Algorithm for Using a Long-Pulsed Nd:YAG Laser in the Treatment of Deep Cutaneous Vascular Lesions

DON GROOT, MD, FRCP(C), FACP, JAGGI RAO, MD, PATRICIA JOHNSTON, MCLSC, MBA, AND THOMAS NAKATSUI, MD, FRCP(C)

BACKGROUND. Conventional therapies for deep cutaneous vascular anomalies have demonstrated poor efficacy and many side effects. New laser systems offer greater potential to treat these difficult lesions, but the lack of specific treatment guidelines has restricted consistent success.

OBJECTIVE. To establish a rational, user-friendly algorithm that incorporates basic components of deep vascular lesions to define the correct laser settings required for safe, effective, and reproducible treatment.

METHODS. Within 18 months, 162 deep vascular lesions of various types and anatomic sites were evaluated for vessel size, depth, color, and pressure. An algorithm incorporating these characteristics was employed to determine laser parameter settings. Using a high-peak power, long-pulse 1064-nm Nd:YAG laser system, the vascular lesions were then treated.

RESULTS. Within 6 months of follow-up, 80% of treated areas demonstrated a 50% or greater resolution after a single treatment session, with complete clearance shown in 19%. Only minimal and transient side effects were observed. Of note, 74% of areas on the extremities and 83% within the oral cavity showed a 50% or greater resolution after one treatment.

CONCLUSION. Previously challenging deep cutaneous vascular anomalies may be safely reduced or cleared with the use of an appropriate laser system and this algorithm-directed technique. This represents a significant breakthrough in the management of vascular lesions.

D. GROOT, MD, FRCP(C), FACP HAS SERVED AS A CONSULTANT TO ALTUS MEDICAL, INC.

DEEP CUTANEOUS vascular lesions present difficult management problems. Conventional therapies are rarely effective and lead to significant side effects. Laser photocoagulation is a promising modality that is being used increasingly to treat these challenging lesions. To date, however, results have been inconsistent and less than optimal.[1,2]

This article offers a sequential, step-by-step algorithm for the safe, effective, and reproducible laser treatment of various types of deep vascular lesions from session to session. With the rational manipulation of specific variables in a logical stepwise manner, many challenging vascular lesions were successfully treated, with clinical resolution achieved in many. By using this simple treatment algorithm along with a number of practical considerations, it will be possible for laser surgeons to achieve higher rates of success consistently in the treatment of difficult cutaneous vascular lesions.

Methods

Equipment Used

A high peak power, long-pulse neodymium:yttrium-aluminum-garnet (Nd:YAG) laser system (Altus Medical, Burlingame, CA) was used. The laser has a wavelength of 1.064 nm, a maximum peak power of 14,000 W, and pulse duration ranging from 0.1 ms to 300 ms. Maximum fluence that can be delivered by this system is 300 J/cm^2. Spot sizes are adjustable from 3 to 10 mm at the level of the handpiece. Epidermal cooling is achieved with a self-contained, internal cooling system that is administered to tissue by the handpiece. In many deep vascular lesions, chromophore absorption is so great that auxiliary artificial ice cooling is mandatory both preoperatively and postoperatively.

Patient Profile

Over the course of 18 months, 162 healthy male and female patients with Fitzpatrick skin types I–IV, ranging from 2 to 80 years of age (average, 41 years; 40 males and 122 females), were treated for deep cutaneous vascular lesions. Each patient received treatment for vascular anomalies on various anatomic sites, defined as (1) the face and neck, (2) limbs, (3) trunk, or (4) oral cavity. In some cases, treated lesions

Address correspondence and reprint requests to: Don Groot, MD, FRCP(C), FACP, Clinical Professor of Medicine, University of Alberta, Canada, Groot DermaSurgery Center, 200, 9670-142 Street, Edmonton, Alberta, T5N 4B2 Canada, or e-mail: groot@compusmart.ab.ca.

