

# Endovenous Ablation of Truncal Veins

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The use of endovenous procedures to eliminate saphenous and primary branch reflux has been growing exponentially over the last few years. Although initially developed by dermatologic surgeons, the technique has been embraced by many other specialties including radiology, vascular surgery and anesthesiology. Radiofrequency energy was the first used in 1999 for endovenous ablation. More recently, laser technology targeting hemoglobin (810nm, 940nm & 980nm) and water (1320nm) have been developed to quickly and effectively treat saphenous reflux, with minimal side effects. The placement of peri-vascular anesthesia, using the tumescent technique, has further streamlined these procedures. The purpose of this article is to review our experience and outline advantages and disadvantages of the various techniques available.

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The use of endovenous procedures to eliminate saphenous and primary branch reflux has been growing exponentially over the last few years. Since its inception in the late 1990s as a procedure to replace a very invasive procedure of stripping and ligation, the concept of obtaining access to a vein and using a form of energy from the inside to shrink and seal the targeted vein has been gaining more advocates daily. Although initially developed by dermatologic surgeons, the technique has been embraced by physicians in many other specialties, including radiology, vascular surgery, and anesthesiology. It began with the use of a specially and elegantly designed bipolar radiofrequency (RF) catheter for gentle heating and was quickly applied to bare laser fibers fired within the targeted varicose or refluxing saphenous vein.<sup>1</sup> With worldwide clinical experience on more than 60,000 procedures since 1999, RF shrinkage of veins has been a valuable addition to treating large varicose veins resulting from saphenous reflux. Today, there are numerous systems available that use various infrared wavelengths as well as RF to accomplish endoluminal heating and shrinkage of saphenous trunks. The purpose of this article is to review our experience

and outline advantages and disadvantages of the various techniques available. The discussion will be focused on 3 classes of endovenous treatment: RF, laser targeting hemoglobin (810 nm, 940 nm, and 980 nm) and laser targeting water (1320 nm).

## RF Endoluminal Ablation (Closure™)

RF energy can be delivered through a specially designed endovenous electrode to accomplish controlled heating of the vessel wall, causing vein shrinkage or occlusion by contraction of venous wall collagen. This process, the Closure™ system (VNUS Medical, San Jose, CA), minimizes coagulation of blood, which can be the cause of intravascular thrombus and ultimately lead to failure of sealing of a vein. Directing RF energy into tissue to cause very specific destruction is potentially safer and more controllable than other mechanisms for several reasons.<sup>1,2</sup> Endovenous occlusion of the greater saphenous vein with RF energy has been shown to be a safe and effective treatment for saphenofemoral reflux. Operating parameters were selected to provide sufficient energy to controllably and transmurally heat the vein wall to cause collagen contraction and destruction of the vein wall while limiting the degree of perivascular heating. There have been advances in technique, such as ultrasound-guided tumescent infiltration, which have provided an added level of thermal protection to the perivenous tissue.

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**Figure 1** The Closure Plus™ catheter (Courtesy VNUS Medical Technologies, San Jose, CA).

When the RF catheter is pulled through the vein while being feedback-controlled with a thermocouple, the dermatologic surgeon can heat the section of vein wall to a specified temperature. This process is relatively safe because the temperature increase remains localized around the active electrode provided that close, stable contact between the active electrode and the vessel wall is maintained. By limiting temperature to 85 to 90°C, boiling, vaporization, and carbonization of the tissues is avoided.

A recent *in vitro* study demonstrated the safety of the RF to the perivenous tissue.<sup>3</sup> The mean peak adventitial temperatures when the adventitia was lightly bathed in saline was 64.4°C, with a set point temperature of 85°C at a pullback speed of 3 cm/min. When raising the set point to 90°C at double the pullback speed of 6 cm/min, adventitial temperatures reached a maximum of 64.9°C. We have been using the 90°C faster pullback for 3 years and observing the same safety and efficacy as the previous 85°C set point. In the same *in vitro* model, if tumescent anesthesia is simulated with a 2.0-mm layer of saline, the mean peak adventitial temperatures become even lower with the low temperature slower pullback for being 51.3°C and faster pullback at 90°C at 47.7°C.

