Laser Treatment of Superficial Leg Veins: A Review

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BACKGROUND Superficial leg veins affect millions of people worldwide, and treatment of these vessels is a common dermatologic request. The advance of lasers in recent years has led to numerous laser and light devices intended to treat these superficial vessels.

OBJECTIVE AND METHOD A review of the literature on the laser and light devices available for the treatment of superficial leg vessels with historical and recent trends is presented.

RESULTS AND CONCLUSIONS The appropriate choice of light system to treat telangiectases, venulectases, and reticular veins varies depending on anatomical, physiological, and biological differences in the vessels. Safe and efficacious treatment of superficial leg vessels can be achieved with multiple lasers by taking advantage of the oxyhemoglobin absorption peaks.

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Asymptomatic, but visible, small veins on the legs are a common cosmetic complaint and affect an estimated 41% of women and 15% of men.[1] Age, hormonal factors, occupation, and genetics all play a role in the development of visible leg veins. Although these vessels are primarily of cosmetic importance, more than half will become symptomatic.[2,3] Leg vein therapy is one of the most commonly requested cosmetic procedures.[4] For decades, sclerotherapy had been the criterion standard of treatment for leg veins smaller than 4 mm in diameter.[5] Although this technique is highly effective, it requires significant physician experience and typically a series of treatments spread out over several months. Because it may be slightly uncomfortable, it also requires a highly cooperative patient who has no phobia of needles. Sclerotherapy may also be associated with complications such as postinflammatory hyperpigmentation, telangiectatic matting, ulceration, and allergic reactions to the sclerosants.

As a consequence, there has been longstanding interest in finding an effective, noninvasive alternative to sclerotherapy that would provide equivalent efficacy with a higher level of safety and ease of performance for the laser surgeon. With the introduction of laser technology for the treatment of a variety of cutaneous vascular lesions, a variety of lasers have been employed, with different levels of success. This may, in part, be due to the fact that leg telangiectases differ from facial telangiectases in several ways. They are usually larger in diameter, their hemoglobin is not fully saturated, they are often situated deeper in the skin, they have thicker vessel walls as a result of stasis changes, they have high hydrostatic pressures, and the blood content of the surrounding dermis is different.[6,7] In addition, most leg vein ectasias are composed of a heterogeneous mix of vessels of different sizes and different flow rates.

Anatomy of the Lower Leg Vascular Network

The vascular network of the lower extremities is complex. Venous drainage occurs through a superficial cutaneous plexus and a deep muscular plexus. The superficial plexus of veins is found in the skin, superficial fascia, and subcutis and is composed of

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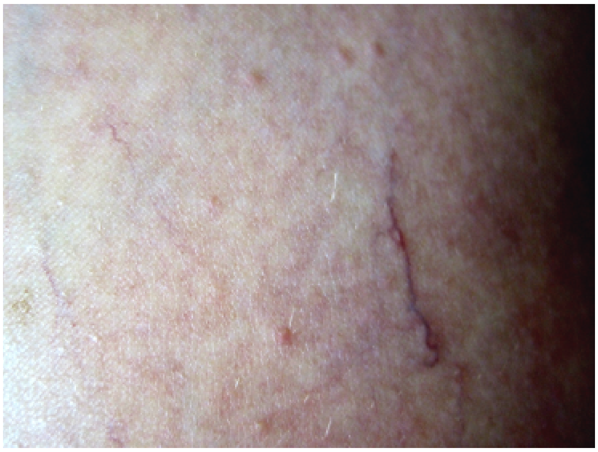

Figure 1. Telengiectasia.

small cutaneous vessels, or spider veins, that are less than 2 mm in size. These smaller vessels are divided into telangiectases, which are small, bright-red vessels up to 0.3 mm in diameter[8] (Figure 1), and venulectases (Figure 2), which are 0.4- to 2-mm red or blue vessels.[9] Perforating veins connect this superficial plexus to the deep venous system within the underlying muscle. Reticular veins are 2 to 4 mm in size (Figure 3) and are named for their location in the reticular dermis and subcutaneous fat. The veins of the lower extremities have one-way valves that direct the flow of venous blood upward and inward from the superficial to the deep venous system. Thus, the larger veins have a higher concentration of deoxygenated blood. Aging, genetics, hormones, pregnancy, upright posture, and trauma can contribute to failure of these one-way valves, resulting in leakage from deep veins to relatively lower-pressure superficial veins and the development of visible "spider" veins.[10] Varicose veins are the result of venous insufficiency and back flow and will not be covered in this review.

Figure 2. Venulectasia.

Figure 3. Reticular veins.

