laser compared with the absorption of the more traditionally used wavelengths between 810 and 1,064 nm.^{9,10} In particular, the reduced hemoglobin absorption of the 1,320 nm laser is related to a reduced carbonization phenomenon at the vein wall during treatment. Additionally, an increased absorption in water allows steam bubble formation already in saline without the presence of red blood cells (own observations; data not shown here). These favorable absorption properties actually cause an inability to produce vein wall perforations during 1,320 nm ELT,⁹ largely mimicking vein wall damage after RF closure.⁷ Such a lack of vein wall perforations avoids direct laser damage of perivenous tissue. Most likely, this fact is responsible for a relatively moderate rate of side effects after 1,320 nm ELT,¹⁰ also mimicking the rate of side effects after RF closure of the GSV.³ For example, the frequency of ecchymosis and hematoma with RF was reported to be 47% at its maximum 1 week after the procedure,³ corresponding to a slightly higher but cumulative frequency of ecchymosis in 62% of patients after 1,320 nm ELT. The rate of patients experiencing no side effects after RF closure at 1 week after the intervention was 35%³; however, it should be mentioned that this rate probably would be slightly lower if reported cumulatively. After 1,320 nm ELT, 18% of patients did not experience side effects any time after the procedure. The cumulative rate of patients without any side effects after 940 nm ELT was 7% with 15 W treatment and only 2% with 30 W treatment. In addition, it must be emphasized that the rate of 18% of patients without any side effects after 1,320 nm ELT was observed using 8 W laser power during continuous fiber pullback. Using only 5 W laser power with 1,320 nm ELT could result in an even higher rate of patients without any side effects, not necessarily worsening the short-term success rate.¹⁰ However, future long-term studies are needed to answer these questions.

For laser wavelengths of 810 and 940 nm, recent data indicated a relationship between delivered laser energy and success in terms of a lack of intravascular flow after ELT.^{12,14} After a median of 30 weeks, no GSV recanalization was observed with a delivered laser energy of more than 80 J/cm of vein¹⁴ or after 3 months if more than 30 J/cm of vein had been applied.¹² This fact is reflected in almost absent recanalization events after ELT if a median LEED of more than 60 J/cm of vein length was achieved in the present study. For 1,320 nm ELT, a continuous laser power of 8 W with a pullback velocity of about 1 mm/s was the basis to achieve LEED values equal to our otherwise most successful 940 nm 30 W ELT protocol. EFE values were also similar for 1,320 nm, 8 W and 940 nm, 30 W protocols, with a median of 33 and 30 J/cm², respectively.

Interestingly, such high occlusion rates have also been reported using this 1,320 nm laser in a 5 W continuous pullback protocol.⁵ As mentioned above, the rates of side

effects were lower with this 1,320 nm, 5 W treatment protocol compared with our 1,320 nm, 8 W ELT. Even though 5 W demonstrated a lower rate of side effects for 1,320 nm endovenous occlusion, it is possible—similar to other wavelengths—that a lower treatment energy may result in a higher rate of recurrence. This will remain unknown until further study.

