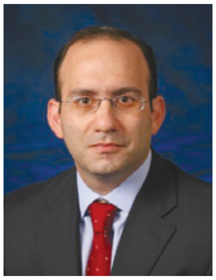

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LASER THERAPY FOR THE TREATMENT OF TELANGIECTASIAS AND RETICULAR VEINS IN THE LOWER EXTREMITY

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Introduction: Principles of Laser Therapy

The term *laser* is an acronym for light amplification by stimulated emission of radiation. A typical laser emits light in a narrow, low-divergence monochromatic beam with a well-defined wavelength. Therapeutic effects are the result of a combination of unique laser properties and complex laser/tissue interactions. For a clinical effect to take place, laser light must be absorbed by chromophores such as water, melanin, and oxyhemoglobin in the case of vascular lesions. Each chromophore preferentially absorbs a specific wavelength of the laser light. When laser light is absorbed by the target chromophores, it has a photochemical, photothermal, and photomechanical effect[1] on tissues.

The output energy of the laser is referred to as the energy density or fluence and is measured in joules/centimeter squared (J/cm^2). The depth of penetration of the laser light depends on its wavelength. Increasing the wavelength will lead to an increase in the depth of penetration and a decrease in scattering, which is more prevalent in the dermis due to its high collagen content. Thermal destruction of a target lesion can be achieved without damage of the surrounding normal tissue.[2] To achieve selective photothermolysis, three basic elements must be considered: 1) selection of a wavelength of light that is preferentially absorbed by the intended tissue target, which in the case of vascular lesions is oxyhemoglobin; 2) the pulse duration of the laser, or the exposure time of the tissue to the laser energy, must be shorter than or equal to the chromophore's thermal relaxation time (defined as the time required for the targeted site to cool to one-half of its peak temperature immediately after laser irradiation); and 3) the energy density delivered by the laser must be sufficient to irreversibly damage the target within the allotted time.[3] In this manner, the laser parameters can be adjusted to target specific vascular lesions, leading to their maximal destruction with minimal damage to the surrounding tissues.

The need for epidermal protection to avoid collateral damage to basal keratinocytes prompted the development of epidermal cooling devices.[4, 5] Selective cooling of the epidermis has been shown to minimize epidermal injury and can be achieved by using various systems. Chill tips, cooled glass chambers, sapphire windows, cold sprays or halogenized hydrocarbons, liquid nitrogen, and the pulsed delivery of cryogen spray have been employed to increase the safety profile of commercially available laser devices approved for the treatment of vascular lesions.[2, 6]

In dermatologic laser therapy, the use of cold air in analgesia can be considered as effective and inexpensive as current treatment alternatives. Raulin and colleagues[7] showed that 86 to 97% of patients preferred the cold air analgesia. The analgesic effect was 37% better than cooling with ice gel. The authors also showed that due to the increased thermal protection of the epidermis, they were able to use higher energy levels and reduce the rate of erythema, purpura, and crusting. Similarly, Greve and associates[8] showed that purpura, erythema, edema, and pigmentation were much less marked in the air-cooled areas. In their report, 69% of patients felt that the laser impulses accompanied by cold air were significantly less painful. The authors conclude that cold air is a safe, effective, economical, and environmentally friendly alternative to a cryogen spray cooling system.

Types of Lasers Used in Superficial Peripheral Vascular Lesions

When choosing a laser for treating vascular lesions, the following determinants need to be considered: vessel depth and diameter, laser wavelength, pulse width, and, to a limited extent, spot size.[9] The 488 and 514 nm wavelength Argon laser carries with it a risk of scarring and dyspigmentation[6] due to nonspecific thermal injury resulting from a pulse duration that is longer than the thermal relaxation time of vessels.[10-11] Argon-pumped tunable dye (APTD),[12-13] Krypton,[14] copper vapor/bromide,[15-16] and KTP[17-18] lasers were all used in treatment of facial telangiectasias, but they delivered pulses as short as 20 ms. This pulse duration did not provide enough time for target vessels to cool and may have lead to complications similar to those associated with the Argon laser.

