

# Endovenous laser ablation for the treatment of varicose veins

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## ABSTRACT

Lower extremity venous insufficiency secondary to saphenous vein insufficiency is a common medical condition that decreases a patient's quality of life. Traditionally treated with high ligation and stripping, minimally invasive procedures using endovenous thermal ablation techniques, such as endovenous laser ablation, have evolved. The use of detailed imaging and advances in the understanding of the anatomy of truncal vein insufficiency are important for performing the endovenous laser ablation procedure successfully. Endovenous laser ablation eliminates reflux with less morbidity, faster recovery, and improved cosmetic results with high patient satisfaction. As such, it has become the preferred treatment method for varicose veins since it was first introduced a decade ago.

*Key words:* • laser ablation • saphenous vein • venous insufficiency • varicose veins

Lower extremity venous insufficiency is a very common medical condition that affects approximately 25% of women and 15% of men (1). Great saphenous vein (GSV) reflux is the most common underlying cause of symptomatic varicose veins. Other reasons for the development of varicose veins are reflux in other truncal veins, such as the small saphenous vein (SSV), the anterior or posterior thigh circumflex vein, the Giacomini vein, and perforating veins. Treatment options for varicose veins include conservative management, minimally invasive procedures, and surgery.

Conservative treatment options include the avoidance of prolonged standing and straining, elevation of the affected leg, exercise, external compression, medical therapies, and weight loss. External compression therapy with bandages or support stockings have been recommended as the initial therapy for varicose veins; however, conservative therapies may relieve the patient's discomfort and slow the progression of the disease but cannot cure it.

Until recently, surgery was considered the standard therapy for varicose veins, especially when the GSV is involved. However, research has shown that the clinical results are not always as expected and that severe side effects, such as infection or nerve damage, are not uncommon (2). The surgical treatment for GSV incompetence is a high ligation with stripping at the saphenofemoral junction (SFJ) with or without phlebectomy. Venous insufficiency of the SSV is conventionally treated by ligation with or without stripping at the saphenopopliteal junction (SPJ). However, recurrence occurs in approximately one-third to two-thirds of patients after five years (3–4). Other disadvantages of surgery are the necessity for general anesthesia and the development of scars and post-operative pain.

Minimally invasive procedures using endovenous thermal ablation techniques (endovenous laser ablation [EVLA] or radiofrequency ablation [RFA]) and ultrasonography (US)-guided foam sclerotherapy are safe and effective ways of eliminating reflux with less morbidity, faster recovery, and improved cosmetic results. The use of detailed imaging and advances in the understanding of the anatomy and pathology of varicose veins are important in the development of new treatment techniques. This article details the technique of EVLA and its mechanism of action, technical outcomes, and complications.

## Etiology

Venous disease resulting from valve reflux appears to be the underlying pathophysiology for the formation of varicose veins. Venous blood normally flows from distal to proximal and superficial to deep. The lower extremity veins rely on one-way valves located at intervals along the main veins. When these valves fail, the affected vein becomes

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incompetent. Incompetent valves in the venous system allow blood to reflux and flow in both directions. As a consequence, venous hypertension develops in a vein, and its associated tributaries fail. The affected veins will eventually dilate and become varicose. However, the mechanism leading to venous valve incompetence is still unknown.

### Diagnosis

The established risk factors for varicose veins include a family history of venous disease, female sex, obesity (especially for women), older age, pregnancy, and gravitational force from prolonged standing or sitting. A prior history of a deep venous thrombosis (DVT) causes varicose veins in a clinical condition called post-thrombotic syndrome. Many people seek medical treatment for varicose veins for cosmetic reasons; however, most people with varicose veins experience clinical symptoms.

Regardless of the underlying cause of valve failure, there is a fairly common presentation of symptoms. Patients present with large bulging varicosities within the lower leg. Varicosities may also be present in the thigh, gluteal or vulvar regions. Varicose veins may or may not cause symptoms, and the clinical presentation varies among patients. Symptoms include pain, burning sensations, itching, heaviness, leg fatigue, leg cramps (especially during the night), and paresthesia. Women are significantly more likely than men to report lower limb symptoms. Interestingly, there has been no correlation between the severity of varicose veins and the severity of symptoms. Symptoms arise from the pressure of dilated veins on the somatic nerves and are often worse at the end of the day, especially after periods of prolonged standing, during the premenstrual period or in warm weather; they usually improve when patients elevate their legs. Left untreated, many patients will eventually experience chronic venous insufficiency characterized by lower extremity swelling, eczema, pigmentation, and ulceration. There is a suspected association between “restless leg syndrome” and varicose veins (5). Patients report significant improvement in their complaints after their varicose veins have been successfully treated.