References

1. Chandler JG, Pichot O, Sessa C, et al. Defining the role of extended saphenofemoral junction ligation: prospective comparative study. *J Vasc Surg* 2000;32:941–53.
2. Navarro L, Min R, Boné C. Endovenous laser: a new minimally invasive method of treatment of varicose veins—preliminary observations using an 810 nm diode laser. *Dermatol Surg* 2001;27:117–22.
3. Lurie F, Creton D, Eklof B, et al. Prospective randomized study of endovenous radiofrequency obliteration (closure procedure) versus ligation and stripping in a selected patient population (EVOLVEs Study). *J Vasc Surg* 2003;38:207–14.
4. Min RJ, Zimmet SE, Isaacs MN, Forrestal MD. Endovenous laser treatment of the incompetent greater saphenous vein. *J Vasc Interv Radiol* 2001;12:1167–71.
5. Proebstle TM, Gül D, Lehr HA, et al. Infrequent early recanalization of the greater saphenous vein after endovenous laser treatment. *J Vasc Surg* 2003;38:511–6.
6. Chang CJ, Chua JJ. Endovenous laser photocoagulation (EVLP) for varicose veins. *Lasers Surg Med* 2002;31:257–62.
7. Weiss RA. Comparison of endovenous radiofrequency versus 810 nm diode laser occlusion of large veins in an animal model. *Dermatol Surg* 2002;28:56–61.
8. Proebstle TM, Lehr HA, Kargl A, et al. Endovenous treatment of the greater saphenous vein with a 940 nm diode laser: thrombotic occlusion after endoluminal thermal damage by laser generated steam bubbles. *J Vasc Surg* 2002;35:729–36.
9. Goldman MP, Detwiler SP. Endovenous 1064-nm and 1320-nm laser treatment of the porcine greater saphenous vein. *Cosmet Dermatol* 2003;31:257–62.
10. Goldman MP, Mauricio M, Rao J. Intravascular 1320 nm laser closure of the great saphenous vein: a 6 to 12 months follow-up study. *Dermatol Surg* 2004;30:1380–5.
11. Proebstle TM, Paepcke U, Weisel G, et al. High ligation and stripping of the long saphenous vein using the tumescent technique for local anesthesia. *Dermatol Surg* 1998;24:453–6.
12. Proebstle TM, Gül D, Kargl A, Knop J. Non-occlusion and early reopening of the great saphenous vein after endovenous laser treatment is fluence dependent. *Dermatol Surg* 2004;30:174–8.
13. Proebstle TM, Sandhofer M, Kargl A, et al. Thermal damage of the inner vein wall during endovenous laser treatment: key role of energy absorption by intravascular blood. *Dermatol Surg* 2002;28:596–600.
14. Timperman PE, Sichlau M, Ryu RK. Greater energy delivery improves treatment success of endovenous laser treatment of incompetent saphenous veins. *J Vasc Interv Radiol* 2004;15:1061–3.

Commentary

Proebstle and colleagues are to be congratulated for a study that gets us closer to answering the question of whether endovenous ablation is best accomplished by hemoglobin heating or the approach of using water around the collagen in the vein wall as a target. It is clear from percutaneous approaches to leg veins that deeply penetrating laser wavelengths with significant deoxyhemoglobin absorption, such as the 1,064 nm neodymium:yttrium-aluminum-garnet (Nd:YAG) laser, have the most utility. When veins are targeted through the skin, one exploits the concept of selective photothermolysis. By targeting deoxyhemoglobin, cutaneous leg vessels absorb preferentially to surrounding water, collagen, and other structures. This allows selective destruction of tiny blood vessels without heating surrounding structures. The mechanism of this destruction by the 1,064 nm laser must be clearly understood by the user. The clinical observation is immediate photodarkening and coagulation. Histologically, this is represented by perivascular hemorrhage and thrombi with vessel fragmentation.¹ This ultimately leads to vessel clearance in about 75% of targeted areas over a 3-month time frame.² For the cutaneous approach, this is clearly state of the art. We must take a step back and think whether this is the best approach for what we are trying to achieve in endovenous laser ablation in which selective photothermolysis is not a factor.

For endovenous ablation, we are trying to maximize vein shrinkage and closure with the least amount of blood coagulation and the maximum amount of vein wall contraction. We know from previous methods involving electro-surgical blood coagulation that the long-term success rates based on coagulation of blood are very low.^{3,4} On the contrary, the success rates for radiofrequency (RF) vein shrinkage specifically avoiding coagulation of blood are very high.^{5–7} These typically involve applying energy after the vein is emptied of blood by gravity, external pressure, or, most importantly, tumescent anesthesia. This was shown with the first RF endovenous system, cleared by the US Food and Drug Administration in 1999. Since then, about 75,000 endovenous RF procedures have been performed, with a 90% long-term success rate. This concept of preferential vein wall shrinkage without blood coagulation is one that can also be translated to the application of endovenous laser energy.

As the authors correctly point out, there is a clear advantage of targeting water over hemoglobin when performing endovenous laser treatment. There is a statistically reduced rate of pain postoperatively, with a higher rate of success, while at the same time applying lower energy. The translation is greater safety for the patient with a water-only wavelength placed endovenously.

