Endovenous Laser Photocoagulation (EVLP) for Varicose Veins

Cheng-Jen Chang, MD[1]* and Jun-Jin Chua, MBBS (S'pore), FRCS (Edin), FRCS (Glas)[2]
[1]*Department of Plastic and Reconstructive Surgery, Chang Gung Memorial Hospital, Chang Gung University, Taipei, Taiwan*
[2]*Department of Plastic Surgery, Singapore General Hospital, Singapore*

Background and Objectives: Untreated varicose veins have significant morbidity and potential mortality. Treatment aims to relieve symptoms, improve appearance, and to prevent deterioration. Current therapeutic options include graduated compression stockings, sclerotherapy, ambulatory phlebectomy, surgical ligation, and stripping. Results of laser photocoagulation of vascular anomalies have been encouraging. Applying these concepts of laser–tissue interactions, we developed a new method of treatment for varicose veins of the lower extremities.

Study Design/Materials and Methods: One hundred and forty-nine patients with 252 varicose greater saphenous veins underwent endovenous laser photocoagulation (EVLP) from January 1996 to January 2000. Subject's age ranged between 23 years 9 months and 80 years 7 months with a mean age of 50 years 8 months. There were 122 females and 27 males. Only patients with primary varicose veins and saphenofemoral reflux documented by Duplex ultrasound were treated. All patients received surgical ligation of the saphenofemoral junction (SFJ). EVLP was performed using the neodymium:yttrium–aluminium–garnet (Nd:YAG) (1,064 nm) laser, delivered with a 600 μm optical fiber. Laser power was set at 10 or 15 W, delivered with a pulse duration of 10 seconds. The outcome was compared before and after EVLP, based on the score of severity of the varicose veins by Hach's classification.

Results: The range of total delivered energy is from 9,200 to 20,100 J. The entire procedure was completed in 95–175 minutes (mean 122.33 minutes) for bilateral procedures, and 65–100 minutes (mean 81.07 minutes) for unilateral procedures. The follow-up period ranged from 12 to 28 months with a mean of 19 months. One hundred and forty-one patients with 244 legs involved (96.8%) demonstrated remarkable improvement ($P < 0.05$). Common early complications of EVLP are: local paraesthesia of the treated area in 92 legs (36.5%), ecchymosis and dyschromia in 58 legs (23.0%), superficial burn injury in 12 legs (4.8%), superficial phlebitis in four legs (1.6%), and localized hematoma in two legs (0.8%) at 3 weeks post-operatively. The final outcome showed no significant morbidity or mortality. All patients recovered completely.

Conclusions: EVLP is a simple effective treatment modality for varicose veins. This less invasive method can minimize the complications of conventional surgery. Lasers Surg. Med. 31:257–262, 2002. © 2002 Wiley-Liss, Inc.

Key words: varicose vein; laser; photocoagulation

INTRODUCTION

Chronic venous disease of the lower limbs is one of the commonest conditions affecting mankind [1]. Visible tortuous varicose veins can be found in 20–25% of women and 10–15% of men above the age of 15 [2]. Minor degrees of varicosis (e.g., reticular veins) affect 50% of women and 45% of men [3,4]. The risk factors include age, female gender, pregnancy, geographical sites, and race [2].

Primary varicose veins are mostly caused by the failure of a single valve in a critical location, while secondary varicose veins occur when thrombophlebitis causes deep system and perforator valve damage. In primary varicosis, the retrograde venous inflow (reflux) allows high pressure to pass into unsupported superficial veins. These veins become dilated, tortuous, and incompetent. Untreated venous hypertension has significant morbidity and potential mortality. The sequelae include chronic pain and edema, recurrent cellulitis and dermatitis, pigmentation, lipodermatosclerosis, non-healing leg ulcers (ulcer cruris), cutaneous infarction (atrophie blanche), hemorrhage from varices, superficial thrombophlebitis, deep vein thrombosis, pulmonary embolism, and even malignant transformation [5]. Bleeding from varices of the lower extremities resulted in 23 fatalities in England and Wales in 1971 [6]. Patients with varicose veins may present with a variety of non-specific symptoms. These include pain, swelling, soreness, burning, aching, itching, throbbing, cramping, muscle fatigue, and a restless leg.