The first laser that was specifically developed for selective photothermolysis of vascular lesions was the flashlamp-pumped pulsed dye laser (PDL).[19] With a pulse duration of 450 µs, it can target small- to medium-sized vessels. Initially the laser utilized a 577 nm wavelength,[20-21] but this was later increased to 585 nm to reach deeper lesions and simultaneously increase vascular specificity.[22-23] Initially, PDL was used to treat vascular lesions in non-dark-skinned patients,[24] but several studies have proved the lack of side effects when used on dark-skinned patients.[25-26] PDL energy density ranges between 3-10 J/cm^2, and spot sizes of 2-10 mm are used. Depending on the patient's age and the site of the lesion, the fluence and spot size can be adjusted. For example, in delicate tissue areas, lower fluence is used. Additionally, fluence should be lowered by 10-20% when PDL is applied to areas with higher risk of textural change, such as the neck and anterior chest. Deeper and larger caliber vessels such as those in the leg veins may require larger spot sizes. Areas with increased pilosebaceous units and thicker skin may need additional treatment sessions.[31] Recently, PDL systems with longer wavelengths (590, 595, and 600 nm) and extended pulse duration (1.5–40 ms)[27-28] are being used to target deeper vascular lesions.

Purpura is the most apparent side effect following PDL treatment and may remain clinically apparent for 2-14 days. Long-term complications include hyperpigmentation, atrophic scarring, hypopigmentation, and hypertrophic scarring. However, most of these changes are only focal and predominantly transient. Darker skin increases the risk of complications and decreases the depth of penetration, because the energy of the PDL is absorbed by melanin. However, patients with darker skin (Fitzpatrick V) should not necessarily be excluded from treatment, provided that treatment expectations and risks are fully appreciated.[29]

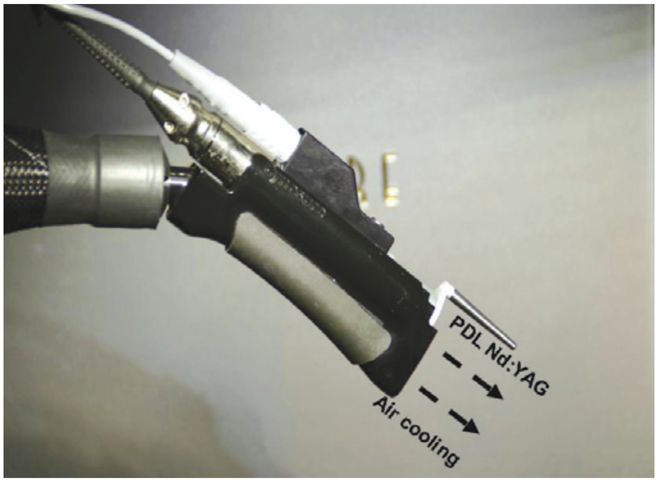

Figure 1. Device hand-piece that combines a PDL with a 1064 nm Nd:YAG laser and an air cooling system.

Intense pulsed light (IPL), a noncoherent light source with wavelengths ranging from 500-1200 nm, has been used to treat vascular lesions such as port wine stain (PWS), facial telangiectasias, and hemangiomas.[30-31] Filters are used to remove shorter wavelengths, creating a concentrated light beam with better dermal penetration and less absorption by epidermal melanin. IPL gives single, double or triple light pulses, with each pulse lasting from 2-25 ms and the delay between each pulse ranging from 10-500 ms. This provides what is called "additive healing" and leads to better results when treating deeper vascular lesions.[1]

The Nd-YAG laser has shown favorable results by investigators in the treatment of telangiectasias.[22, 23, 24] Limitations arise when it is used in dark-skinned patients. The Nd-YAG laser, with a wavelength of 1064 nm and a pulse duration of up to 200 ms, was developed to treat leg veins with a diameter up to 3 mm.[33-34] A study by Weiss and Weiss[48] showed 75% resolution of leg telengiectasias 3 months after treatment with a Nd-YAG laser when using a fluence ranging between 130-140 J/cm^2 and a pulse duration of 16 ms.