Conversely, when using a wavelength strongly absorbed by hemoglobin, such as 810 nm, there is a lot of intraluminal blood heating with transmission of heat to the surrounding tissue

through long heating times. Temperatures in animal models have been reported as high as 1,200°C.⁸ When we have tried ex vivo vein treatment without blood, the 810 nm wavelength simply chars the inside of the vein. Minimizing direct contact with the vein wall for hemoglobin-dependent methods minimizes the charring of the vein wall and probably lowers the postoperative pain levels. Ideally, for a hemoglobin-absorbed wavelength to work, it would be best to have a well-defined layer of hemoglobin between the fiber and the vein wall. In the real world, however, varicose veins are saccular, and irregular pockets of hemoglobin are frequently encountered, leading to sharp rises in temperature and vein perforations. When using tumescent anesthesia and a hemoglobin-targeting wavelength, it can be very difficult to gauge the correct amount to compress the vein because some hemoglobin is necessary for the mechanism of action. If too much tumescence is used, there can be charring of the inner wall of the vein without heating of the vein wall, with resulting pain and failure to close the vein. For all of these reasons, it makes far more sense to use a water-absorbing wavelength within the vein for endovenous ablation.

In this article, there is reduced pain reported with 1,320 nm versus 940 nm, probably related to fewer vein perforations and more uniform heating by 1,320 nm targeting water in the vein wall. Although some patients still experience pain after 1,320 nm, this is probably related to heat dissipated into surrounding tissue, not vein perforations. As the authors speculate, this might be minimized by using the minimal effective energy to shrink the vein. In our own unpublished studies, we have found that emitting 5 W of 1,320 nm through a 600 μ fiber moving at 1 mm/s in a 2 mm-thick vein wall, the highest temperature recorded on the exterior of the vein wall is 48°C. Unfortunately, in a saphenous vein, for effective sealing and shrinkage, higher energies must sometimes be used. In this study, 8 W of 1,320 nm was employed, probably accounting for the postoperative pain incidence. We believe that effective energy for vein sealing in our

practice is mostly between 5 and 6, thus minimizing postoperative pain to less than 5%.

In summary, this is a landmark article in the endovenous ablation laser field. The conclusion is well justified by the data indicating that endovenous ablation of the GSV using a 1,320 nm Nd:YAG laser causes fewer side effects compared with a 940 nm diode laser. When the laws of physics and physiology are satisfied, so, typically, are the patients and physicians.

ROBERT A. WEISS, MD
Hunt Valley, MD

References

1. Sadick NS, Prieto VG, Shea CR, et al. Clinical and pathophysiologic correlates of 1064-nm Nd:YAG laser treatment of reticular veins and venulectasias. *Arch Dermatol* 2001;137:613-7.
2. Weiss RA, Weiss MA. Early clinical results with a multiple synchronized pulse 1064nm laser for leg telangiectasias and reticular veins. *Dermatol Surg* 1999;25:399-402.
3. Politowski M, Zelazny T. Complications and difficulties in electrocoagulation of varices of the lower extremities. *Surgery* 1966;59:932-4.
4. Otsu A, Mori N. Therapy of varicose veins of the lower limbs by light coagulator. *Angiology* 1971;22:107-13.
5. Sofka CM. Duplex ultrasound scan findings two years after great saphenous vein radiofrequency endovenous obliteration. *Ultrasound Q* 2004;20:66.
6. Pichot O, Kabnick LS, Creton D, et al. Duplex ultrasound scan findings two years after great saphenous vein radiofrequency endovenous obliteration. *J Vasc Surg* 2004;39:189-95.
7. Weiss RA, Weiss MA. Controlled radiofrequency endovenous occlusion using a unique radiofrequency catheter under duplex guidance to eliminate saphenous varicose vein reflux: a 2-year follow-up. *Dermatol Surg* 2002;28:38-42.
8. Weiss RA. Comparison of endovenous radiofrequency versus 810 nm diode laser occlusion of large veins in an animal model. *Dermatol Surg* 2002;28:56-61.