A physical examination of the patient's leg may reveal a characteristic pattern of varicosities that are commonly associated with reflux of a specific vein. For example, GSV reflux often produces varicose veins along the medial aspect of the leg. Anterior thigh circumflex (or anterolateral) vein incompetence produces varicose veins along the anterior thigh. Insufficiency of the Giacomini vein may cause varicose veins around the popliteal fossa; however, varicosities in this area can also originate from SSV or perforating vein insufficiencies. Certain patterns of varicosities suggest that the underlying venous insufficiency actually originates outside the venous system of the leg. Groin varicosities are usually due to iliac vein or gonadal vein insufficiencies, and varicosities on the posterior inferior thigh are due to inferior gluteal vein insufficiency (6–8). It is important to delineate the venous insufficiency that has caused the present varicose veins before treatment.

Imaging studies are generally not necessary for diagnosis, but a thorough examination of the extremity with color Doppler US (CDUS) is important. US examination must be performed while the patient is standing. The superficial veins distal to the knee can also be examined with CDUS while the patient is sitting. CDUS can assess the anatomy and physiology of the lower extremity venous system. It can evaluate acute and occult DVT, superficial thrombophlebitis, and reflux of the superficial, deep and perforator veins.

Although varicose veins may cause varying degrees of discomfort or cosmetic concerns, they are rarely associated with significant medical complications. Skin pigmentation, infection, superficial thrombophlebitis, and venous ulceration are possible complications. Although very rare, an external hemorrhage resulting from the perforation of a varicose vein and pulmonary embolisms originating from a varicose vein thrombosis have been reported (9).

### Endovenous laser ablation

#### Indications

The indications for treatment are largely based on the patient's preferences. The most common indication for EVLA is insufficiency of the GSV or SSV visualized using CDUS. However, the treatment choice is also affected by

symptoms, costs, potential for iatrogenic complications, and the presence or absence of deep venous insufficiency. Patients have CEAP scores ranging from C2 to C6. In addition to primary truncal varicosities, accessory and perforating veins, recurrent truncal varicosities, varicosities in patients with post-thrombotic syndrome after a DVT and Klippel-Trenanay syndrome have been treated successfully with EVLA.

There are no absolute contraindications for EVLA (10). However, EVLA is not performed during pregnancy or for woman planning to become pregnant during the follow-up period. Severe peripheral artery disease can be a relative contraindication because laser energy can damage small arterial branches around the vein in patients with compromised arteries. Allergies to local anesthetic agents and severe hypercoagulability syndromes are relative contraindications. A history of a previous DVT or concomitant deep vein insufficiency is not an absolute contraindication, and patients with these conditions have been treated successfully with EVLA. However, the risk/benefit ratio should be carefully evaluated for patients with a history of a DVT or deep venous insufficiency.

### Sedation

The majority of physicians use local anesthesia for needle punctures and tumescent anesthesia to prevent pain that would originate from the effects of laser energy on the venous wall. A number of centers use epidural and general anesthesia. Intravenous conscious sedation, mostly in combination with dormicum and fentanyl citrate, is another option. These two medications have a rapid onset of action and a short duration. They decrease anxiety related to the procedure, relieve pain, and have an amnestic effect, which is preferred for some patients. Intravenous conscious sedation can be performed without the supervision of an anesthesiologist. US-guided femoral and sciatic nerve blocks have been used with varicose vein surgery but rarely for EVLA (11).

### Mechanism of endovenous laser ablation

Laser generators generally use a 600-nm laser fiber to deliver the energy. Laser energy generates high-energy, bundled light that is monochromatic (one wavelength), coherent (in phase),

and collimated (photons run parallel). The mechanism of the laser is not entirely clear, but a thermal reaction after the laser exposure is the suspected mechanism. The produced heat may reach up to 800 °C at the tip of the fiber and results in the formation of steam bubbles. The bubbles cause the blood to boil and induce thermal injuries to the venous endothelium. The intravascular heat decreases to 90 °C at 4 mm from the laser tip. Steam bubbles that form at the tip of the fiber dissipate quickly and pose no systemic risk of tissue burns around the vein. Histological studies show that EVLA damages the endothelial and intimal layers, the internal elastic lamina and the media to some degree. The adventitia is rarely affected (12).