The PDL-595 and the Nd:YAG-1064 lasers are well known for their effectiveness in the treatment of vascular lesions. Nd:YAG is superior in treating 1-3 mm veins but can be painful, and side effects from over-treatment can easily occur. The PDL is the treatment of choice for veins <600 µm in diameter but not deeper than 1 mm. Its side effect is usually purpura, typically lasting approximately 7-14 days.

Recently, the introduction of a combined laser platform (Cynergy with Multiplex, Cynosure, Westford, MA) has allowed the 595 nm PDL and 1064 nm Nd:YAG wavelengths to be emitted sequentially from the same hand piece. In this application, the PDL is used to "pre-heat" the blood to approximately 70° C. This converts a percentage of the oxyhemoglobin to methemoglobin, which has a 4- to 7-fold greater absorption of the Nd:YAG 1064 nm wavelength than the hemoglobin. This means that less fluence is needed to be effective, resulting in fewer side effects for the same depth of penetration. Taken together with vessel depth, diameter, and location, the blood flow rate is an important factor in determining the delay needed between delivery of the 595 nm and the 1064 nm laser light. In a randomized controlled trial, Karsai and colleagues[35] compared the efficacy of this dual laser therapy and the use of a single wavelength laser in treating facial telangiectasias. The trial demonstrated significant therapeutic effectiveness of the dual wavelength laser treatment when compared to the use of a single wavelength laser (either the Nd:YAG or the PDL). The highest rate of clearance (90%) was achieved in almost half of the sites treated with the dual wavelength laser, whereas not one site treated with either of the single wavelengths showed similar results. The only adverse effects related to treatment were transient purpura and post-treatment erythema.

Treatment of Telangiectasias or Reticular Veins in the Lower Extremity

The most common leg vein anomalies include spider veins, reticular veins, and varicose veins arising within the system of the greater and smaller saphenous veins. Laser treatment of leg veins is difficult because of the wide range of vein size and depth, the wide range of blood flow rates, and the many different types of leg vein ectasias. An appropriate work-up should be performed before considering treatment options. If deep venous disease is present, this should ideally be treated first, as this often causes regression of the superficial veins. In the presence of venous reflux disease, endovenous laser treatment, or endovenous radiofrequency ablation may also clear a significant portion of the more superficial and reticular veins, and these procedures should have priority before considering the selective treatment of superficial spider veins alone.[9] In the absence of deep venous insufficiency, sclerotherapy remains the treatment of choice for superficial spider veins and small reticular veins. Some of the side effects of sclerotherapy include needle or puncture site bleeding, post sclerosis pigmentation, and telangiectatic matting.

In recent years, more patients are demanding effective alternatives to sclerotherapy. Laser therapy has emerged as a viable and effective treatment option, especially in patients with needle phobias. Visible light devices targeting the oxyhemoglobin absorption peaks may be acceptable for treating very superficial telangiectasias on the legs. These laser and light devices are the KTP laser, the PDL, the Nd:YAG, the long-pulsed alexandrite laser, and IPL devices with various filters to emit wavelengths that selectively target the oxyhemoglobin peaks. When treating leg veins, these visible light devices may work on superficial vessels but are limited by their shallow depth of penetration and high risk for pigmentary complications. Of these devices, the 595 nm PDL has been used with the greatest success.[36]

Hsia and associates[37] have demonstrated that long-pulse PDL may have utility in treating leg telangiectasias. They treated 20 patients using PDL at 595 nm and 1.5 ms. Vessel diameters ranging from 0.635 to 1.067 mm were treated using energy densities of 15 and 18 J/cm^2 and a 2 x 7 mm elliptical spot size. Clearance of telangiectasias and complications were scored at 6 weeks and 5 months following the single treatment and showed a >50% clearance by 6 weeks in 42.3% and 45.2% of patients using 15 J/cm^2 and 18 J/cm^2 energy fluences, respectively. By 5 months, >50% clearance was noted in 53.0% and 64.7% of patients using 15 J/cm^2 and18 J/cm^2 fluences, respectively. Complications were minor and infrequent.