ISSN: 1076-0512/02/$15.00/0 • Dermatol Surg 2003;29:35–42

Table 1. Type of Treated Vascular Lesions

Type of Vascular Lesion	*Number of Lesions*
Vascular tumors	13 (8%)
Vascular malformations	61 (38%)
Small-caliber ectasias	42 (26%)
Large-caliber ectasias	46 (28%)

spanned across two anatomic sites. In these cases, although treatment of the entire lesion may have occurred, only one site was recorded for statistics, namely that which contained the deeper or darker components. By categorizing vascular lesions to be treated, the predictability of response may be later determined. Treated lesions were categorized as (1) vascular tumors (e.g., hemangiomas), (2) vascular malformations (mostly port-wine stains with nodular components), and (3) ectasias, which were classified as either small-caliber ectasias (e.g., telangiectasias) or large-caliber ectasias (e.g., dilated leg and facial veins). A vessel diameter of 2 mm or more was chosen to differentiate large-caliber ectasias from small-caliber ectasias. Tables 1 and 2 summarize the type and anatomic distribution of treated vascular lesions. Many patients had received prior treatment of their vascular lesions, with less than satisfactory results.

Preoperative Considerations

Either a sample area or the entire lesion was treated. Special effort was made to direct laser energy away from vital structures such as the orbit of the eye. Each of the 162 deep vascular anomalies were assessed for the characteristics of vessel size, depth, color, and pressure. Using the laser treatment algorithm summarized in Table 5, laser settings (pulse duration, spot size, and fluence) were carefully selected according to the sequential order of the protocol, incorporating the lesion characteristics specified. In some cases, settings were altered according to the results obtained from a test site.

Exposure Method

Intraoperative cooling was used between laser pulses to provide epidermal protection from photothermal damage and to increase patient comfort. When small vessels were treated, the laser handpiece was used to precool the area to be treated for at least 1 second. Immediately following cooling, a single pulse of laser energy was applied, followed by postcooling of the area by holding the handpiece over the treated site for at least 1 second. For small, red, or pink vessels treated with a 3-mm spot size, two to three nonoverlapping pulses were administered before postcooling.

For larger vessels or when using larger spot sizes, auxiliary precooling and postcooling with frozen gel packs was always employed with each pulse. The handpiece was then moved to an adjacent, nonoverlapping location on the lesion, and the same procedure was repeated until completion. Many vascular lesions are heterogenous, and parameters were altered depending on vessel location, size, depth, and color within any given area. The desired clinical endpoint was constriction, darkening, or lightening of vessels. If this was not observed at lower settings, fluence was gradually increased by 5 to 10 J/cm^2 at a time, or the spot size was incrementally increased to attain greater depth of penetration. In some instances, an increase in spot size was accompanied by a decrease in fluence to prevent overheating. Caution was taken to prevent overlapping of laser spots, particularly in the treatment of large vessels. Signs of epidermal damage, including vesiculation or gray discoloration, were vigilantly monitored. If such changes were detected, fluence, spot size, or both were immediately reduced.

Table 2. Anatomic Distribution of Treated Vascular Lesions

Anatomic Site	*Number of Lesions*
Face and neck	74 (46%)
Limbs	43 (27%)
Trunk	33 (20%)
Oral cavity	12 (7%)

Postoperative Considerations

All patients were advised to expect some degree of erythema, swelling, and rarely erosion after the procedure. For larger leg veins, self-adhesive compression dressings were used up to 3 weeks postoperatively to assist in reducing vessel recanalization. For lesions where there were signs of postoperative erosion, patients were instructed to apply mupirocin ointment on a twice-daily basis for 1 week if any erosion was seen and take analgesia in the form of acetaminophen as required. They were seen again in follow-up 1 to 6 weeks postoperatively. Treatment was repeated in some patients at an interval of 6 weeks or longer between sessions, depending on the rate of clearance of their lesions.

Results

All patients tolerated the procedure moderately well, although discomfort was a limiting factor in select instances. It was noted that involution progressed more slowly in vessels of larger diameter and was not

Table 3. Efficacy Results After a Single Laser Session According to Lesion Type*

Type of Vascular Lesion	*Category I (Treated areas with 0% to 49% resolution)*	*Category II (Treated areas with 50% to 99% resolution)*	*Category III (Treated areas with 100% resolution)*
Vascular tumors	0	13	0
Vascular malformations	21	31	9
Small-caliber ectasias	6	25	11
Large-caliber ectasias	6	29	11

The results shown were noted within 6 postoperative months.

necessarily evident immediately during the initial treatment session. Immediately after treatment, it was common to observe an urticarial reaction associated with the treated site. Swelling was self-limited and resolution expedited with the application of a midpotency topical corticosteroid (mometasone furoate ointment). Portions of larger vascular lesions sometimes darkened and hardened from focal thrombosis, evident some days, weeks, and rarely up to 5 months after treatment. This effectively resolved with time. Rarely, transient side effects were observed, namely postinflammatory hyperpigmentation, superficial erosions, and crusting.