Delivering adequate energy is crucial in achieving a successful ablation of the treated vein. Regardless of which technique is used for EVLA, substantial heat transfer to the vein wall is necessary to obtain a durable occlusion of the treated vein. Fluence (Joules/cm<sup>2</sup>) is the most important parameter to quantify the amount of energy delivered. The amount of energy in Joules (J) depends on the power (in watts) and the duration of exposure of the laser beam to the area (energy=power×time). Because the surface area of the venous wall is difficult to measure, most studies report Joules/cm instead of Joules/cm<sup>2</sup> as a marker of fluence. A multivariate analysis showed that the amount of energy administered during EVLA is an independent predictor of the GSV occlusion (13). Studies have indicated that the administration of a linear energy density of ≥80 J/cm<sup>2</sup> is usually sufficient to achieve an effective ablation during short-term follow-up (14). Energy dosing dependent on diameter of the vein has been proposed, i.e., the use of higher energy levels for large diameter veins and lower energy levels for small diameter veins (15). To support this hypothesis, a histological study demonstrated that the optimal thermal tissue damage in the venous wall was obtained in veins <9.7 mm in diameter (12).

The amount of energy delivered depends on the wattage and duration of the laser energy over the surface of the vein wall. The use of 10–20 W is the most common practice, but wattages as high as 30 W have also been used.

All wattages from 10 W to 30 W appear to be sufficient to achieve an adequate ablation. However, there is not much evidence comparing the effectiveness of EVLA with different powers. A recent randomized study with a small patient population suggested that EVLA using 30 W was more effective than 15 W using a 940 nm diode laser (15). Another small case series showed that 11 W was as effective as 15 W, and it was associated with fewer side effects (16).

All currently available laser wavelengths have been successfully used to treat venous insufficiency. The primary mechanism responsible for delivering the laser energy to the vein wall is the same for all wavelengths: the generation of steam bubbles. It appears that all laser wavelengths used for EVLA work well, and no single wavelength has proven superior to the others (17, 18).

Using the pulse mode or continuous mode usually does not influence the effectiveness of the outcome. The major advantage of the continuous mode is that duration of treatment is shorter. The pulse mode is considered to have a higher risk of adverse events, such as microperforation (19).

### Technique

EVLA can be performed under local tumescent anesthesia in an outpatient setting. The procedure varies among centers. The technique described below is one of the most commonly used techniques. The target vein is identified using US from the ankle to the SFJ. The saphenous nerve is distant from the GSV above the knee compared to below the knee. Some practitioners prefer to cannulate the GSV at the level of the knee so as not to harm the saphenous nerve, which is prone to injury with ablations below the knee. Venous access is obtained by a needle puncture under US guidance. Needle puncture can cause venous spasm at the access site; then, the vein can be punctured again a few cm above the first puncture site. A 21 G needle is preferred as venous trauma and spasm will be less likely. After entering the vein, a guide wire (mostly J tip or a straight tip) is inserted. If the varicose vein is tortuous, has a small diameter, has a large dilated branch emanating from it, or contains thrombotic, sclerotic segments (after a DVT or a previous EVLA), advancing the wire can be difficult. In such cases,

US examination of the area to visualize the tip of the wire, rotating the wire, or exchanging the wire for a hydrophilic one usually solves the problem. If severe tortuosity or obstructions of the vein cannot be crossed, then a second (or even a third) puncture can be performed at higher levels, and ablation can be completed segment by segment.

After the guide wire is in place, the needle is removed, a small incision is made at the skin, and a long introducer sheath is inserted. The tip of the sheath is located at the SFJ; the laser fiber is inserted through the sheath so that the tip of the laser fiber is positioned 1–2 cm distal to the SFJ and 1–2 cm away from the tip of the plastic introducer sheath using US guidance. One should ensure that the laser tip lies beyond the end of the catheter before activating the laser energy.