Treatment aims to eliminate symptoms, improve appearance, and to prevent deterioration. The myriads of options available include compression stockings, sclerotherapy,

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Cheng-Jen Chang is working as Associate Professor at Chang Gung Memorial Hospital.
*Correspondence to: Cheng-Jen Chang, MD, Department of Plastic and Reconstructive Surgery, Chang Gung Memorial Hospital, 199, Tung Hwa North Road, Taipei, Taiwan.
E-mail: chengjen@adm.cgmh.org.tw

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ambulatory phlebectomy, surgical stripping, surgical ligation, and radio-frequency ablation, either singly or in combination [7–19].

Lasers have been used to treat a variety of vascular conditions. Safe and effective use of lasers in angioplasty [20] and for the treatment of vascular lesions [21–24] and hemangiomas [25,26], has been variously reported. Encouraged by these clinical applications of lasers, we treated varicose veins of the lower limbs by a new method we named endovenous laser photocoagulation (EVLP). Our goals were to simplify the treatments.

MATERIALS AND METHODS

Patients

One hundred and forty-nine patients with 252 varicose greater saphenous veins (GSV) underwent EVLP at our center between January 1996 and January 2000. There were 122 females and 27 males. Their age ranged from 23 years 9 months to 80 years 7 months, with a mean age of 50 years 8 months. At the outpatient clinic, the presenting complaints and other relevant medical histories were obtained. The physical examination included clinical assessment of the venous system of the lower limbs. Preoperative photographic records were obtained. All patients received a Duplex ultrasonographic imaging at the vascular laboratory. Only patients with primary varicose veins and documented saphenofemoral junction (SFJ) reflux were included in this study. The scoring of severity of primary varicosis of the GSV were graded using Hach's classification: 4, varices about the groin; 3, varices about the midthigh; 2, varices about the upper calf; 1, varices about the ankle; 0, no varices visible [27]. A paired *t*-test for comparison of the severity changes before and after the laser treatment was used for statistical analysis.

Operative Technique

In the operating theater, pre-operative marking of the varices and photography were performed with the patient standing upright. Any incompetent perforators were identified by Duplex ultrasound scan prior to surgery. Spinal anesthesia was administered in the majority of cases. The remaining patients underwent general anesthesia.

A skin incision measuring 2 cm in length was made at the groin crease over the SFJ. Using blunt dissection, the SFJ and all the terminal tributaries draining into the GSV were identified and flush ligated with non-absorbable sutures. Similarly the distal end of the GSV was identified and ligated through a small incision anterior to the medial malleolus.

Using a number 11 blade, a 2 mm longitudinal venotomy of the distal GSV just proximal to the ligature was created. A bare 600 μm optic fiber connected to a neodymium: yttrium–aluminum–garnet (Nd:YAG) laser system (Sharplan, Inc., NJ, USA) was inserted into the lumen of the GSV and threaded upwards along its course towards the SFJ. The passage of the optic fiber could be identified by the transillumination of the overlying skin offered by the helium–nedium guide light at the tip of the fiber. A successful passage up the GSV would yield the guide light at the SFJ. In the ten patients where a complete upward passage of the laser was not possible (due to severely tortuous axial vein), the optic fiber was passed in a retrograde fashion from the SFJ.

The Nd:YAG laser system was calibrated to deliver laser pulses at a wavelength of 1,064 nm with 10–15 W of energy and pulse duration of 10 seconds upon each trigger by a foot pedal. The optic fiber was gradually retracted at a speed of 10 seconds per centimeter (Fig. 1). The use of the pulse mode when delivering the laser energy allows the surgeon more control than that of a continuous wave. A continuous flow of chilled water at 4°C and the surgeon's hand placed over the treatment area avoided overheating of the overlying skin. A visible shrinkage and a palpable firmness of the varices signaled the end-point of the treatment. The proximal and distal ends of the treated GSV were then doubly ligated and divided.