Kono and colleagues[38] evaluated the efficacy and complications of 595 nm wavelength long PDL in the treatment of leg veins. Fourteen patients with 38 lesions were enrolled and treated using a long-wavelength PDL equipped with a cryogen spray cooling device. Variable pulse durations ranging from 1.5 to 20 ms and energy fluences from 10 to 20 J/cm^2 were utilized depending on the size of the treated vessels. Patients with vein diameters <1 mm had complete clearing, while patients with vein diameters between 1 and 2 mm still showed an excellent response. Hyperpigmentation was the only observed complication, lasting several months in 57.9% of the treated sites.

Long-wavelength near-infrared (IR) lasers allow deeper penetration into the tissues and may even be used to target deeper reticular veins. Oxyhemoglobin has an increase in its absorption coefficient at near-IR wavelengths between 800 to 1,100 nm. Longer wavelengths also heat more uniformly than the shorter wavelengths with higher absorption coefficients. One such near-IR laser that has been used to treat leg veins is the 1,064 nm Nd:YAG.[51] Sadick[39] evaluated the efficacy of a high-power 50 ms 1,064 Nd:YAG laser in the treatment of lower extremity veins between 0.2 and 3 mm in diameter that had received up to three treatment sessions. By varying spot size, fluence, and pulse duration, 80% of patients achieved greater than 75% clearing and were highly satisfied with the treatment results at 6 months.

Parlette and associates[40] conducted a study to determine an optimal pulse duration for clearance of leg veins using the Nd:YAG laser. They tested a range of pulse durations (3-100 ms) and showed that in comparison to shorter pulses (<20 ms), longer pulses may result in gentler heating of the vessel and a greater ratio of contraction to thrombosis. They postulated that this was due to the fluence thresholds for immediate vessel changes, which vary depending on spot size and vessel diameter, with larger fluences required for smaller spot sizes and smaller vessels. Shorter pulse durations (20 ms) were also associated with occasional spot-sized purpura and spot-sized post-inflammatory hyperpigmentation. Longer pulse durations (40-60 ms) achieved superior vessel elimination with less post-inflammatory hyperpigmentation. With a single laser treatment, 71% of the treated vessels were cleared.

Effective amelioration can be achieved with one or two treatments using new technology that combines PDL with a high-powered 1064 nm Nd:YAG laser and an air cooling system (Figure 1). The PDL light is utilized first because blood has an approximately 50-fold greater absorbance of the 585 nm than at the 1064 nm wavelength emitted from the Nd:YAG laser. Therefore, less energy is necessary to heat the blood and convert hemoglobin to methemoglobin. This conversion in turns allows a reduction in the Nd:YAG fluence requirement because the methemoglobin isoform and thrombus absorb the 1,064 nm wavelength light up to five times more effectively than unconverted blood. This lower energy requirement, combined with the use of an air cooling system, reduces the risk of thermal injury to the tissues. The sequential combination of PDL and Nd:YAG laser technology appears to be a superior alternative to single wavelength lasers.

Conclusion

In recent years, more patients are demanding effective alternatives to sclerotherapy, and laser therapy has emerged as a viable and effective treatment option. Clinically, it is far more important to know which immediate skin responses are desired than to memorize various treatment parameters. In practice, treatment should be individualized to patient response. When considering laser- or light-based treatment for vascular lesions, treatment parameters have to be optimized based on the individual response to the initial pulse. Each lesion is different, and every device has a different clinical endpoint — such as mild bruising for the PDL, vessel disappearance for Nd:YAG and diode lasers, and mild erythema or edema for IPL sources.