Local tumescent anesthesia (5 mL epinephrine, 5 mL bicarbonate and 35 mL 1% lidocaine diluted in 500 mL saline or prilocaine 2% without bicarbonate, diluted in 500 mL saline) is then injected along the entire course of the saphenous vein from the cannulation site up to the SFJ under US guidance using a syringe or an automated pump. The needle tip is positioned as close to the vein wall as possible, and the solution is injected. It is not a problem if the tip of the needle touches the vein wall. The solution will remain in the saphenous fascia mostly; however, it will also diffuse to extrafascial areas. For one leg, 250–500 mL of solution is usually sufficient. The tumescent anesthesia has three functions:

- 1) it protects the perivenous tissue from the effects of laser energy via a cooling effect,
- 2) it removes the blood from the lumen by collapsing the vein, increasing the effectiveness of the laser ablation, and
- 3) it increases the surface area contact between laser tip and the vein wall.

The act of forcing the blood from the vein prior to ablation is important because it allows for ablation of the vein wall and does not cause a thrombosis within the lumen. If the venous lumen cannot be completely collapsed, elevation of the leg may help. Before activation of the laser, each person in the room should wear protective laser goggles. The parameters used, including the power, the wavelength, and the

speed at which the laser fiber is pulled back, are variable.

Patients are usually discharged with an anti-inflammatory medication, such as diclofenac 50 mg taken three times daily for one or two weeks or as needed. Elastic bandages or class II (20–30 mmHg) graduated supporting stockings are recommended for one to three weeks. Compressive stockings not only compress the vein and help to increase the effectiveness of the treatment, but they also decrease the patient's postprocedural discomfort.

### Treatment outcome

The efficacy of EVLA is expressed in the percentage of venous occlusions. However, saphenous vein insufficiency is a disease with a wide spectrum of symptoms and signs that decreases the quality of patients' lives. The physician treating the venous insufficiency should embrace a commitment not only to ablate the incompetent saphenous vein but also care for the clinical problems related to the venous insufficiency. A variety of clinical scoring systems are used as the study endpoint. The C of the CEAP score, the Venous Clinical Severity Score or the Aberdeen Varicose Vein Questionnaire score should be part of the clinical evaluation and treatment outcomes. The treatment of varicose veins reduces the symptoms and the complication rate of venous insufficiency and increases patients' health-related quality of life (HRQOL).

The first studies demonstrating the efficacy of EVLA were published in 2001 (20–21). A success rate of 100% one week after EVLA and a success rate of >90% on one-year and three-year follow-up have been reported in most series since then (22–25). Freedom from recurrent varicose veins was achieved in 79% of patients after a five-year follow-up in a randomized trial (26). There are few studies comparing EVLA with other treatment modalities, mainly surgery. These studies showed comparable or superior outcomes with EVLA in terms of technical success, recurrence rates and HRQOL when compared to surgery (26, 27). Compared to RFA and foam sclerotherapy, a meta-analysis of minimally invasive therapies showed that EVLA had the best results for the long-term effectiveness parameters for occlusion at the end of follow-up and recanalization,

recurrence and the development of new veins (28). When the entire GSV is incompetent, EVLA just above the knee improves but does not completely relieve medial ankle pain and swelling. Ablation of a longer segment of the GSV also reduces the need to treat residual varicose veins.

The GSV and the SSV have some differences. Because the pressure column in these veins varies, the length of the treated area is shorter for the SSV and the relation to the neighboring nerves (more distant in GSV) is different. The SSV runs in the saphenous fascia, whereas the GSV is extrafascial in a considerable number of patients, especially around the knee. Another important difference is that anatomy of the SSV at its junction with the popliteal vein is variable when compared to the more predictable anatomy of the GSV at the SFJ. A recent literature search showed that EVLA had a significantly higher success rate when compared to surgery (94% vs. 48%) for the treatment of SSV insufficiency with similar complication rates (29). Until now, no randomized controlled trials have been performed comparing surgery and endovenous techniques for SSV insufficiency.

Foam sclerotherapy and ambulatory phlebectomy can be performed concomitantly with EVLA or deferred until the results of the laser therapy are known. After EVLA, some of the varicose veins disappear, making a second intervention obsolete. However, in at least half of the patients, residual varicosities remain. Each technique, concomitant therapy or deferral of sclerotherapy, has advantages and disadvantages. On one hand, concomitant therapy prevents a second intervention and wearing the pressure stocking again; on the other hand, some of the varicose veins are treated in vain because the residual varices would have shrunk after the laser ablation of the truncal vein insufficiency.