Within a 6-month period after one laser session, efficacy was globally evaluated for any given treatment area and categorized according to the percentage resolution (Tables 3 and 4). Areas showing less than 50% resolution were placed in category I, whereas those demonstrating between 51% and 99% resolution were placed in category II. Those areas that cleared completely i.e., demonstrated 100% resolution) were placed in category III. It should be noted that only treated areas were evaluated for laser efficacy and not untreated areas of lesions. Excellent results were achieved in nearly all of the patients treated, many requiring only one treatment session. Of all areas treated, 80% (129 of 162) demonstrated category II and category III resolution, with 19% (31 of 162) showing complete clearance. Of special significance, 74% (32 of 43) of treated areas on the extremities and 83% (10 of 12) within the oral cavity showed category II and category III resolution. In contrast, prior experience with extremity lesions, particularly leg veins, as well as intraoral vascular anomalies, have been generally resistant, if not recalcitrant to laser therapy.

Some patients had only partial clearing of their vascular lesions and subsequently had two or more treatment sessions to any given area. In these cases, repeat sessions were performed, carefully adhering to the same laser treatment algorithm and eventuating in desirable results. These results are not reflected in Tables 3 and 4, which represent results only after one laser session. Frequent follow-up over a period of 3 to 24 months after treatment demonstrated few recurrences of treated vascular lesions.

In general, pale-colored lesions did not respond as well as darker ones. Likewise, lesions on the nose also did poorly, comprising most of category I for the face and neck. It was noted that port-wine stains that had nodular components responded better (demonstrating category II or category III resolution) than their flat counterparts, which showed mostly category I resolution, after one treatment session. All vascular tumors showed category II resolution after one treatment.

Discussion

The effective treatment of deep vascular lesions of the skin and mucosa is desirable but especially challenging. These anomalies include (1) vascular tumors (lesions that arise from endothelial hyperplasia) such as hemangiomas, (2) vascular malformations (resulting from an aberration in embryologic development but exhibiting normal endothelial turnover) as in port-

Table 4. Efficacy Results After a Single Laser Session According to Anatomic Site*

Anatomic Site	*Category I (Treated Areas with 0% to 49% Resolution)*	*Category II (Treated Areas with 50% to 99% Resolution)*	*Category III (Treated Areas with 100% Resolution)*
Face and neck	18	49	7
Limbs	11	24	8
Trunk	2	18	13
Oral cavity	2	7	3

The results shown were noted within 6 postoperative months.

wine stains, and (3) ectasias (permanent dilation of preexisting vessels) seen with small-vessel telangiectasias and larger caliber facial or leg veins.[3] These lesions may be associated with significant morbidity with accompanying problems such as pain and bleeding. Depending on location, they may pose functional difficulties in breathing, eating, speech, and movement. As well, the unpleasant appearance of these lesions may cause substantial psychological trauma.[4] Although surgical resection with or without embolization has been advocated for some deep vascular lesions,[5,6] several alternative therapeutic modalities have also been attempted. These include electrocautery,[7] cryotherapy,[8] sclerotherapy,[9] radiation therapy,[10] and the use of medications such as corticosteroids,[11] intralesional interferon,[12] and cytotoxic agents.[13] Commonly, however, extensive and diffuse vascular lesions are refractory to these therapies, which may cause significant side effects.