The catheter design includes collapsible catheter electrodes around which the vein may shrink and a central lumen to allow a guidewire and/or fluid delivery structured within the 5-F (1.7 mm) catheter (Fig. 1). This permits treatment of veins as small as 2 mm and as large as 8 mm. A larger 8-F catheter allows treatment of saphenous veins as large as 12 mm in diameter. Both catheters have



**Figure 2** RF generator, version 2. Note clear displays of time, temperature, impedance, and watts. (Courtesy VNUS Medical Technologies, San Jose, CA).

**Table 1** Side Effects of RF Endovenous Ablation

Side Effect	Incidence	Percentage (%)
Pulmonary embolism	1/985	0.1
DVT	9/985	0.9
Skin burn before using tumescent anesthesia	10/542	1.8
Skin burn after using tumescent anesthesia	2/443	0.5
Infection	2/985	0.2
Lymphedema	0/985	0

thermocouples on the electrodes embedded in the vein wall that measure temperature and provide feedback to the RF generator for temperature stabilization. The control unit displays power, impedance, temperature, and elapsed time so that precise control may be obtained. The second-generation RF generator delivers an audio tone to indicate withdrawal speed (Fig. 2). If the pullback is too quick, then the frequency and pitch increase to warn the physician. The unit delivers the minimum power necessary to maintain the desired electrode temperature. For safety, if a coagulum forms on the electrodes, the impedance rises rapidly and the programmed RF generator automatically cuts off.

More than 5 years of clinical experience with more than 800 endovenous RF treatments in our facility suggest that the Closure™ procedure is effective at occluding saphenous veins and abolishing reflux with a 90% long-term success rate. Success is defined as absence of the saphenous vein or absence of reflux in the treated vein. Other long-term experiences with RF have been recently published. In a prospective multicenter study for RF, varicose vein free rates were 1 year: 90.1%; 2 years: 87.2%; and 3 years: 88.2%. Duplex ultrasound demonstrated a reflux-free rate of approximately 88% over the course of 3 years. Total occlusion of veins was 1 year: 81%; 2 years: 80.4%; and 3 years: 75%.<sup>4</sup> Another study following patients up to 5 years showed a high degree of long-term efficacy.<sup>5</sup> There were 1006 patients (1222 limbs) treated, 90% great saphenous vein above-knee segments with mean vein diameter 7.5 mm, with a maximum size of 24 mm. Using Duplex sonography, vein occlusion rates for 5 years in descending years of follow-up were 87.1%, 88.2%, 83.5%, 84.9%, and 87.2%, whereas reflux-free rates were 88.2%, 88.2%, 88.0%, 86.6%, and 83.8% yearly. Clinical symptom improvement was observed in 85% to 94% of limbs with anatomical success from 6 months to 5 years. Symptoms improved in 70% of limbs even with anatomical failures after the RF obliteration.

Our experience is that RF and other endovenous techniques seal all the major tributaries at the sapheno-femoral junction except for the superior epigastric tributary that continues to empty superiorly into the common femoral vein. We believe that there is a high margin of safety by maintaining flow through this tributary. The high flow rate

Table 2 Endovenous Lasers

Wavelength	Manufacturer	Brand Name	Target	Mechanism
810nm*	Diomed	EVL <sup>TM</sup> : endovenous laser treatment	Hemoglobin	Heating blood, transmitting to vein wall
940nm	Dornier	ELT: endovenous laser treatment	Hemoglobin	Heating blood, transmitting to vein wall
980nm	Biolitec	ELVeS <sup>TM</sup> : Endo Laser Vein System	Hemoglobin	Heating blood, transmitting to vein wall
1320nm	New Star, Cool Touch	CTEV <sup>TM</sup> : Cool Touch Endovenous	Water	Heating of water in vein wall

Lase 810-nm and by MedArt<sup>®</sup> called ILVO<sup>TM</sup> Intra-luminal Laser Vein Occlusion using MedArt 426.