References

1. Tanzi EL, Lupton JR, Alster TS. Lasers in dermatology: four decades of progress. J Am Acad Dermatol. 2003 Jul;49(1):1-31.
2. Zenzie HH, Altshuler GB, Smirnov MZ, Anderson RR. Evaluation of cooling methods for laser dermatology. Lasers Surg Med. 2000;26:130-44.
3. Alster TS, Railan D. Laser treatment of vascular birthmarks. J Craniofac Surg. 2006 Jul;17(4):720-3.
4. Nelson JS, Milner TE, Anvari B, Tanenbaum BS, Kimel S, Svaasand LO, Jacques SL. Dynamic epidermal cooling during pulsed laser treatment of port-wine stain. A new methodology with preliminary clinical evaluation. Arch Dermatol. 1995 Jun;131(6):695-700.
5. Nelson JS, Milner TE, Anvari B, Tanenbaum BS, Svaasand LO, Kimel S. Dynamic epidermal cooling in conjunction with laser-induced photothermolysis of port wine stain blood vessels. Lasers Surg Med. 1996;19(2):224-9.
6. Gilchrest BA, Rosen S, Noe JM. Chilling port wine stains improves the response to argon laser therapy. Plast Reconstr Surg. 1982 Feb;69(2):278-83.
7. Raulin C, Greve B, Hammes S. Cold air in laser therapy: first experiences with a new cooling system. Lasers Surg Med. 2000;27(5):404-10.
8. Greve B, Hammes S, Raulin C. The effect of cold air cooling on 585 nm pulsed dye laser treatment of port-wine stain. Dermatol Surg. 2001 Jul;27(7):633-6.
9. Astner S, Anderson RR. Treating vascular lesions. Dermatol Ther. 2005 May-Jun;18(3):267-81.
10. Noe JM, Barsky SH, Geer DE, Rosen S. Port wine stains and the response of argon laser therapy: successful treatment and the predictive role of color, age, and biopsy. Plast Reconstr Surg. 1980 Feb;65(2):130-6.
11. Geronemus RG. Argon laser for the treatment of cutaneous lesions. Clin Dermatol. 1995 Jan-Feb;13(1):55-8. 2073-75.
12. Geronemus RG. Argon laser for the treatment of cutaneous lesions. Clin Dermatol. 1995;13:55-58. (argon) and 577 nm (yellow). Lasers Surg Med. 1993;13:106-12.
13. Apfelberg DB. Argon-pumped tunable dye laser. Ann Plast Surg. 1994;32:394-400.
14. Thibault PK. A patient's questionnaire evaluation of krypton laser treatment of facial telangiectases: a comparison with the copper vapor laser. Dermatol Surg. 1997;23:37-41.