The use of laser energy as a therapeutic option offers a more conservative, yet effective approach in the treatment of vascular lesions. The pulse dye laser (PDL) has been used successfully in treating many superficial vascular lesions but is less than ideal, particularly for deeper lesions. Port-wine stains rarely clear completely, and hypertrophic port-wine stains and hemangiomas do not respond consistently.[1] Multiple treatment sessions are necessary, and the resultant purpura commonly lasts 10 days after treatment, although newer systems shorten the period of cosmetic disability. With the advent of lasers capable of longer pulse durations and longer wavelengths,[14] deeper and larger caliber vessels could be treated more effectively with less treatment sessions and less purpura. The 1,064-nm Nd:YAG laser for example is able to create a coagulation effect at a depth of 5 to 6 mm[15] and can therefore treat moderately deep, large caliber vessels and feeding reticular veins.[16] Although earlier literature has shown that the Nd:YAG laser can be effective in the treatment of large or deep vascular lesions,[2,16,17] total eradication has been rare and infrequently reproducible.[2]

There currently exists a lack of specific guidelines to direct the laser surgeon to achieve safe and reproducible results in the treatment of particularly deep vascular lesions. It has been shown that the Nd:YAG laser can potentially clear these lesions, yet the results have not been global. Using the algorithm described in this report to select the parameters for using a high peak power 1,064-nm Nd:YAG laser for a variety of deep vascular lesions, complete clinical resolution was achieved in many lesions treated, with few side effects. After an initial learning curve that directed the development of the algorithm, adverse effects such as scar formation and crusting were very rare. This algorithm represents a safe, effective, and simple guideline for laser surgeons to achieve consistent, reproducible results. It incorporates many scientific principles and practical considerations already used by many laser surgeons and offers a sequential, step-by-step, rational manipulation of individual variables that should eventuate in greater therapeutic success. For reproducibility, it is important to follow strictly the preoperative and postoperative considerations, in addition to the algorithm itself. To follow is an explanation of this algorithm, and the rationale behind its success.

The Algorithm

This algorithm incorporates many well-established scientific principles, coupled with personal experience, to produce a practical therapeutic schema. The skin is a complex organ with many components. The goal of the laser surgeon is to accomplish a microsurgery in which the unwanted component is altered or removed and the surrounding tissue is left essentially untouched.[18] It is paramount that the sequence of parameter selection to be manipulated be maintained, as each setting relies on the constancy of the previous

Table 5. Algorithm for the Laser Treatment of Deep Vascular Lesions

	Wavelength constant at 1,064 nm	
	↓	
	Pulse Duration	
Increase with		Decrease with
Large-diameter vessels		Small-diameter vessels
Higher vascular volume		Lower vascular volume
	↓	
	Spot Size	
Increase with		Decrease with
Deep vessels		Superficial vessels
Large-diameter vessels		Small-diameter vessels
	↓	
	Fluence	
Increase with		Decrease with
Pink or red vessels		Purple or blue vessels
Small-diameter vessels		Large-diameter vessels
Deep vessels		Superficial vessels
Small spot sizes		Large spot sizes
High-pressure vessels		Flaccid vessels

parameter setting (Table 5). With the order of the algorithm maintained, it is then crucial that the amount of energy delivered to the tissue be controlled and not be excessive. To this end, appropriate surface cooling measures must be employed, particularly to protect the overlying epidermis. If cooling is removed from the protocol or is insufficient, inconsistent and possibly adverse results may occur. When in doubt, we recommended that a small test site be performed with longer pulse durations, smaller spot sizes, and lower fluences to minimize tissue damage.

Wavelength

The first variable, wavelength of the laser system, is the only constant parameter in this algorithm (Table 5). The choice of an appropriate wavelength is essential to the effective treatment of vascular lesions. Oxyhemoglobin contained in blood vessels has initial peaks of absorption below 600 nm and a broad band of absorption from 800 to 1,100 nm[19] (Figure 1). The high peak power, long-pulse 1,064-nm Nd:YAG laser system approximates this latter, broad peak in oxyhemoglobin absorption. It also offers the necessary capability to provide sufficient high peak power to achieve deep vascular photocoagulation. Also, at 1,064 nm, the difference in absorption spectra between melanin and oxyhemoglobin is greater than at the initial absorption peaks (Figure 1), thus reducing epidermal absorption of laser energy and the possibility of dyschromia, blistering, and crusting. In addition, the long wavelength of 1,064 nm provides deep penetration into tissue, allowing for the treatment of deeper and larger vascular malformations. With the wavelength selected, the parameters of pulse duration, spot size, and fluence must then be determined, based on the characteristics of the lesion to be treated. Heterogenous vascular lesions must be treated with variable parameters in various locations dependent on the components of the vascular lesion and how the laser parameters best parallel these components. Postoperative swelling and comfort considerations may necessitate fractionation of therapy.