Recurrence following varicose vein surgery or EVLA can occur. Recurrences after EVLA are usually noted in the short term, which may indicate, at least in some of the patients, inadequate initial treatment rather than true recurrences (22). When veins recanalize after EVLA, most occur within the first 6 months, and all recanalizations occur within the first 12 months. Recurrent varicosities after EVLA can be in the

form of truncal vein insufficiency in a short segment or all along the vein or as neovascularization, which is a common and well-known problem after surgical treatment of the GSV. A repeated EVLA can effectively treat recurrent truncal insufficiency (30).

### Complications

The vast majority of complications occurring after EVLA are minor and transient. These include bruising, soreness, tenderness, and indurations along the treated vein segment. These complaints are most apparent in the first two weeks postoperatively and then gradually subside and disappear completely. The postprocedural complaints can be reduced by graduated compression stockings and anti-inflammatory medications. The degree of pain is usually much more variable than the bruising or indurations in patients. Some patients do not report any pain, whereas some experience significant pain that can result in the absence from work. Patients may feel a "pulling cord" sensation along the course of the GSV. This sensation is likely a sign of developing vein fibrosis, which may rarely cause difficulty in flexing the knee and walking for short periods of time after the procedure. Skin pigmentation, which is a side effect of sclerotherapy, can be seen rarely after the EVLA procedure, especially along the course of superficial veins. Superficial thrombophlebitis along the treated vein segment or along the nearby tributaries has been reported in 5% of patients. This requires simple symptomatic treatment with compression and anti-inflammatory medications.

The minimally invasive treatment of varicose veins reduces surgical side effects but may be associated with side effects specific to the procedure. Skin burns are rare and can be prevented with good tumescent anesthesia, especially in areas where the vein courses superficially. DVTs are a feared complication and are reported to occur in 0%–8% of cases (10). A CDUS examination a few days after EVLA to exclude DVTs or administering low molecular weight heparin for a week postoperatively has been recommended. However, the anticoagulation of all patients, even for a short period of time, is debatable, as the incidence of proven DVTs is usually less than 1%. Anticoagulation can be considered for patients who

had a prior DVT. One study showed that one day after EVLA, D-dimer levels were elevated in about half of the patients, especially in those who had the procedure bilaterally (31). A pulmonary embolism was found in one patient among 2750 cases (32). A major adverse event of surgical stripping is the risk of saphenous nerve damage, which occurs in approximately 7% in short- and 40% in long-segment stripping procedures (33). Paresthesia is observed in 0% to 12% of cases and likely will be higher in long-segment EVLA than in short-segment EVLA (10). Paresthesia also resolves spontaneously but may take weeks or months to achieve complete recovery. Aside from simple paresthesias, significant nerve injuries can rarely occur, causing pain and restlessness in the leg. Other side effects are cellulitis secondary to incisions and rarely to needle puncture, diffuse phlegmenous phlebitis with pus formation, arterial aneurysm and arteriovenous fistula formation, all of which are very rare and reported as case reports (34).

Device-related complications after EVLA include retained fiber in the vein because of significant bending, a retained guide wire, or retained introducer sheath segment because of pulling of the fiber and not of the sheath, causing the laser tip to melt and disconnect the plastic sheath fragment. In one patient, the detached sheath perforated the septum of the right ventricle and resulted in a therapy-resistant cardiac arrhythmia.

EVLA is a new technique, but the frequency of the practice has been increasing rapidly because venous insufficiency is very common. Although the list of complications contains many adverse events, the most common complications are usually self-limited and spontaneously resolve, and the major complications are very rare (<1%). Awareness of each complication is important to explain to the patient and to avoid with simple measures, if possible.

As a conclusion, since a decade after its introduction, EVLA appears to be a safe and effective treatment of venous insufficiency. As a minimally invasive technique, it is a popular choice for both patients and physicians. The procedure has high immediate technical success, a short recovery time, and good cosmetic results. Minor

complications are frequent but usually temporary and self-limited, and major complications are rare. EVLA is an efficient treatment method for the treatment of the GSV, the SSV, and other truncal venous insufficiencies, achieving good short-term and long-term results.

#### Conflict of interest disclosure

The authors declared no conflicts of interest.

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