As well as the axial GSV, the varices of its branches were also treated by laser photocoagulation. At each of these

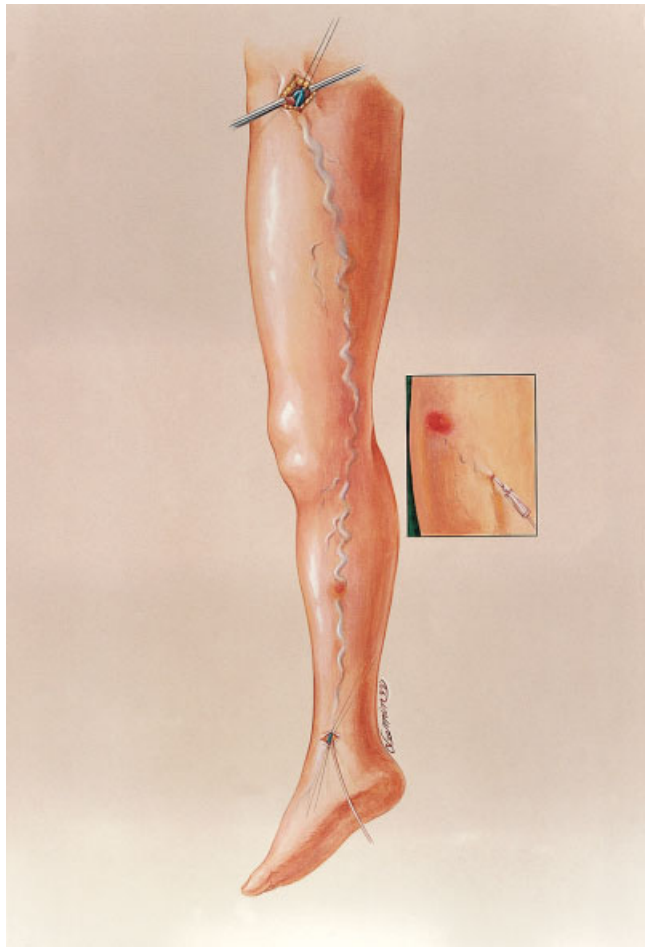

Fig. 1. The optic fiber deliver the Nd:YAG laser energy within greater saphenous vein, and a No. 18 g needle was used to puncture into the local lesion and lead the optic fiber into the nidus for photocoagulation.

sites, percutaneous cannulation of the varices or perforators was achieved with an 18-gauge metallic vascular canula (Angiocath®). A back-flow of blood or a resistance offered by the deep fascia confirmed the accurate placement of the canula respectively. The optic fiber was inserted into the canula and the tip identified by the guide light. The canula was withdrawn out of the skin to prevent inadvertent thermal injury to the skin by heat conducted from the fiber to the canula during treatment. Laser pulses were then conveyed in a similar manner as described above (Fig. 1).

Upon completion of the laser photocoagulation, the skin incisions were closed with sutures and external compression applied to the entire lower extremity with loose gauzes and elastic bandages. The total energy delivered was calculated as a product of the power (W), pulse duration (seconds), and the total number of pulses. This value was recorded in the operative notes.

The total laser energy delivered was from 9,200 to 20,100 J, with a mean of 15,240 J. The operating time for bilateral EVLP was from 95 to 175 minutes (mean 122.33 minutes) and for unilateral procedure 65–100 minutes (mean 81.07 minutes).

Post-operatively, the patients were encouraged to ambulate and to elevate the treated limbs while in bed. Cold packs were applied to the lower limbs in the first 72 hours. The majority of patients was discharged on the day following the operation. The compression dressings were maintained until the first outpatient review on the third or fourth post-operative day. Thereafter, the patients wore gradient compression stockings (24–26 mmHg) for another 6 weeks. Reticular veins and telangiectasias were additionally treated by outpatient sclerotherapy and flashlamp pulsed dye lasers. All patients were seen and photographed at regular intervals in the outpatient clinic.