\*Other 810-nm devices are presently being sold by Vascular Solutions called Vari-

appears to diminish the possibility of extension of any thrombus (in the unlikely event that this would occur) from the greater saphenous vein (GSV). In our personal experience, thrombus has not been observed.<sup>6</sup>

For clinical symptoms, the RF endovenous occlusion procedure rapidly reduces patient pain, fatigue, and aching correlating with a reduction in clinical-etiological-anatomic-pathophysiological (ie, CEAP) clinical class for symptoms and clinical severity of disease.<sup>7</sup> When patients have had surgical stripping on the opposite leg, the degree of pain, tenderness, and bruising have been far greater on the leg treated by stripping. A central registry kept by VNUS Medical Inc. indicates that serious side effects of the Closure<sup>TM</sup> technique are minimal (Table 1) and are much lower than surgical stripping. For minor and temporary adverse sequelae we typically note some small degree of bruising at the access site, rare mild erythema over the course of the treated GSV but no paresthesias with the use of tumescent anesthesia. We have not seen DVT at our site.

Previously published studies have looked at side effects and efficacy. Three separate articles detail a similar cohort of patients treated in a multicenter study ranging from 16 to 31 clinics with 210 to 324 patients with 6- to 12-month follow-up.<sup>8-10</sup> The vein occlusion rate at 1 year examination was 91.6% from 9 centers and 81.9% from 14 centers. Forty-nine patients were followed at 2 years with Duplex scans and showed a 89.8% closure rate. There was a 3% incidence of paresthesia as well as a 1.6% rate when treatment was confined to the thigh. Two limbs (0.8%) developed scarring from skin burns, and 3 patients developed a DVT with 1 embolism. The reason for the increase in adverse effects appears to be the use of general anesthesia without tumescent anesthesia.

Class 2 compression hosiery is worn for 3 days for endovenous RF alone and 14 days if one is performing an adjunctive ambulatory phlebectomy. Anesthesia of the treated portion of the leg may persist for 8 to 24 hours. To gain experience, it is recommended that, for the initial cases, one re-evaluate the treated veins after 3 days by Duplex ultrasound. This monitoring will allow correlation of results with the pullback rate or any difficulty encountered during the procedure. Once comfortable with the procedure, the physician may want to see the patient for a Duplex ultrasound follow-up study at 6 weeks. At that

time, any open segments can be treated by foamed sclerosant Duplex guided sclerotherapy. It has been our experience that when closed at 6 weeks, the GSV will remain closed, fibrosed, and almost indistinguishable from surrounding tissue at 6 months. Symptom reduction is rapid with many patients experiencing relief at three days but some not until 4 to 6 weeks. Clinical improvement in appearance of varicosities is typically observed within 4 to 6 weeks as well.

## Tumescent Anesthesia: the Role in Reduction of Side Effects

Dermatologic surgeons, already experienced with large volume, low concentration tumescent anesthesia for liposuction, were the first to apply tumescent infiltration to endovenous techniques. Tumescent anesthesia or the placement of large volumes of dilute anesthesia in a perivascular position serves several purposes: (1) to protect perivascular tissues from the thermal effects of intravascular energy such as RF; (2) to decrease the diameter of the treated vein to allow for better contact of the RF electrodes with the vein wall, and thus secondarily reduce intravascular blood for nonspecific coagulation; and (3) provide better and safer anesthesia for patients.

Our initial results revealed that using this method the GSV could be sealed with endovenous techniques as a relatively painless procedure with little down-time and immediate ambulation of the patient. Our experience with tumescent anesthesia used in every one of our patients is absence of deep vein thrombosis (DVT). The incidence as measured by Duplex ultrasound follow-up at 3 to 14 days is 0%. We firmly believe that the use of tumescent anesthesia in unsedated conscious patients followed by immediate ambulation at the conclusion of the procedure is the reason for our lack of serious adverse sequelae such as DVT.

## Endoluminal Laser Ablation (810 nm, 940 nm and 980 nm) Targeting Hemoglobin

Endovenous laser treatment allows the delivery of laser energy directly into the blood vessel lumen to produce endo-



**Figure 3** CoolTouch CTEV™ 1320 nm laser and automatic pullback device. (Courtesy of CoolTouch, CoolTouch Corp., Roseville, CA.)