15. Pickering JW, Walker EP, Butler PH, van Halewyn CN. Copper vapour laser treatments of port wine stains and other vascular malformations. Br J Plast Surg. 1990;43: 273-82.
16. McCoy SE. Copper bromide laser treatment of facial telangiectasia: results of patients treated over five years. Lasers Surg Med. 1997;21:329-40.
17. Silver BE, Livshots YL. Preliminary experience with the KTP/532 nm laser in the treatment of facial telangiectasia. Cosmet Dermatol. 1996;34:1-25.
18. Kauvar ANB, Frew KE, Friedman PM, Geronemus RG. Cooling gel improves pulsed KTP laser treatment of facial telangiectia. Lasers Surg Med. 2002;30:149-53.
19. Anderson RR, Parrish JA. Selective photothermolysis: precise microsurgery by selective absorption of pulsed radiation. Science 1983;220:524-27.
20. Anderson RR, Parrish JA. Microvasculature can be selectively damaged using dye lasers: a basic theory and experimental evidence in human skin. Lasers Surg Med. 1981;1:263-76.
21. Renfro L, Geronemus RG. Anatomical differences of port-wine stains in response to treatment with the pulsed dye laser. Arch Dermatol. 1993;129:182-88.
22. Alster TS, Wilson F. Treatment of port-wine stains with the flashlamp-pumped pulsed dye laser. Ann Plast Surg. 1994;32:478-84.
23. Nguyen CM, Yohn JJ, Huff C, Weston WL, Morelli JG. Facial port wine stains in childhood: prediction of the rate of improvement as a function of the age of the patient, size and location of the port wine stain and the number of treatments with the pulsed dye (585 nm) laser. Br J Dermatol. 1998;138:821-25.
24. Ashinoff R, Geronemus RG. Treatment of a port-wine stain in a black patient with the pulsed dye laser. J Dermatol Surg Oncol. 1992;18:147-48.
25. Sommer S, Sheehan-Dare RA. Pulsed dye laser treatment of port-wine stains in pigmented skin. J Am Acad Dermatol. 2000;42:667-71.
26. Ho WS, Chan HH, Ying SY, Chan PC. Laser treatment of congenital facial port-wine stains: long-term efficacy and complications in Chinese patients. Lasers Surg Med. 2002;30:44-7.
27. Bernstien EF. Treatment of a resistant port-wine stain with the 1.5 msec pulsed duration, tunable, pulsed dye laser. Dermatol Surg. 2000;26:1007-09.
28. Rothfleisch JE, Kosann MK, Levine VJ, Ashinoff R. Laser treatment of congenital and acquired vascular lesions: a review. Dermatol Clin. 2002;20:1-18.
29. Smit JM, Bauland CG, Wijnberg DS, Spauwen PHM. Pulsed dye laser treatment, a review of indications and outcome based on published trials. Br J Plast Surg. 2005;58:981-87.
30. Goldman MP. Treatment of benign vascular lesions with the photoderm VL high-intensity pulsed light source. Adv Dermatol. 1997;13:503-21.
31. Raulin C, Werner S. Treatment of venous malformations with an intense pulsed light source (IPLS) technology: a retrospective study. Lasers Surg Med. 1999;25:170-77.
32. Goldberg DJ, Meine JG. A comparison of four frequency-doubled Nd:YAG (532 nm) laser systems for treatment of facial telangiectasias. Dermatol Surg. 1999;25:463-67.
33. Sadick NS. Long term results with a multiple synchronized pulse 1064 nm Nd:YAG laser for the treatment of leg venulectasias and reticular veins. Dermatol Surg. 2001;27:365-69.
34. Lupton JR, Alster TS, Romero P. Clinical comparison of sclerotherapy versus long-pulsed Nd:YAG laser treatment for lower extremity telangiectases. Dermatol Surg. 2002;28:694-97.
35. Karsai S, Roos S, Raulin C. Treatment of facial telangiectasia using a dual-wavelength laser system (595 and 1,064 nm): a randomized controlled trial with blinded response evaluation. Dermatol Surg. 2008;34:702-08.
36. Railan D, Parlette EC, Uebelhoer NS, Rohrer TE. Laser treatment of vascular lesions. Clin Dermatol. 2006;24:8-15.
37. Hsia J, Lowery JA, Zelickson B. Treatment of leg telangiectasia using a long-pulse dye laser at 595 nm. Lasers Surg Med. 1997; 20:1-5.
38. Kono T, Yamaki T, Riza A, Erçöçen AR, Fujiwara O, Nozaki M. Treatment of leg veins with the long pulse dye laser using variable pulse durations and energy fluences. Lasers Surg Med. 2004;35:62-67.
39. Sadick NS. Laser treatment with a 1064 nm laser for lower extremity class I-III veins employing variable spots and pulse with parameters. Dermatol Surg. 2003; 29:916-19.
40. Parlette EC, Groff WF, Kinshella MJ, Domankevitz Y, O'Neill J, Ross EV. Optimal pulse durations for the treatment of leg telangiectasias with a neodymium YAG laser. Lasers Surg. Med. 2006; 38:98-105.