RESULTS

Of these 149 Patients, 122 patients (81%) of the study population were female. Ninety patients (58.5%) had a family history of varicose veins. The commonest presenting complaint was pain, with 70 patients (45.5%) affected. Examination revealed hyperpigmentation in 26 patients (16.9%), dermatitis in ten patients (6.5%), superficial phlebitis in four patients (2.6%), and stasis ulcers in two patients (1.3%). One hundred and three (69.1%) had bilateral varicose veins and 46 (30.9%) had unilateral disease. All were primary varicose veins of undetermined etiology. SFJ reflux and a patent deep venous system were evidenced on clinical and Duplex ultrasound examination. Every patient was at least a Class 2 according to the CEAP classification devised by the Consensus Group of the American Venous Forum [28]. Visible varices were found along the truncal GSV systems. Based on the Hach's score of severity, 38 legs (14.9%) were scored 4, 94 legs (37.3%) were scored 3, 109 legs (43.3%) were scored 2, and 11 legs (4.5%) were scored 1.

The mean follow-up period was 19 months with a range of 12–28 months. Improvement of post-operative complications was almost universal in our patients. One hundred and forty-one patients with 244 legs (96.8%) demonstrated eradication of their varices within 6 months ($P < 0.05$) (Fig. 2), please see Table 1. Six legs (2.4%) at the calf area and two legs (0.8%) at the ankle area developed recurrent varices. In the outpatient clinic, these remaining sites were treated by sclerotherapy using 10% hypertonic saline solution.

Fig. 2. **Left**: A 66-year-old male presented with severe varicose vein (Grade I) at right groin, medial thigh, and leg. **Right**: Complete resolution of his symptoms was demonstrated.

Complications were observed at 3 weeks (early) and at 6 months (late) after EVLP (Table 2). As expected, all patients developed post-operative swelling of the lower limbs. The commonest complication in early convalescence was local paraesthesia of treated areas in 92 legs (36.5%). This was followed by ecchymosis and dyschromia in 58 legs (23.0%), superficial burns in 12 legs (4.8%), superficial phlebitis in four legs (1.6%), and localized hematomas in two legs (0.8%). Most of these complications resolved spontaneously or with conservative measures. At 6 months post-operatively, local paraesthesia was found in only seven legs (2.8%). Only two legs (0.8%) presented persistent hyperpigmentation and six legs (2.4%) with burn injuries showed minimal scarring. In conclusion, 23 legs were still affected by these minor problems at 6 months post-operatively. These problems all disappeared completely within the 28 months study period (Table 2).

DISCUSSION

The objectives of treatment in varicose veins of the lower limbs are to relieve symptoms, improve appearance, to halt deterioration and spread of disease to other connected veins. These objectives can be achieved by addressing the

TABLE 1. The Score of Severity Before and After Endovenous Laser Photocoagulation in 149 Patients With 252 Affected Greater Saphenous Veins

	0 (%)	1 (%)	2 (%)	3 (%)	4 (%)	Total (%)
Pre-treatment	0 (0)	11 (4.5)	109 (43.3)	94 (37.3)	38 (14.9)	252 (100)
Post-treatment*	244 (96.8)	2 (0.8)	6 (2.4)	0 (0)	0 (0)	252 (100)

*These values were calculated at 6 months post-operatively. Please see Table 2 for the final outcome.
$P < 0.05$.

saphenofemoral reflux and the varicosities. The options include external compression, sclerotherapy, or surgery [10–14,16,17].

Graduated compression stockings can provide adequate external pressure at the SFJ to prevent reflux. Heaviness and aching of the lower limbs can be relieved, but these stockings are difficult to put on, unsightly, uncomfortable and must be worn for an entire lifetime [29]. Sclerotherapy cannot treat SFJ reflux but is most effective for the treatment of small-caliber varices (e.g., reticular veins, telangiectasias, and varicose veins from incompetent perforators). However, only a few physicians can claim good results for treating large varices with sclerotherapy. The well-established surgical choices are ambulatory phlebectomy, ligation, and stripping. Ambulatory phlebectomy by stab avulsion of varices enables the removal of most incompetent veins below the SFJ. Within 20 years of its introduction, saphenofemoral ligation performed alone has been shown to be inadequate in patients with SFJ reflux, resulting in an unacceptably high incidence (22–72%) of recurrent, or persistent, varicose veins [7,18]. Ligation and stripping of truncal varicose veins guarantee the elimination of axial reflux and also remove the varices. These surgical alternatives share a few annoying complications of dysesthesia from injury to saphenous and sural nerves, hematomas, and cutaneous hyperpigmentation [15].