thelial and vein wall damage with subsequent fibrosis. The various lasers available for endovenous are summarized in Table 2. The presumed target for lasers with 810-, 940-, and 980-nm wavelengths is intravascular red blood cell absorption of laser energy with dissipation of heat and thrombotic vein occlusion with some intramural heat damage. Steam bubbles occurring as blood is boiled within the lumen have been shown to occur as the primary mechanism of occlusion effects.<sup>11</sup> Direct thermal effects on the vein wall without the presence of blood probably do not occur.<sup>12</sup> The extent of thermal injury to tissue is strongly dependent on the amount and duration of heat the tissue is exposed to, which for these lasers are dependent on multiple factors include blood in the lumen, rate of pullback and amount of tumescent anesthesia placed around the vein.<sup>13</sup>

In vitro models have predicted that thermal gas production by laser heating of blood in a 6-mm tube results in 6 mm of thermal damage.<sup>11,12</sup> These authors used a 940-nm diode laser with multiple 15J, 1-second pulses to treat the GSV. An median of 80 pulses (range, 22-116) were applied along the treated vein every 5 to 7 mm. Histologic examination of one excised vein demonstrated thermal damage along the entire treated vein with evidence of perforations at the point of laser application described as “explosive-like” photo-disruption of the vein wall. This produced the homogeneous thrombotic occlusion of the vessel. Because

optical properties of a 940-nm laser beam within circulating blood is that it can only penetrate 0.3 mm, the formation of steam bubbles is the mechanism of action of heating surrounding tissue.<sup>11</sup>

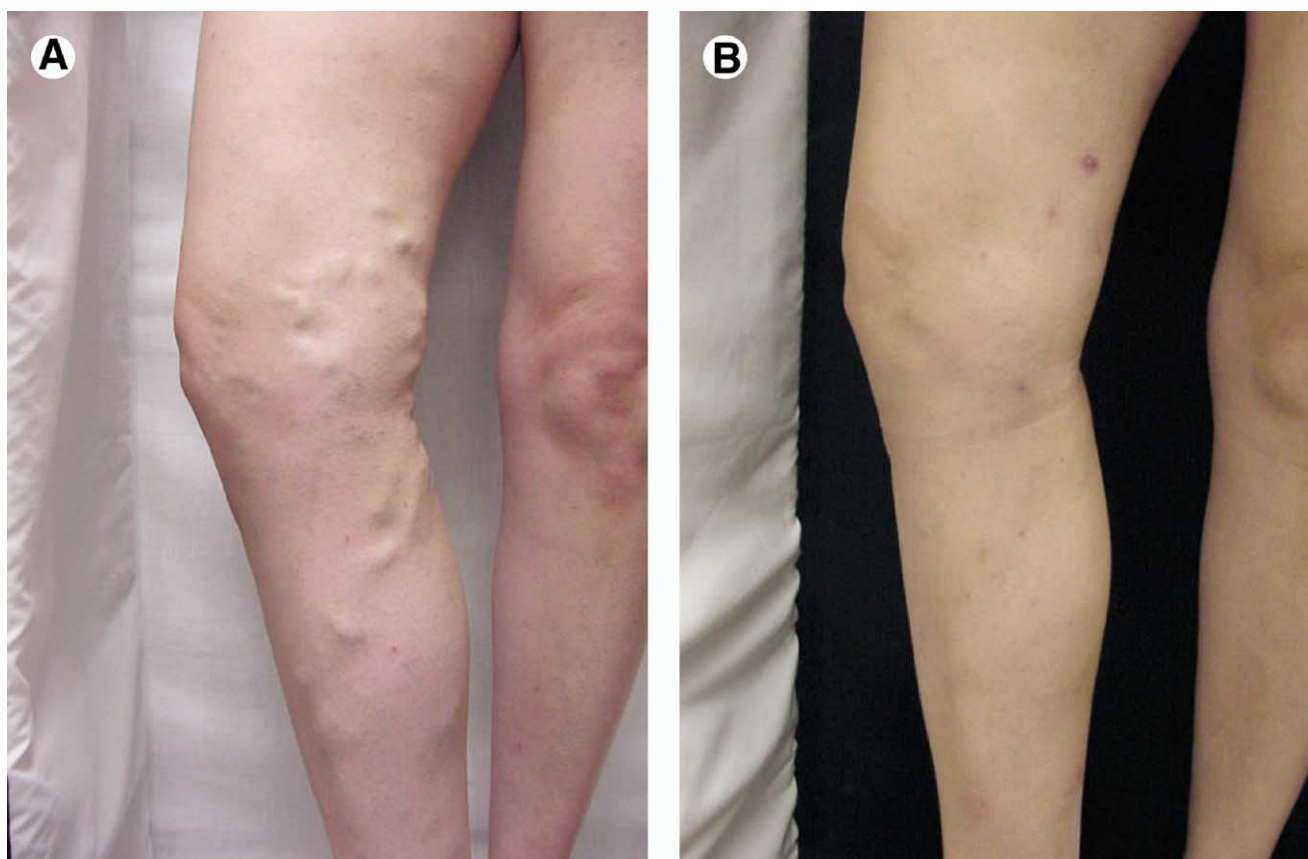
Initial reports have shown this technique with an 810-nm diode laser to have good short-term efficacy in the treatment of the incompetent GSV, with 96% or higher occlusion at 9 months with a less than 1% incidence of transient paresthesia.<sup>14,15</sup> Most patients, however, experience major degrees of postoperative ecchymosis and discomfort. Skin burns have observed by our center and recently reported using the 810-nm wavelength.<sup>16</sup> DVT extending into the femoral vein have also been recently reported with endovenous laser treatment.<sup>17</sup>

