LASER TREATMENT OF VASCULAR LESIONS

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The principle of selective photothermolysis (SPTL), applicable to the laser treatment of a variety of cutaneous lesions, was introduced by Anderson and Parrish in 1983.2 They postulated that selective thermal destruction could be predicted by choosing the appropriate wavelength, pulse duration, and pulse energy for a particular target .2, 6 For vascular structures, the chromophore (target) is oxyhemoglobin, the peak absorptions of which are at approximately 418 nm, 524 nm, and 577 nm. The flashlamp-pumped pulsed-dye laser was the first laser to follow the principle of SPTL for vascular lesions. Producing yellow light at a wavelength of 585 nm, the energy delivered is absorbed preferentially by oxyhemoglobin. More recently, other yellow light lasers, such as the argon-pumped tunable dye, copper vapor, copper bromide, and krypton lasers also have been shown to be effective in the treatment of telangiectases. The earliest lasers used to treat vascular lesions were the continuous-wave argon (488 nm and 514 nm), the continuous-wave carbon dioxide (10,600 nm) and the Nd:YAG (1064 nm) lasers. The CO2 laser is effective in treating telangiectasias, but because the chromophore is water, the destruction of tissue is nonselective, resulting in ablation of the epidermis and destruction of the underlying dermis. Such an effect can lead to a high risk of scarring and pigmentary changes. The Nd:YAG laser in the near-infrared spectrum at 1064 nm penetrates deeper than the argon or CO2 lasers. It also is absorbed by hemoglobin, although not to the same degree as the visible light laser systems. This article reviews the currently available vascular lesion laser technology and discusses the use of these lasers in a variety of vascular lesions.

ARGON LASER

The argon laser was the first widely-used vascular lesion laser .3 Although it can be effective in treating vascular lesions, this laser often leads to pitted, atrophic, hypopigmented scars. Although oxyhemoglobin is one of the chromophores impacted by this laser's wavelength, the continuous beam of the argon laser results in thermal damage to melanocytes and the surrounding dermis and epidermis. The argon laser is a nonpulsed, continuous-wave laser emitting blue-green visible light. This laser produces light with peak emission wavelengths of 488 nm and 514 run. These bands coincide with the first absorption peak of oxyhemoglobin. Although this laser is clearly effective in improving a variety of vascular lesions, a 5% to 40% incidence of scarring and a 20% incidence of long-term pigmentary changes have been noted. For these reasons, the argon laser is no longer the laser

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of choice for pediatric vascular lesions. Nevertheless, the argon laser can be used quite effectively in the treatment of some venous malformations and adult hypertrophic vascular malformations.

ARGON-PUMPED TUNABLE-DYE LASER

This laser system consists of an argon laser that is used to energize a variety of organic dyes. This leads to emission of a broad band of light. Emitted wavelengths range from blue to red wavelengths (488 nm-638 nm). In the treatment of port-wine stains, this laser is adjusted to allow emission of yellow wavelengths between 577 nm and 585 nm. This corresponds to the second peak of oxyhemoglobin absorption spectrum. Although this laser generally can be used to create better port-wine stain results (compared with the argon laser), the risks of permanent scarring and pigmentary changes remain.

Various tracing techniques developed for use with the argon-pumped tunable-dye laser have been utilized to minimize postoperative complications; however, these techniques are tedious to perform, highly technique dependent, and require extensive time to treat large vascular lesions.

More recently, robotized optical scanners and automated handpieces have been attached to these lasers. Such scanners dramatically reduce the postlaser complications seen with continuous-wave lasers. This technology is less effective and requires more treatment sessions when compared with comparable treatment with the pulsed-dye laser, however.

Copper vapor and copper bromide lasers

The copper vapor and copper bromide lasers are quasicontinuous-wave lasers that deliver a train of short 20-nsec pulses with rapid repetition. The chain of pulses is electronically gated to produce a short series of pulses from 0.075 to 0.3 seconds in duration. The laser uses heated elemental copper to produce yellow light, with a wavelength of 578 nm. Similar to the argon and continuous-dye lasers, this system can be used to treat port wine stains and telangiectasias with various tracing techniques and robotized scanning devices (Fig. 1). Clinically and histologically, the effect on vascular tissue is comparable with that of a continuous-wave laser.