Use of Lasers and Light Sources for Treating Lower Leg Vessels

Indications for Lasers and Light Sources

Although sclerotherapy has long been considered the criterion standard for treating visible leg veins, laser technology has improved so rapidly that it can often provide near-equivalent results. Lasers are especially useful in treating superficial, fine vessels that are so small in caliber they cannot be cannulated even with the smallest of needles; telangiectatic matting, areas prone to ulceration, such as the ankle (Figure 4); patients with a history of poor response

Figure 4. Telangiectatic matting.

to sclerotherapy; patients who are allergic to sclerosing agents; and patients who cannot tolerate sclerotherapy because of needle phobia. Variations in vessel size, depth, and oxygenation may also influence the efficacy of laser leg vein therapy.

Absorption of Light by Blood Vessels

The green and yellow laser wavelengths correlate well with absorption peaks of hemoglobin but have limited penetration depth because of absorptive interference caused by melanin found in the epidermis and due to scattering of light by the dermis. Oxyhemoglobin has a broad absorption coefficient at near-infrared wavelengths from approximately 700 to 1,100 nm. Highly penetrating wavelengths in the near-infrared spectrum from approximately 700 to 1,200 nm have been shown to penetrate skin to 3 mm or more.[11] The longer wavelengths not only penetrate deeper in the skin, but also heat more uniformly, although wavelengths greater than 900 nm are less selectively absorbed by hemoglobin and may also be absorbed by intracellular and extracellular water.[10,12] Penetration of light at 1,064 nm into blood held in glass capillaries is on the order of 2 mm with 50% absorption.[11] This low absorption will result in the need to use higher energy to achieve effective blood heating and can lead to greater pain and greater risk of collateral damage.

Changes in Leg Veins After Laser Treatment and Complications

Typical end-points in laser leg vein treatment are immediate vessel disappearance, visible intravascular thrombosis, and rupture of the vessel causing immediate purpura. Microthrombi in the vessel lumen or perivascular extravasation of blood may also be immediately apparent from vessel rupture. Very short pulse durations ($<$20 ms) can cause purpura the size of the laser spot to develop. Leg veins ranging from 0.2 to 0.8 mm in diameter have thermal relaxation times of 20 to 300 ms,[13] so pulse durations of 40 to 60 ms provide optimal treatment parameters of spider leg veins, resulting in clinical elimination of the vessel, histologic vessel contraction, and hyalinized perivascular collagen formation.[13] Postinflammatory hyperpigmentation is the most common adverse effect after laser treatment of leg veins. This complication is more common in patients with darker skin types, in patients with significant sunlight exposure, in patients in whom insufficient proximal larger veins (feeder veins) are not treated before treating the distal veins, after use of shorter pulse durations ($<$20 ms), in patients who develop purpura from the rupture of blood vessels by the laser light or other light source, and in patients with vessels that develop thrombus formation after treatment.[13] The hyperpigmentation usually fades spontaneously over several months. Ulceration and subsequent scarring may also occur but typically only after use of inappropriately high energies, excessively long pulse durations, or inadequate epidermal cooling.

Successful treatment of superficial leg vessels with laser therapy is best achieved by first treating underlying venous insufficiency. In a study by Goldman and colleagues in which superficial telangiectases were treated using a pulsed dye laser (PDL), best results were seen in patients in whom no underlying feeder vessel was identified.[14] Dover and colleagues suggest the following rationale for a cost-effective, efficient, and rational approach to leg vessel treatment. First, varicosities, incompetent perforators, and reticular veins should be treated using endovascular means or sclerotherapy where appropriate. This should be follow by sclerotherapy of smaller vessels, leaving behind resistant, smaller-caliber vessels that are most likely to be amenable to laser therapy.[2] Venous insufficiency can be assessed using duplex ultrasonography of the saphenous vein. Proper assessment and treatment of venous insufficiency before laser treatment of leg vessels minimizes complications including postinflammatory hyperpigmentation and may lead to better long-term treatment outcomes.

Lasers and Light Sources Used to Treat Leg Veins

The current trend in laser leg vein treatment has been toward the use of longer wavelengths, which allow for deeper penetration and greater sparing of the epidermis. The most commonly used lasers to treat visible leg veins are the frequency-doubled and normal neodymium-dope yttrium aluminum garnet (Nd:YAG), PDL, potassium titanyl phosphate (KTP), alexandrite, diode, and intense pulsed light (IPL) lasers. These will be discussed individually (Table 1).