Our patients treated with an 810nm diode laser have shown an increase in posttreatment purpura and tenderness. Most of our patients do not return to complete functional normality for 2 to 7 days as opposed to the 1 day “down-time” with RF closure of the GSV. Using 1320-nm endovenous ablation (CTEV, CoolTouch, Roseville, CA) there is also very limited to no downtime, similar to endovenous RF. Recent studies suggest that pulsed 810-nm diode laser treatment, with its increased risk for perforation of the vein, may be responsible for the increase symptoms with 810-nm laser versus RF treatment.<sup>18</sup> Our experience with trying to vary the fluence and treating with a continuous laser versus pulsed laser has not resulted in an elimination of vein perforation using 810-nm diode laser, although some authors have claimed that continuous laser reduces vein perforations and increases efficacy.<sup>19</sup>

A report of 280 patients with 350 treated limbs treated with 940-nm laser with 18-month follow-up demonstrated complete closure in 96%.<sup>20</sup> Twenty vein segments were examined histologically. Veins were treated with 1-second duration pulses at 12 J. Perforations were not present. When the fluence was increased to 15 J with 1.2- and 1.3-second pulses, microperforations did occur and were said to be self-sealing. A clinical study using an endoluminal 1064-nm Nd:YAG laser in the treatment of incompetent GSV in 151 men and women with 252 treated limbs was reported.<sup>21</sup> This wavelength is not commonly used because of the superficial burns in 4.8% of patients, paresthesia in 36.5%, superficial phlebitis is 1.6%, and localized hematomas in 0.8% reported in the study.

When using a wavelength strongly absorbed by hemoglobin, such as 810 nm, there is 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 1200°C.<sup>18</sup> When we have tried ex vivo vein treatment without blood, the 810-nm wavelength simply chars a groove along the inside of the vein. When blood is added to ex vivo veins and then treated with 810-nm numerous localized vein explosions are observed (personal communication, Dr. M. Hirokawa, Tokyo, Japan, 2005).

Minimizing direct contact with vein wall for hemoglobin dependent methods minimizes the charring of the vein wall and probably lowers the postoperative pain levels.



**Figure 4** Clinical result seen with CoolTouch CTEV™ 1320-nm laser. (A) Before treatment; (B) After 6 weeks. There is marked improvement of a varicosity associated with reflux of the greater saphenous vein. (Color version of figure is available online.)

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 frequently are encountered, leading to sharp increases in temperature and vein perforations when using hemoglobin-absorbed wavelengths such as 810 nm.

Additionally, when using tumescent anesthesia with a hemoglobin-targeting wavelength, it can be very difficult to gauge the correct amount of compression to apply to the vein because some hemoglobin is necessary for the mechanism of action. If too much tumescence is used, and hemoglobin is eliminated, 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.