Pulse Duration

Pulse duration refers to the length of time that a pulse of laser light is emitted. The main criterion in choosing pulse duration is the size of the vessels to be treated. The volume of individual vessels within a vascular lesion determines this. Shorter pulse durations are best for small diameter vessels, and longer pulse durations are best for larger diameter vessels. For example, the small telangiectasia shown in Figure 2 were treated with a pulse duration of 20 ms, whereas the larger

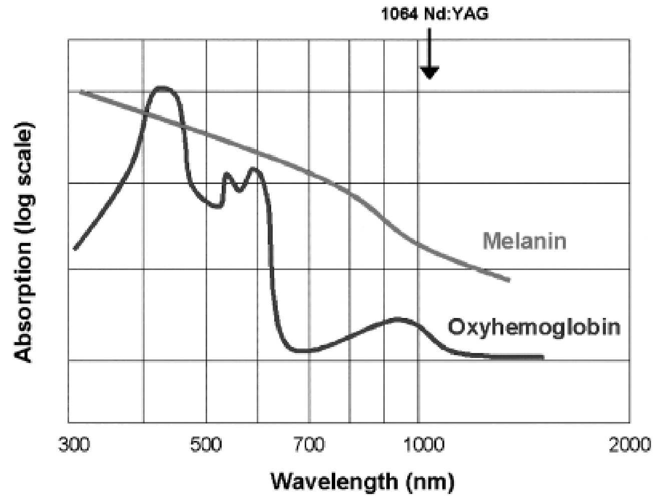

Figure 1. Absorption of melanin and oxyhemoglobin as a function of wavelength. Note that the Nd:YAG laser operates at 1064 nm, closely approximating the latter, broad absorption peak of oxyhemoglobin.[19]

Figure 2. Small-caliber facial telangiectasia. Small-caliber, red, facial telangiectasia shown (A) before and (B) 5 weeks after a single session using the laser treatment algorithm. Laser settings were 20 ms, 7-mm spot size, 100 J/cm^2. Experience now would dictate using a smaller spot size and higher fluence, such as 3 mm and 130 J/cm^2 (magnification $\times$ 2).

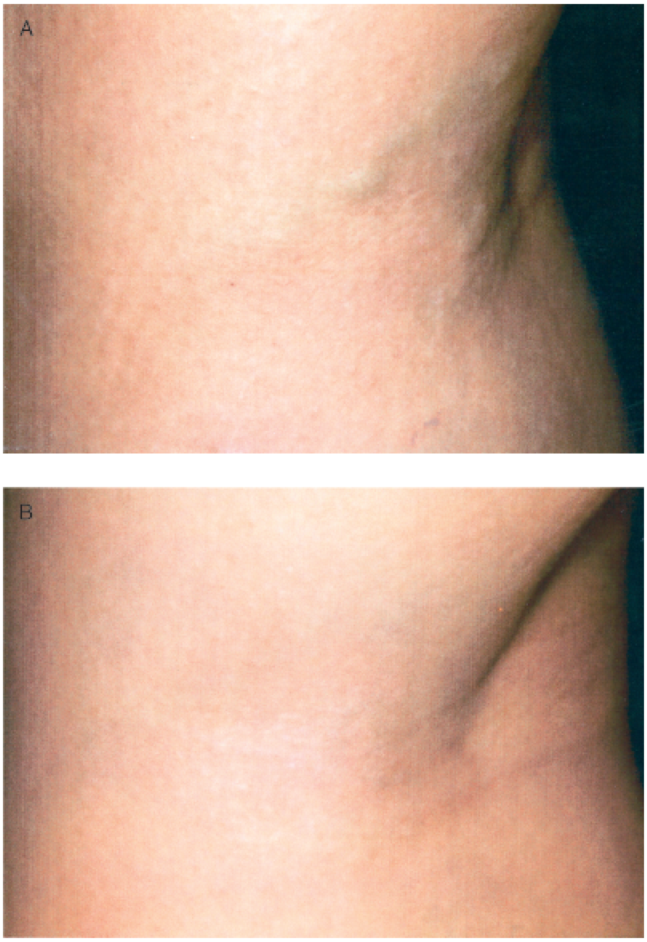

Figure 3. Large-caliber dilated leg vein. Large-caliber, violaceous, dilated leg vein shown (A) before and (B) 3 months after a single session. Laser settings were 45 ms, 7-mm spot size, 90 J/cm^2 (magnification $\times$ 2).