When a laser is delivered to a target tissue, it may be reflected, transmitted, refracted, scattered, or absorbed. The immediate tissue effect is dependent on the thermal properties and absorption spectrum of the tissue, and the wavelength and energy of the laser. Common tissue effects include photocoagulation, photovaporization, and photodisruption [30]. These effects may be harnessed to achieve desired therapeutic effects. Cutaneous lasers are limited by poor tissue penetration and are ineffective against varicosities located within the superficial fascia. In addition, direct application through the skin may cause non-selective thermal injury.

Our method of intravenous photocoagulation delivers the Nd:YAG laser beam via a bare optic fiber into the varices. The optic fiber overcomes the difficulties of insufficient tissue penetration and skin burns by transmitting the laser beam directly into the varices. Nd:YAG laser pulses of 1,064 nm wavelength penetrate deeply (5–7 mm) into biological tissue [30]. The energy emitted by the laser radiates from the tip of the optic fiber causing tissue destruction. Tissue water is the major target chromophobe. The pulse mode is preferred to the continuous mode because it delivers energy in a more controlled and predictable fashion [31]. Microscopic examination of an untreated varicose vein revealed intimal fibroelastic thickening, hypertrophic circular smooth muscle, and loosely arranged longitudinal smooth muscle fibers (Fig. 3A). Immediately after EVLP with Nd:YAG laser, there is coagulative necrosis of the vessel and its surrounding tissues (Fig. 3B). EVLP probably affects intravascular thrombogenesis and photocoagulation of surrounding tissues, leading to thrombus blockade, ischemia, sclerosis, fibrosis, and ultimately the obliteration of the varices and their tributaries.

The excellent long-term results in our series compare favorably to those by other surgeons [32–36]. Harris is one example. He reported the use of radio-frequency ablation of the greater saphenous vein, without high ligation. In the long term follow-up study of this treatment, a 12%

TABLE 2. Post-Operative Complications of Endovenous Laser Photocoagulation in 149 Patients With 252 Affected Greater Saphenous Veins

Complications	Early (at 3 weeks) (%)	Late (at 6 months) (%)	Final outcome (12–28 months)
Swelling	252 (100)	0 (0)	0 (0)
Paraesthesia	92 (36.5)	7 (2.8)	0 (0)
Pigmentation	58 (23.0)	2 (0.8)	0 (0)
Superficial burns/ scarring	12 (4.8)	6 (2.4)	0 (0)
Superficial phlebitis	4 (1.6)	0 (0)	0 (0)
Hematoma	2 (0.8)	0 (0)	0 (0)
Recurrent varices	0 (0)	8 (3.2)	0 (0)