KTP Laser (Frequency-Doubled YAG)

The green light from the KTP laser comes from frequency doubling a Nd:YAG laser at 1,064 nm so that the light is emitted at a wavelength of 532 nm. This wavelength closely matches the second oxyhemoglobin absorption peak, but because the absorption of melanin in the epidermis causes absorptive interference, it does not penetrate as deeply as the PDL and thus is only effective for the treatment of superficial, small vessels less than 1 mm in diameter and less than 1 mm in depth from the skin surface. One study of 56 patients treated three times with the KTP laser using fluences of 15 to 16 J/cm^2, a pulse diameter of 10 ms, and three pulses per second resulted in complete clearance of veins smaller than 0.6 mm in 33% of patients. Vessels with larger diameters did not respond.[15]

Frequent pigmentary changes occur after KTP laser treatment, with hyperpigmentation occurring in 23% of one group of study patients. Another study using the KTP laser in multipulse mode (3 stacked pulses of 100-, 30-, and 30-ms duration with an interpulse delay of 250 ms) with a fluence of 60 J/

TABLE 1. Characteristics of Lasers/Light Sources Used to Treat Superficial Leg Vessels

Laser or light source	*Wavelength (nm)*	*Fluence (J/cm^2)*	*Pulse duration (ms)*	*Color emitted*	*Target chromophore*
Potassium titanyl phosphate	532	Up to 240	1–100	Green	Vascular, melanin, tattoo pigment
Pulsed dye laser	585–595	Up to 40	0.45–40	Yellow	Vascular
Alexandrite	755	Up to 100	3–100	Near infrared	Vascular, melanin, tattoo pigment
Diode	800	10–100	5–400	Infrared	Melanin, hemoglobin
Neodymium-doped yttrium aluminum garnet	1,064	5–900	0.25–500	Infrared	Hemoglobin, melanin and tattoo (Q-switched)
Intense pulsed light	400–1,200	10–80	2–200	Visible to near infrared	

cm^2, and spot size of 0.75 mm applied to 0.5- to 1-mm leg telangiectases resulted in 53% vessel clearance after one treatment, 78% vessel clearance after two treatments, and 93% vessel clearance after four treatments.[16] This technique resulted in 18% of patients developing hypopigmentation, but no hyperpigmentation was seen.

Spider veins smaller than 0.75 mm in diameter on the legs of 15 study patients were treated with frequency-doubled Nd:YAG at 532 nm, with 10-ms pulse duration, 16 J/cm^2 of fluence, and three passes over each visible vein.[17] Results showed clearance of more than 33% of veins after a single treatment and more than 75% of clearance after a second treatment 6 weeks later. Side effects included pain at the time of treatment, erythema, temporary edema after treatment, hyperpigmentation for 6 weeks after treatment, and two subjects reporting blisters at the treatment sites. When 46 patients with spider veins on the legs were treated using the frequency-doubled Nd:YAG laser at 532 nm with a pulse duration of 50 ms and fluences from 18 to 20 J/cm^2, 68% of veins smaller than 1 mm in diameter had greater than 75% clearance after two treatments,[18] whereas veins 1 to 2 mm in diameter demonstrated greater than 75% clearing in 44% after two treatments.

Pulsed Dye Laser

The original PDL was designed to deliver yellow light initially at a wavelength of 577 nm and then quickly changed to emit yellow light at 585 nm to selectively target the small, superficial blood vessels in port wine stains, but the pulse duration and shorter wavelength of this system proved ineffective in treating larger and deeper leg blood vessels. A subsequent generation of PDLs was designed to emit a longer 595-nm wavelength of orange–yellow light to permit deeper penetration to make it more effective for treating smaller spider leg veins than earlier models, but even this device had only limited efficacy in the treatment of leg veins larger than 1 mm in diameter.[19–21]

The newest PDL specifically designed for the treatment of leg veins uses an oval, 3- × 10-mm spot size to selectively target a longer segment of the small telangiectatic vessels and minimize collateral tissue damage. For leg vessels up to 1 mm in diameter, a fluence of 20 J/cm^2 showed significantly more effectiveness than 18 or 16 J/cm^2.[20] A combination approach using sclerotherapy for the larger-caliber vessels and PDL on the smaller vessels has also been effective.[22] Common side effects after PDL therapy include purpura and hyperpigmentation. Post-treatment hyperpigmentation is more common when higher fluences are used.[20,23–26] Cooling with hydrogel dressings to prevent this can produce a 35% reduction in transmitted energy.[20]