dilated vein shown in Figure 3 was treated with a pulse duration of 45 ms. The laser operator must bear in mind that pulse durations that are too short may cause purpura from poor coagulation and vessel lysis. Conversely, pulse durations that are too long can create swelling from the accumulation of interstitial fluid caused by excessive coagulation. Similarly, stacking of pulses, rapid applications of adjacent pulses, and high light intensity may cause excess collateral thermal damage beyond the vasculature itself. With the pulse duration chosen, it should then remain constant during a given treatment session if a vascular lesion is homogeneous.

Spot Size

Spot size refers to the diameter of a laser beam spot and is usually controlled at the level of the laser handpiece. In this algorithm, spot size selection is based primarily on the tissue depth of the vessels to be treated and to a lesser degree the size of the treated lesion. When considering vessel depth, it is important to consider the deepest part of the vessel and not its closest distance from the epidermis. In general, smaller spot sizes are best for superficial and smaller diameter vessels. Larger spot sizes in the order of 7 to 10 mm result in greater light penetration and are best for treating deeper and larger vessels. Spot sizes that are small result in greater scatter of laser energy and are therefore not as effective in thermocoagulating large or deep vessels. Spot sizes that are large scatter little light and may deliver greater energy to the desired target, resulting in more photocoagulation and swelling. One should not underestimate the dramatic increase in delivered energy to tissues upon increasing spot size. When in doubt, smaller spot sizes are recommended, with manipulation of the fluence to achieve the desired energy at the target level.

Fluence

Fluence is the energy of laser light delivered per unit area. This variable can most readily be manipulated and is therefore the final consideration in the algorithm. Selection of fluence is based mainly on vessel color, but other determinants, including vessel size, vessel depth, spot size setting, and vessel pressure, are also of importance. Purple and blue vessels tend to absorb light energy more than pink and red vessels and therefore require less fluence. For example, the light blue dilated vein in Figure 4 was treated with a fluence of 130 J/cm^2, whereas the dark purple cavernous hemangioma in Figure 5 was treated with a lower fluence of 60 J/cm^2. To illustrate the importance of vessel size and depth as determinants of fluence setting, the cavernous vascular malformation in Figure 5 was treated with less than half the fluence of the very large and deep cavernous vascular malformation shown in Figure 6, although they are of comparable color. To thermocoagulate larger and deeper vessels, the delivery of higher fluence and large spot sizes is often necessary to enhance penetration into the dermis. Special care must be taken to ensure that excessive fluence is not employed for large spot sizes to prevent excessive tissue damage.

It may initially seem counterintuitive in some instances that one would increase fluence when small vessels are treated with small spot sizes. Smaller vessels, however, have less light absorbancy because of the small amount of chromophore, and small spot sizes are associated with greater light scatter, necessitating a compensatory higher fluence (i.e., greater light intensity). As well, vessels may vary in their intravascular pressure depending on their anatomic site.