If a hemoglobin-absorbed wavelength is used, it must be used at higher fluences with concomitant increased risks. Using 980 nm for endovenous ablation, failure of vein sealing has been shown to be related to the administration of low laser fluences.<sup>13</sup> This study lists risk factors for non-occlusion, which are lower laser fluence, lower laser energy per centimeter of vein length, and larger diameter of the vein before treatment. Because there typically is a thrombus with hemoglobin-targeting wavelengths, this study also showed that increased distance of the thrombus distal to the saphenofemoral junction at day 1 after treat-

ment adversely affected outcome. This same author has recently compared a hemoglobin-targeting wavelength of 980 nm with a water-targeting wavelength of 1320 nm and found significant reduction of patient symptoms with the 1320 nm wavelength as discussed below.<sup>22</sup>

### Endoluminal Laser Ablation (1320 nm) Targeting Water

In an attempt to bypass the problems associated with laser absorption by hemoglobin as the chromophore, 1320 nm was investigated for endovenous use beginning in 2002. Clinical trials were performed resulting in FDA clearance in September 2004 for treatment of the greater saphenous vein. By August 2005 sufficient data for approval for obliteration of reflux in the lesser saphenous vein was cleared by the Food and Drug Administration.

The CoolTouch CTEV™ (CoolTouch, Roseville, CA) treatment is an endovenous ablation system designed to overcome deficiencies of previous laser systems. Using a special 1320-nm conducting laser fiber coupled to an automatic pull-back device preset to pull back at 1 mm/s (Fig. 3). Tissue water is the target and the presence or absence of red blood cells within the vessels is unimportant. This 1.32- $\mu$ m wavelength is unique among en-

dovenous ablation lasers in that this wavelength is absorbed only by water and not by hemoglobin. This makes it significantly different in mechanism of action compared with the other (hemoglobin targeting) wavelengths used for endovenous laser treatments.

For all the potential problems with high temperatures with the target chromophore of hemoglobin, and the fact that a laser fiber is always surrounded by hemoglobin when inserted into a vein, there is potential benefit from targeting water in the vein wall or more mildly heating the water molecules in blood. In contrast, when targeting veins in a percutaneous approach, when the vein is surrounded by a high water content it is much more effective to target smaller leg telangiectasias with deeply penetrating laser wavelengths that target deoxyhemoglobin absorption, such as 1064-nm Nd:YAG. When veins are targeted through the skin, the concept of selective photothermolysis is paramount to select hemoglobin instead of water, allowing selective destruction of tiny blood vessels without heating surrounding structures. Our own experience reflects this, with a reduction in pain and bruising of 80% when switching from 810-nm endovenous to 1320-nm endovenous. No significant pain interfering with walking, such as observed with 810 nm, has been observed. A typical clinical result is shown in Fig. 4. Having treated more than 200 greater saphenous veins with 1320 nm, our incidence of mild pain is 5% and our success rate of vein ablation is 95% at 2 years. Goldman<sup>23</sup> has reported a similar experience with concluding that at 6 months follow-up, a 5-W, 1320-nm intravascular laser with 1 mm/s automatic pullback, delivered through a diffusion-tip fiber, is safe and effective in treating an incompetent great saphenous vein up to 1.2 cm in diameter.

We believe that there is reduced pain with 1320 nm versus hemoglobin targeting wavelengths probably due to less vein perforations, less thrombus formation and more uniform heating by 1320 nm targeting water in the vein wall. Although rarely patients experience mild pain after 1320 nm, this is probably related to heat dissipated into surrounding tissue, not vein perforations, as the incidence of bruising is extremely low. In our own unpublished studies we have found that emitting 5 W of 1320 nm through a 600- $\mu$  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 utilized. We believe that effective energy for vein sealing in our practice is mostly between 5 W and 6 W, thus minimizing postoperative pain to less than 5%. Our experience and those of others indicate that water-targeting 1320 nm versus 810 nm, 940 nm or 980 nm hemoglobin-targeting endovenous occlusion is gentler, leading to far less bruising and postoperative pain.

## Summary

The latest techniques for endovenous occlusion using RF ablation catheters or endoluminal laser targeting water are

our preferred methods to treat saphenous related varicose veins. Our clinical experience with endovenous techniques in more than 1000 patients shows a high degree of success with minimal side effects, most of which can be prevented or minimized with use of tumescent anesthesia. Tumescent anesthesia is critical to the safety of endovenous techniques. Within the next 5 years, these minimally invasive endovenous ablative procedures involving saphenous trunks should have virtually replaced open surgical strippings. More than 100,000 patients already have been treated worldwide.