The next development in PDLs for treating vascular lesions was to lengthen the duration of the pulse. The long-pulse PDLs have been shown to clear leg blood vessels with diameters smaller than 0.5 mm,[21] but for vessels 0.5 to 1 mm, improvement, but not clearance, is achieved.[21] The newest generation of PDLs can deliver eight consecutive subpulses within each pulse, and the pulse can be stretched out over 40 ms. In a study of 35 sites of lower extremity spider veins larger than 1.5 mm, with an average fluence of 20.4 J/cm^2, a 3- × 10-mm spot size, and a pulse duration of 40 ms, 44% of patients obtained between 50% to 76% response after three treatments.[26] Purpura was seen in 19% to 31% of treatment sites, and hyperpigmentation was seen in 12 of the 35 sites. Kono's study[25] of long-pulse PDL using fluences from 10 to 20 J/cm^2 and pulse durations from 1.5 to 20 ms demonstrated complete clearance in all vessels smaller than 0.2 mm, but patients with larger (1.1 to 2 mm) vessels showed only 26% to 75% clearance. In a study of 20 patients with leg telangiectases with diameters from 0.1 to 1.2 mm in diameter, 80% of patients exhibited at least 75% clearance after a single treatment with the 595-nm PDL using the three-micropulse format, a pulse width of 40 ms and fluences from 14 to 16 J/cm^2 with up to three passes.[23] Transient purpura lasting less than 7 days was typical to obtain these results. Subpurpuric doses did not provide efficacious single-treatment clearance and 55% experienced hyperpigmentation. Twenty patients with leg vessels ranging from 0.63 to 1.07 mm were treated with the PDL at 595 nm and 1.5-ms pulse duration with fluences of 15 and 18 J/cm^2 and a 2- × 7-mm elliptical spot.[24] Results demonstrated greater than 50% clearance in 42.3% to 45.2% of patients at 6 weeks and 53% to 64.7% clearance at 5 months. Hyperpigmentation was noted in 30.8% of patients at 6 weeks of follow-up, but this had resolved spontaneously in all patients by 5 months.

In a comparative study of 10 patients with leg veins up to 1.0 mm in diameter, there was no statistically significant difference in the efficacy of the PDL at 25 J/cm^2 and pulse duration of 40 ms and the 532-nm frequency-doubled Nd:YAG laser at 20 J/cm^2 and 50 ms pulse duration.[27]

Alexandrite Laser

The alexandrite laser emits a near-infrared beam of light at 755 nm that has twice the photoabsorption by hemoglobin as the Nd:YAG laser at 1,064 nm but less hemoglobin absorption than lasers emitting light of 532 to 595 nm. However, the alexandrite has much deeper penetration than the shorter-wavelength lasers, and there is more-effective vessel heating per J/cm^2 than with the Nd:YAG laser at 1,064 nm. Most studies of alexandrite lasers have focused on the treatment of leg veins, with varying degrees of success. Medium-sized vessels respond better than vessels larger than 1.0 mm or those smaller than 0.3 mm, probably the result of inadequate heat generation in larger vessels or because the infrared wavelengths simply bypass the smaller vessels and have no interaction. Post-treatment purpura, hyperpigmentation, and telangiectatic matting are disadvantages of treatment with the alexandrite laser, especially at shorter pulse diameters, which have limited the use of the alexandrite laser in leg vein treatment.

The alexandrite laser penetrates tissue between 2 and 3 mm[6] and is only safe in treating nontanned skin and skin types I to III because melanin absorbs it significantly.[28] It is effective in treating blood vessels from 0.4 to 2 mm in diameter,[29,30] but to obtain maximal clearance, higher fluences (>50 J/cm^2) are needed.[6] McDaniel and colleagues[29] treated leg telangiectases three times using the 755-nm alexandrite laser with a fluence of 20 J/cm^2, a 5-ms pulse duration that was double pulsed, and a 10-mm spot size at a rate of 1 Hz. This resulted in 42% improvement in all treated blood vessels. The highest clearance rate was noted in medium-sized vessels (0.4–1 mm). Vessels smaller than 0.4 mm and larger than 1 mm in diameter responded poorly. Side effects included bruising, erythema, crusting, and hypopigmentation. Clearance rates greater than 75% occurred in 65% of patients with leg telangiectases smaller than 2 mm in diameter after one to three passes of the 755-nm alexandrite laser using an 8-mm spot, fluences between 60 and 80 J/cm^2, and a 3-ms pulse duration to the clinical endpoint of vessel disappearance or thrombus formation.[30] Hyperpigmentation persisted in 26% of sites after 12 weeks. Treatment of vessels smaller than 1 mm in diameter was associated with more pain.

Because the duration of the pulse may play a role in the incidence of side effects with the alexandrite laser, Ross and colleagues examined the effect of using longer pulse duration on complications and vessel clearance. The pulse duration was varied from 3 to 100 ms, and test sites were treated until the end points of persistent bluing and immediate stenosis of vessels had occurred. The test sites were evaluated 21 days later. Once the optimal settings (greatest clearance with minimal side effects) were identified, they were used to treat larger areas of similar-sized blood vessels. The optimal pulse duration for most patients was determined to be 60 ms, and clearance with this pulse duration approached 65% at week 12. Although the majority of previous alexandrite laser studies used pulse durations of 3 ms, Ross and colleagues suggested that increasing the pulse duration improved epidermal tolerance and decreased purpura while achieving acceptable levels of clearance.[31]

Combination therapy with sclerotherapy may also be beneficial for achieving clearance of refractory or recurrent blood vessels on the leg. McDaniel and colleagues[29] combined alexandrite laser treatment and sclerotherapy, obtaining an 87% reduction in leg telangiectases when 23.4% hypertonic saline sclerotherapy was performed 3 to 7 days after alexandrite laser therapy was used at a fluence of 20 J/cm^2 and a pulse duration of 5 ms.