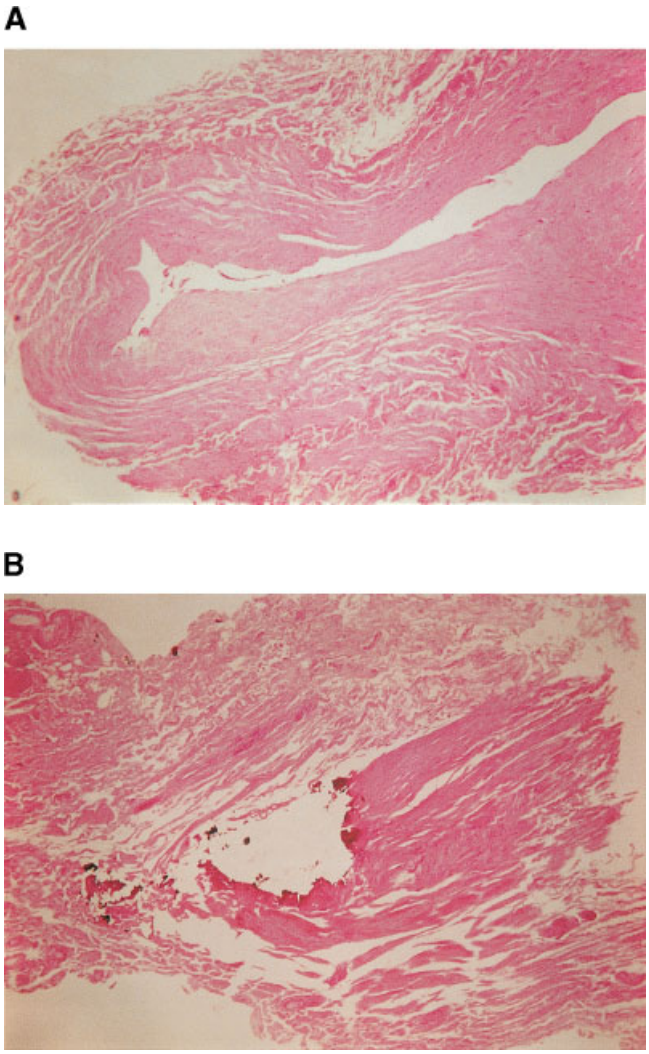

Fig. 3. **A**: Histopathological examination shows a strip of intimal fibro-elastic thickening and hypertrophic circular smooth muscle. The outer longitudinal muscle is loosely arranged (× 400). **B**: Following Nd:YAG laser treatment, histopathological examination shows obvious atrophic and necrotic changes of previous hypertrophic, thickened endothelium. The muscular layer shows coagulative degeneration and inflammatory cell infiltration in the connective tissue (× 400).

recanalization rate was reported [19]. In all our patients, we abolished the proximal SFJ reflux with ligation and eliminated the varices with EVLP. We believe this to be one of the reasons why EVLP reported no long term recanalization. Our principle is to always treat the proximal varices before distal telangiectasias, and to completely treat an entire vessel during a single session. Emptying the veins of blood before therapy may prevent excessive hematoma and subsequent hyperpigmentation. Application of compressive bandages on the operating table is also of paramount importance to prevent hematoma formation. Sustained compression is an important adjunct for successful outcome by reducing intravascular thrombus formation, encouraging fibrosis of the collapsed vessel, and preventing deep venous thrombosis. Keeping the patients ambulant also helps to avert deep venous thrombosis.

In the first 3 weeks after EVLP, local paraesthesia of treated areas occurred in 36.5%, ecchymosis in 23%, and superficial burns in 4.8% of the treated legs. There was no wound infection or deep venous thrombosis. Within 6 months, only 2.8% of the treated legs demonstrated local paraesthesia and 0.8% developed persistent hyperpigmentation. Within the follow-up period, all patients recovered completely. We believe that all these complications are caused by the direct thermal effects of laser treatment. Heat injury of the sensory nerve led to sensory impairment. Positioning the optic fiber too superficially probably caused burns of the overlying skin. Delivering too much laser energy too slowly might also be responsible. The temperature at the varices can be controlled by cooling with chilled water during the procedure and application of cold packs for the first 72 hours after EVLP.

EVLP is not without risks and disadvantages. (1) It is operator-dependent and has a steep initial learning curve. (2) Special and expensive equipment is needed. (3) Establishment of a setup requires specialized training of staff. (4) The laser is potentially hazardous. Safety regulations and precautions must be strictly followed.

With proper execution, EVLP is effective and has many potential benefits. (1) Apart from the two incisions made for ligation and for the insertion of the optic fiber, EVLP is a minimally invasive surgery, though it may also require small punctures to treat engorged branches. (2) EVLP involves minimal risk of injury to nerves and lymphatics. (3) There is little intra- and post-operative bleeding. (4) The surgeon can easily tailor the amount of treatment depending on severity. (5) The use of the pulse laser allows ease of control, and means that thermal damage is predictable. (6) The post-operative care is simple with little need of wound care. (7) Treatment of residual varices can be combined with other methods.

In conclusion, EVLP is a simple effective treatment modality for varicose veins. Further research is warranted. We propose three areas of prospective studies to further improve clinical outcomes: (1) To develop lasers with additional wavelengths and increased specificity for vascular lesions. (2) To design systems that allow bare fiber delivery of a variety of different wavelengths. (3) To conceive a more effective, sensitive, and responsive cooling system to be used in conjunction with laser delivery in order to avoid undesired side effects.

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