## References

1. 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* 28:38-42, 2002
2. Goldman MP, Amiry S: Closure of the greater saphenous vein with endoluminal radiofrequency thermal heating of the vein wall in combination with ambulatory phlebectomy: 50 patients with more than 6-month follow-up. *Dermatol Surg* 28:29-31, 2002
3. Zikorus AW, Mirizzi MS: Evaluation of setpoint temperature and pullback speed on vein adventitial temperature during endovenous radiofrequency energy delivery in an in-vitro model. *Vasc Endovascular Surg* 38:167-174, 2004
4. Nicolini P: Treatment of primary varicose veins by endovenous obliteration with the VNUS closure system: results of a prospective multicentre study. *Eur J Vasc Endovasc Surg* 29:433-439, 2005
5. Merchant RF, Pichot O: Long-term outcomes of endovenous radiofrequency obliteration of saphenous reflux as a treatment for superficial venous insufficiency. *J Vasc Surg* 42:502-509, 2005
6. Goldman MP, Weiss R, Gradman W: Regarding "Deep vein thrombosis after radiofrequency ablation of greater saphenous vein: a word of caution." *J Vasc Surg* 41:737-738, 2005
7. Kistner RL, Eklof B, Masuda EM: Diagnosis of chronic venous disease of the lower extremities: the "CEAP" classification. *Mayo Clin Proc* 71:338-345, 1996[see comments]
8. Chandler JG, Pichot O, Sessa C, et al: Defining the role of extended saphenofemoral junction ligation: a prospective comparative study. *J Vasc Surg* 32:941-953, 2000
9. Manfrini S, Gasbarro V, Danielsson G, et al: Endovenous management of saphenous vein reflux. *Endovenous Reflux Management Study Group. J Vasc Surg* 32:330-342, 2000
10. Merchant RF, Depalma RG, Kabnick LS: Endovascular obliteration of saphenous reflux: a multicenter study. *J Vasc Surg* 35:1190-1196, 2002
11. 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* 35:729-736, 2002
12. 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* 28:596-600, 2002
13. Proebstle TM, Krummenauer F, Gul D, et al: Nonocclusion and early reopening of the great saphenous vein after endovenous laser treatment is fluence dependent. *Dermatol Surg* 30:174-178, 2004
14. Min RJ, Zimmet SE, Isaacs MN, et al: Endovenous laser treatment of the incompetent greater saphenous vein. *J Vasc Interv Radiol* 12:1167-1171, 2001
15. Navarro L, Min RJ, Bone C: Endovenous laser: a new minimally invasive method of treatment for varicose veins—preliminary observations using an 810 nm diode laser. *Dermatol Surg* 27:117-1122, 2001
16. Sichlau MJ, Ryu RK: Cutaneous thermal injury after endovenous laser ablation of the great saphenous vein. *J Vasc Interv Radiol* 15:865-867, 2004
17. Mozes G, Kalra M, Carmo M, et al: Extension of saphenous thrombus

- into the femoral vein: a potential complication of new endovenous ablation techniques. *J Vasc Surg* 41:130-135, 2005
18. Weiss RA: Comparison of endovenous radiofrequency versus 810 nm diode laser occlusion of large veins in an animal model. *Dermatol Surg* 28:56-61, 2002
  19. Min RJ, Khilnani NM: Endovenous laser ablation of varicose veins. *J Cardiovasc Surg (Torino)* 46:395-405, 2005
  20. Bush RG: Regarding "Endovenous treatment of the greater saphenous vein with a 940-nm diode laser: thrombolytic occlusion after endoluminal thermal damage by laser-generated steam bubbles." *J Vasc Surg* 37:242, 2003
  21. Chang CJ, Chua JJ: Endovenous laser photocoagulation (EVLP) for varicose veins. *Lasers Surg Med* 31:257-262, 2002
  22. Proebstle TM: Comparison of 940 nm and 1320 nm endovenous ablation. *Dermatol Surg*, in press
  23. Goldman MP, Mauricio M, Rao J: Intravascular 1320-nm laser closure of the great saphenous vein: a 6- to 12-month follow-up study. *Dermatol Surg* 30:1380-1385, 2004