Diode Lasers

Multiple diode lasers are now available, and different systems can emit infrared light at a variety of wavelengths, including 800, 810, 940, and 980 nm. All of these devices are capable of being absorbed by the tertiary hemoglobin peak and can be effective in treating leg telangiectases. The longer diode laser wavelengths penetrate more deeply than yellow light and are poorly absorbed by melanin, but they also have limited but significant hemoglobin absorption. For that reason, the 980-nm diode laser can be safely used in patients with skin types I to IV skin.[28]

The 800-nm diode can also be used to provide effective treatment of leg blood vessels by using stacked pulses (5–8 stacked pulses), a 50-ms pulse duration, a 3-mm spot size, and fluences of 210 to 336 J/cm^2. Using up to three separate treatments, it was possible to achieve 50% to 74% improvement in 60% of patients (6/10).[32]

The 810-nm pulsed diode used with a fluence of 80 to 100 J/cm^2, a 12-mm spot size, and a 60-ms pulse duration demonstrated complete clearance of leg vessels in 15 of 35 patients after a single treatment,[33] although at 6-month follow-up, only six patients maintained complete resolution of vessels.

The 940-nm-diode laser had no effect when used to treat small blood vessels but was capable of improving larger visible leg veins of 0.8 to 1.4 mm in 88% of patients in one study.[34] Twelve of 26 patients treated with the 940-nm diode laser at fluences of 300 to 350 J/cm^2, 40- to 70-ms pulse durations, and a 1-mm handpiece demonstrated greater than 75% clearance after 4 weeks.[35] A study of 20 patients treated with a single pass of the 940-nm diode laser at 300 to 350 J/cm^2, 40 to 70-ms pulse duration, and a 1-mm spot achieved greater than 75% clearance of treated blood vessels in 75% of patients at 12 months of follow-up.[36]

A study of the 980-nm diode used to treat blue leg telangiectases achieved greater than 50% clearance of treated blood vessels in five of 10 patients.[37] One patient developed post-treatment hypopigmentation, and one developed telangiectatic matting. By combining 980-nm diode pulses with radiofrequency current, lower fluences of 60 J/cm^2 could be used for effective vessel clearance (50% of patients achieved greater than 75% clearance rate at 6 months), which may decrease the side-effect profile.[38] Biopsies showed contracted vessels with hyalinization, suggesting that the combined diode and radiofrequency current therapy is an effective treatment for leg veins. Combining the 915-nm diode with radiofrequency current demonstrated greater than 50% vessel clearance in 75% of patients.[39]

Nd:YAG Laser (at 1,064 nm)

Promising results for the treatment of leg veins are now being achieved with the use of the near-infrared 1,064-nm, Nd:YAG laser.[12,28,40] As with the other near-infrared lasers, hemoglobin is the target because of its broad absorption spectrum of 700 to 1,100 nm. Although the light absorption of hemoglobin at 1,064 nm is low, it is still approximately 10 times as high as the light absorption of water, which is the major absorber in the dermis at this wavelength.[41] Although selective photothermolysis is applied for treatment of vascular lasers at this wavelength, the selectivity and precision is much less than that seen at the 585-nm wavelength. The advantages of the Nd:YAG laser over the alexandrite and diode lasers is that deeper penetration is possible and there is less absorption interference caused by melanin.[42]

At the 1,064-nm wavelength of the Nd:YAG, the absorption of light in oxyhemoglobin decreases up to a factor of 100 in comparison to pulsed dye lasers.[41] Because of less scattering, deeper penetration, and the low absorption coefficient of oxyhemoglobin at 1,064 nm, there is no gradient of light energy inside large vessels, and the homogeneous distribution of intravascular photons leads to uniform heating of the whole vessel, even for larger vessels (up to 3 mm).[7,41,43] In comparison, at 532 nm, only the vessel circumference is heated with treatment.[43] The lower absorption coefficient of blood at 1,064 nm also requires use of higher energies, which result in greater risk of overheating the vessels and causing collateral damage to the surrounding dermis. The high temperature in the dermis results from heat transfer of excess thermal energy from the targeted larger vessel, as well as direct heating of the dermis derived from the targeted vessels.