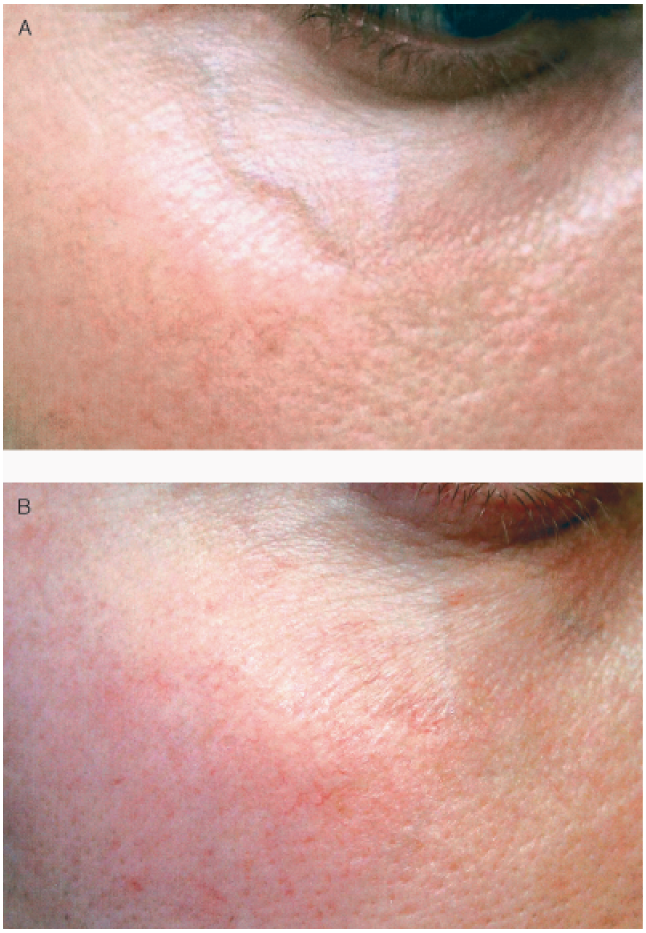

Figure 4. Large-caliber dilated facial vein. Large-caliber, light blue, dilated facial vein shown (A) before and (B) 2 months after a single session. Laser settings were 35 ms, 7-mm spot size, 130 J/cm^2 (magnification $\times$ 2).

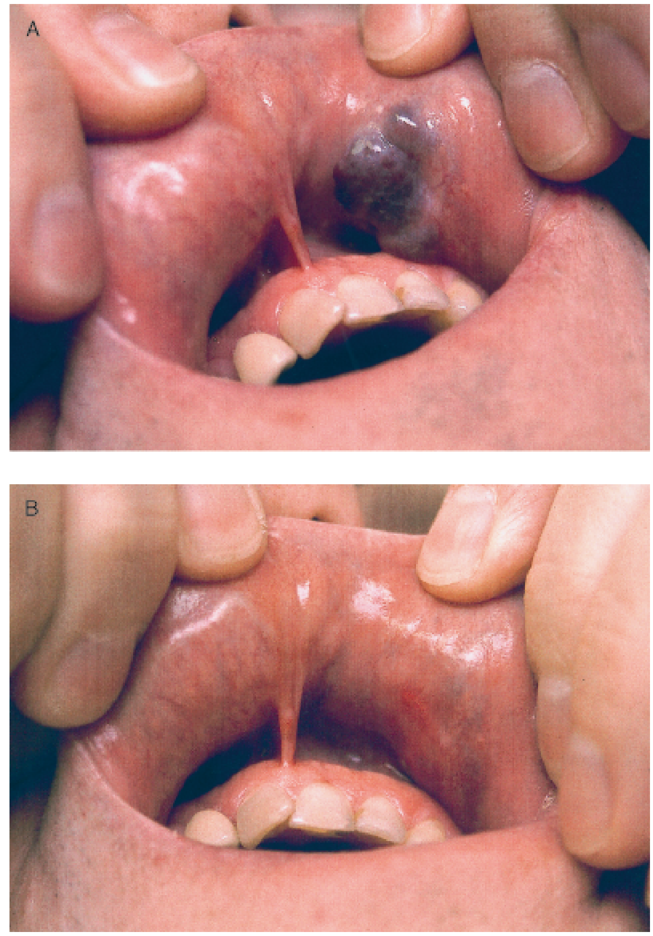

Figure 5. Vascular malformation of labial mucosa. Purple, deep vascular malformation shown (A) before and (B) 6 weeks after a single session. Laser settings were 35 ms, 7-mm spot size, 60 J/cm^2.

Vessels under greater intravascular pressure, such as on the nose or legs, require higher fluences to achieve effective thermocoagulation than those with less intravascular pressure.

A thorough understanding of these variables and their manipulation is critical to successful and reproducible treatment using the algorithm. Advanced optical devices, such as those that employ polarized lenses, may be used to visualize the treatment area better and to improve therapeutic efficacy further. At present, the specific laser settings remain somewhat subjective, dependent on the operator's judgment of vessel size, depth, color, and pressure. It is conceivable that technologies such as a photoacoustic probe[20] and other measuring devices, may improve the objectivity of operators using the algorithm. Although the experience presented in this report resulted from for the use of our algorithm with the long-pulsed, high peak power Nd:YAG laser system, it is possible that

Figure 6. Vascular malformation of the tongue. Purple, deep, nodular and extensive malformation shown (A) before and (B) 3 months after four fractionated sessions. Laser settings were 35 ms, 7-mm spot size, 130 J/cm^2. At no time was any given area treated more than once. Fractionated sessions were employed to minimize thermal damage and swelling. Tongue distortion is related to prior scalpel debulking surgery.

other laser devices may also demonstrate success by using the algorithm with different techniques and settings.