When the vessels reach a core temperature of approximately 70°C, methemoglobin (Met-Hb) is formed, and the absorption coefficient of Met-Hb is approximately three times as high as that of oxyhemoglobin at 1,064 nm.[41] At fluences higher than 100 J/cm^2, the temperature difference between the vessel and the dermis is similar for large and small vessels, although the ratio of surface area to vessel volume is much smaller for larger vessels. Therefore, the heat flow from the hot vessel into the dermis needs much longer to cool a large vessel than a small vessel. Thus, in a large vessel, the elevated temperature will remain above the critical temperature of 70°C for a longer period of time than in a small vessel. Consequently, the effectiveness of leg vein coagulation increases with vessel size, which explains why the Nd:YAG laser is more efficacious in the treatment of larger leg veins. The low absorption of oxyhemoglobin at 1,064 nm, together with the small number of light-absorbing erythrocytes in small vessels, contributes to the lower efficacy of this wavelength for small vessels. Increasing fluence in attempts to achieve coagulation of these smaller vessels increases the risk of side effects. It is for that reason that Bäumler and colleagues[41] suggest using a pulsed dye laser, if available, for leg veins smaller than 0.7 mm in diameter.

Theoretically, the laser spot size should be as large as possible, to minimize scatter and maximize beam penetration, but because the 1,064-nm laser already penetrates deeply, there is no reason for the beam diameter to exceed the vessel diameter by more than 0.5 mm. Moreover, use of larger spot sizes leads to greater pain and greater risk of overheating and ulceration. Bäumler and colleagues[41] recommended using a spot size approximately 25% larger than the maximum vessel size being treated. The smaller spot size yields higher efficiency because less energy is used at equal fluence.

The energy fluence should be chosen to achieve the end point of immediate vessel disappearance (stenosis) or bluing (thrombosis).[7] Lower fluences (100 to 200 J/cm^2) and longer pulse durations are more efficacious for larger vessels (1.5 to 3 mm), whereas higher fluences (250 to 400 J/cm^2) and shorter pulse durations are better for treating vessels smaller than 0.5 mm.[44] Longer pulses may provide gentler heating of the vessel and superior vessel elimination of leg veins 0.1 to 1.6 mm in diameter.[13] Longer pulse durations are also associated with less purpura, edema, and hyperpigmentation.[7] Pulse durations in the 20- to 60-ms range seem to be the most effective with the fewest side effects.[7] Treatment of larger-caliber vessels using the 1,064-nm Nd:YAG may cause more discomfort because of the volumetric heating of tissue.

In one study of 20 patients with 1- to 3-mm reticular veins, a single treatment using a 1,064-nm Nd:YAG laser at a fluence of 100 J/cm^2 and a 50-ms pulse duration resulted in greater than 75% clearance in two-thirds of the treated vessels.[45] Another study reported treating red and blue telangiectatic vessels with the Nd:YAG at 1,064 nm with a 1.5- to 3-mm spot size, fluences ranging from 250 to 600 J/cm^2, and a 30- to 60-ms pulse duration.[46] At 6-month follow-up, 80% of patients had greater than 75% clearing. Two treatments with the 1,064-nm Nd:YAG at fluences of 90 to 187 J/cm^2 and pulse durations of 10 to 50 ms to 21 different sites of 0.25- to 4-mm blue and red vessels resulted in significant improvement in 71% of sites.[47] Blue vessels demonstrated a more-dramatic result than red vessels, and larger vessels of 2.1 to 4.0 mm were more successfully cleared than smaller vessels of 0.25 to 1.0 mm. Hyperpigmentation was present at 62% of treated sites at the 3-month follow-up visit and was most significant at sites where blue vessels or larger vessels of 2.1 to 4.0 mm had been treated. The 3- to 4-mm blue reticular veins responded to the lowest fluences of 90 to 100 J/cm^2 at 40- to 50-ms pulse durations, whereas the smallest vessels consisting of 0.25-mm red telangiectases required fluences greater than 140 J/cm^2 and 10- to 15-ms pulse durations.

A multipulse Nd:YAG laser system composed of an initial high-energy pulse that was 60% of the total fluence, followed by two lower-energy pulses that contained 20% of total fluence per pulse and a total fluence of 300 to 360 J/cm^2, resulted in 55% vessel clearance after one treatment and 98% clearance after three treatments.[48] Weiss and Weiss[12] studied treatment of 50 lower extremity sites on 30 subjects with a multiple synchronized pulsed 1,064-nm Nd:YAG laser. Vessels 1 to 3 mm in diameter were treated using a single 14- to 16-ms pulse and fluence of 110 to 130 J/cm^2. Vessels 0.6 to 1 mm in diameter were treated using a double synchronized pulse of 7 ms separated by a 20- to 30-ms pause and a fluence of 90 to 120 J/cm^2 or a single pulse of 10 ms at a fluence of 100 to 110 J/cm^2. Vessels 0.3 to 0.6 mm were treated using a triple synchronized pulse of 3 to 4 ms and a fluence of 80 to 110 J/cm^2. Using these parameters, the majority of sites were improved by 75% at 3-month follow-up. Immediate bruising associated with vessel rupture occurred in 50% of treatment sites, and hyperpigmentation was seen in 42%. Sadick[40] treated 25 patients in up to three treatment sessions using the 1,064-nm Nd:YAG laser and a double pulse of 7 ms at 120 J/cm^2 for vessels 0.2 to 2 mm in diameter and a single pulse of 14 ms at 130 J/cm^2 for vessels 2 to 4 mm in diameter. At 1-year follow-up, 64% of patients maintained greater than 75% clearing of vessels after a maximum of three treatment sessions. In a comparative study, the long-pulse 1,064-nm Nd:YAG laser was found to be superior to the long-pulse 755-nm alexandrite and 810-nm diode laser in the treatment of 0.3- to 3-mm leg veins,[28] although the Nd:YAG was also associated with more discomfort than the other two lasers.

Initial studies comparing the long-pulse 1,064-nm Nd:YAG laser with standard sclerotherapy found it to be inferior,[3] but more recent studies have shown it to be equivalent.[37,45] Twenty patients with superficial leg telangiectases 0.1 to 1.5 mm in diameter were given two treatments to one leg using the 1,064-nm Nd:YAG at 125 to 150 J/cm^2 using a 5.5-mm spot size and a pulse duration of 25 to 50 ms and two treatments of sodium tetradecyl sulfate sclerotherapy on the other leg.[3] This study showed earlier vessel clearance and higher average improvement scores in the sclerotherapy-treated leg. In another study of 14 patients with leg telangiectases ranging from 0.5 to 2 mm, one site was treated using long-pulse 980-nm Nd:YAG, a second site was treated using sclerotherapy, a third site was treated using laser followed by sclerotherapy 3 weeks later, and a fourth site was treated using sclerotherapy followed by laser 3 weeks later.[49] Laser settings included a fluence of 100 to 125 J/cm^2, a pulse duration of 10 ms, and a 2.5-mm spot size. There were no significant differences between the four sites. In a study of 20 patients with leg veins ranging from 0.25 to 3 mm, one site was treated using sodium tetradecyl sulfate sclerotherapy, and a second site was treated using a Nd:YAG laser at a fluence of 130 to 190 J/cm^2, pulse duration of 50 to 100 ms, and a 3- or 5-mm spot size.[45] Nine of the 20 patients received a second laser treatment at 8 weeks. Results in clearance were similar, but 45% of patients preferred sclerotherapy because of the greater discomfort associated with laser treatment, and 35% of patients preferred the laser treatment because of better vessel clearance and lack of hyperpigmentation.

Intense Pulsed Light (515–1,200 nm)

IPL systems emit multiple wavelengths of light ranging from 515 to 1,200 nm. Each wavelength is emitted with a different intensity, and filters can be used to target certain wavelengths. Shorter wavelengths can be used to heat smaller vessels 0.6 to 1.5 mm in size, and longer wavelengths are better at heating larger vessels 3 to 5 mm in size.[50] In theory, combining shorter and longer wavelengths could be used to treat variously sized vessels occurring at the same treatment site, but smaller vessels seem to respond better to IPL, with a reported 90% clearance rate in vessels from 0.2 to 1 mm in diameter.[51] IPL devices are commonly used with 550- to 570-nm filters to deliver primarily yellow and red light, with a minor component of near-infrared light.[52] The main advantages of IPL devices are the large spot sizes and minimal purpura.[53] The most common side effects are erythema, edema, and a mild burning sensation. High fluences and shorter pulse durations can result in erythema, burning discomfort, purpura, dyspigmentation, and scarring.

In a multicenter IPL study of 159 patients, a 90% clearance rate was seen in vessels smaller than 0.2 mm and an 80% clearance rate in vessels from 0.2 to 1 mm in diameter.[54] In another multicenter study of 40 patients, a 92% clearance rate with vessels smaller than 0.2 mm and an 80% clearance rate with vessels from 0.2 to 1 mm was reported.[54] Fifty patients with leg veins 0.1 to 4 mm in diameter were treated using a combined approach with a Nd:YAG laser and IPL device.[10] IPL with wavelength of 550 nm, a cutoff filter, and a fluence of 40 J/cm^2 was used to treat vessels smaller than 1 mm in diameter, and a 1,064-nm Nd:YAG with fluence of 140 J/cm^2 was used to treat vessels 1 to 4 mm in diameter. An average of 2.5 sessions produced greater than 75% clearing in 80% of patients.