Conclusion

By strictly adhering to the method and sequence of this algorithm, many deep vascular lesions were successfully treated with minimal complications using the long-pulsed, high peak power Nd:YAG laser. This simple approach is a systematic, sequential protocol that is designed to treat challenging vascular malformations in a safe, effective, and reproducible manner.

References

1. Dover JS. New approaches to the laser treatment of vascular lesions. Australas J Dermatol 2000;41:14–8.
2. Suen JY, Waner M. Treatment of oral cavity vascular malformations using the neodymium:YAG laser. Arch Otolaryngol Head Neck Surg 1989;115:1329–33.
3. Mulliken JB. Classification of vascular birthmarks. In: Mulliken JB, Young AG, eds. Vascular Birthmarks, Hemangiomas, and Malformations. Philadelphia: Saunders, 1988.
4. McClean K, Hanke CW. The medical necessity for treatment of port-wine stains. Dermatol Surg 1997;23:663–7.
5. Watzinger F., Gossweiner S, Wagner A, et al. Extensive facial vascular malformations and haemangiomas: a review of the literature and case reports. J Craniomaxillofac Surg 1997;25:335–43.
6. Slaba S, Herbreteau D, Jhaveri HS, et al. Therapeutic approach to arteriovenous malformations of the tongue. Eur Radiol 1998;8: 280–5.
7. Thompson WM, Johnsrude JS, Jackson DC, et al. Vessel occlusion with transcatheter electrocoagulation: initial clinical experience. Radiology 1979;133:335–40.
8. Murphy JB. The management of a large hemangioma of the oral cavity with cryotherapy. J Oral Med 1978;33:104–6.
9. Sadeghi E, Gingrass D. Oral hemangioma treated with a sclerosing agent: report of a case. Int J Oral Maxillofac Surg 1989;18: 262–3.
10. Rudman RA, Clark WJ. A large vascular malformation of the tongue treated with radiation therapy. J Oral Maxillofac Surg 1997;55:509–14.
11. Bennett ML, Fleischer AB Jr, Chamlin SL, Frieden IJ. Oral corticosteroid use is effective for cutaneous hemagniomas: an evidence-based evaluation. Arch Dermatol 2001;137:1208–13.
12. Ohlms LA, Jones DT, McGill TJ, Healy GB. Interferon alfa-2a therapy for airway hemangiomas. Ann Otol Rhinol Laryngol 1994;103:1–8.
13. Castro R, Meek R, Bean C, et al. Successful treatment of a giant cavernous hemangioma with oral cyclophosphamide (cytoxan) in an infant. Del Med J 1992;64:745–9.
14. Dover JS, Arndt KA. New approaches to the treatment of vascular lesions. Lasers Surg Med 2000;26:158–63.
15. Landthaler M, Hohenleutner U, El Raheem TA. Therapy of vascular lesions in the head and neck area by means of argon, Nd:YAG, and flashlamp-pumped pulsed dye lasers. Adv Otorhinolaryngol 1995;49:81–6.
16. Preeyanont P, Nimsakui N. The Nd:YAG laser treatment of hemangioma. J Clin Laser Med Surg 1994;12:225–9.
17. Landthaler M, Haina D, Brunner R Laser therapy for vascular lesions. J Am Acad Dermatol 1986;14:107–17.
18. Anderson RR, Parrish JA. Selective photothermolysis precise microsurgery by selective absorption of pulsed irradiation. Science 1983;220:524–7.
19. Boulnois JL. Photophysical processes in recent medical laser developments: a review. Lasers Med Sci 1986;1–17.
20. Viator JA, Au G, Paltauf G, Jacques SL, et al. Clinical testing of a photoacoustic probe for port wine stain depth determination. Lasers Surg Med 2002;30:141–8.