Conclusions

Laser surgery is one of the most rapidly advancing fields in medicine. The laser surgeon can now choose from a variety of different laser and light sources that can be used for the treatment of leg telangiectases. Each system has its own unique advantages and disadvantages, and the surgeon must understand these important differences to obtain the best results. The KTP, Nd:YAG, PDL, and diode lasers and IPL have become the standards in the treatment of leg telangiectases because of their superior clinical efficacy and extraordinary patient safety record (Table 2). Because laser technology continues to evolve, further enhancements are certain to lead to the desired the goals of achieving rapid blood vessel clearance with minimal side effects. Currently, there is no single laser or light source that can predictably treat all telangiectases with equal efficacy and a low risk profile.

Development of highly effective and safe laser applications for leg vessels has lagged behind that for facial telangiectases because of the many anatomic and physiologic differences between telangiectatic vessels of the face and legs. Advancements in producing lasers and other light sources with longer wavelengths, longer pulse durations, and better dynamic cooling devices will further improve the efficacy of laser treatment of leg vessels. Although most practitioners still use sclerotherapy as a mainstay for treating larger and deeper visible leg vessels, many are now incorporating laser devices into their treatment of many leg vessel disorders, such as fine, superficial telangiectases, which do not generally respond well to treatment with sclerotherapy; primary telangiectatic matting; telangiectatic matting secondary to sclerotherapy; vessels below the ankle prone, which are prone to ulceration with sclerotherapy; patients with a history of poor response to sclerotherapy; patients who have had adverse reactions to sclerosants; and patients with needle phobias.

The optimum laser or light source for treating visible leg vessels depends entirely on the type of vessel being treated. Generally, the 1,064-nm Nd:YAG laser is a popular choice because it works best for vessels up to 3 mm in diameter and is safe with most

TABLE 2. Laser and Settings Achieving Greater than 50% Clearance with One Treatment

Laser	*Fluence, J/cm²*	*Spot size, mm*	*Pulse duration, ms*	*Vessel size, mm*	*Comments*	*Authors*
532-nm potassium titanyl phosphate	60	0.75	3 stacked pulses: 100, 30, 30 with 250-ms interpulse delay	0.5–1.0	Multipulse mode	Fournier et al.
595-nm PDL	14–16	Not reported	40	0.1–1.2	Purpuric doses required	Tanghetti et al.
595-nm PDL	15 & 17	2 × 7 elliptical	1.5	0.635–1.067		Hsia et al.
755-nm alexandrite	85–180	3–6	3–100	0.2–1	60-ms optimal pulse duration	Ross et al.
755-nm alexandrite	60–80	8	3	< 2	More pain with vessels > 1 mm	Kauvar et al.
940-nm diode	300–350 815	1 0.5	40–70 50	Blue and red telangiectasias < 1	75% clearance achieved with 815 J/cm settings	Kaudewitz et al.
1,064-nm neodymium-doped yttrium aluminum garnet	100	Not reported	50	1–3		Omura et al.
	250–600	1.5–3	30–60	Blue and red telangiectasias		Sadik et al.
	300–360	2	3–3.5 pulses with 250-ms interpulse delay	1–2	Multipulse system: first pulse 60% of total fluence, second 2 pulses each 20% of total fluence	Mordon et al.
	110–130	Not reported	14–16	1–3		Weiss et al.
	90–120 110	Not reported	7 10	0.6–1	Double synchronized pulse of 7 ms separated by 30- or 10-ms pulse	Weiss et al.
	80–110	Not reported	3–4	0.3–0.6	Triple synchronized pulse	Weiss et al.

skin types. Discomfort is common when treating leg veins larger than 1.5 mm with any of the lasers or light sources. In addition, successful long-term treatment of spider veins of the legs requires the elimination of the feeder veins. Therefore, a combination of sclerotherapy for veins greater than 1.5 mm in diameter and feeder veins and laser treatment for all other spider leg veins may provide the best results. Medium-sized blue veins around the ankles may respond better to treatment with the alexandrite laser, which is much less painful than the Nd:YAG laser in this area. Small telangiectases in fair skin can be eliminated using a long-pulse PDL (Table 2). When larger veins are treated, many physicians advise use of compression stockings for 2 weeks after treatment to improve results and reduce the risk of transient hyperpigmentation, although use of compression after laser treatment of superficial leg veins is not common practice. Laser and light therapy is promising as a primary or adjunctive therapy for leg telangiectasias. Given that multiple treatments may be necessary to achieve total clearance and that side effects are common, a thorough knowledge of the various devices and their risks, benefits, and associated complications is an absolute requirement before beginning treatment of patients. In addition, before commencing treatment, a thorough discussion with patients seeking treatment for their visible leg vessels about their treatment options, as well as their expectations, is vital to obtaining the best possible results.

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