PULSED-DYE LASER

The flashlamp-pumped pulsed-dye laser was the first laser developed based on the principles of SPTL. This laser was designed specifically to treat cutaneous vascular lesions.

Figure 1. Nasal telangiectasia before (A) and after (B) treatment with the copper vapor laser.
Figure 2. Childhood vascular lesions. Telangiectasia before (A) and four weeks after (B) treatment with the pulsed-dye laser. (See Color Plate 1, Fig. 1, A and B.)

Histologic studies have shown findings that correspond to the clinically obvious purpura seen after treatment. After treatment with the pulsed-dye laser, there are histologic findings of agglutinated red blood cells, fibrin, and platelet thrombi within the vessels of the papillary and superficial reticular dermis. As would be expected, there is little or no damage to the surrounding tissue. Following treatment, normal-appearing new vessels replace the destroyed ectatic vessels between 1 and 2 months following laser treatment.

The wavelength and pulse duration of the earlier pulsed-dye lasers are fixed, but the fluence (energy density measured in J/cm²) and spot size can be varied. Energy densities range from 5 to 10 J/cm² with the pulsed-dye laser. Lower fluences usually are used for treatment of macular disorders in young children, whereas higher fluences are used in more mature adult port-wine stains, vascular lesions, hypertrophic scars, and warts. The pulsed-dye laser is effective for treatment of telangiectasias and other cutaneous vascular lesions; its large spot sizes allow for fast treatment (Fig. 2; Color Plate 1, Fig. 1, A and B). The disadvantage with this laser is the postoperative purpura, which lasts 1 to 2 weeks following treatment. Occasional postinflammatory pigmen tary changes, usually lasting 3 to 4 months, can be observed. These complications are commoner in patients with darker complexions. It should be noted that these resolving complications, albeit temporary, can be cosmetically unacceptable to some patients.

The pulsed-dye laser light is delivered through a fiberoptic handpiece. Individual pulses are placed next to each other with a small degree (e.g., 10%) of overlap. Typical spot sizes used are between 2 and 10 mm. Although smaller spot sizes are highly useful for small telangiectasias, such small spot sizes can lead to a reticulated posttreatment appearance following laser treatment. Because complete lightening after only one treatment does not necessarily occur for larger vascular lesions, the reticulated pattern can be treated with a subsequent laser treatment. This effect can be lessened with larger spot sizes.

As a general rule, this laser system is safest in skin types I to IV. For patients with darker complexions, melanin competes with hemo-
globin for laser light absorption. When either 577-nm or 585-nm laser light is applied to darker skin, one would expect clinical and histologic evidence of epidermal damage, and pigmentary alteration. This effect also leads to a decreased clinical response.

Although the immediate posttreatment purpura following pulsed-dye laser treatment lasts approximately 7 to 10 days, it can be minimized by the use of a larger (e.g., 10mm) spot size. Because epidermal damage rarely is seen following the use of this laser, postoperative wound care generally is not required. What is unclear is whether the response with purpura is as good as that seen without purpura.

Recently, a pulsed-dye laser with an emitted wavelength of 595 nm was evaluated for the treatment of port-wine stains in infants and children (Fig. 3; Color Plate 1, Fig. 1, C and D). This laser also can be used for the treatment of spider telangiectasias, superficial pink-red cutaneous strawberry hemangiomas, poikiloderma of Civatte, flushing, and diffuse erythema. Most recently, a longer pulse width higher-fluence pulsed-dye laser has been developed. This new pulsed-dye laser allows delivery of energy up to 30 J/cm² and a longer pulse width of 1.5 msec. This higher energy and longer pulse width could lead to even better treatment of mature, nodular hypertrophic port-wine stains, occasional hemangioma, and larger or deeper facial telangiectasias. This longer pulsed-dye laser also can be used to treat some smaller spider veins. Success can be expected in leg telangiectasias up to 1 mm in diameter. These lasers now can be tuned to a wavelength of 595 nm or 600 nm to obtain increased depth of vascular injury. The pulsed duration of 1.5 msec is three times the pulse duration of the original pulsed-dye laser. This pulse duration conforms better to the thermal relaxation time of these small leg veins. As with all pulsed-dye lasers, posttreatment purpura is to be expected; this generally lasts between 7 to 15 days. This purpura can be followed by transient hyperpigmentation.

**INTENSE PULSED LIGHT**

*Intense pulsed light* is a laser-like device that uses a flashlamp to produce a spectrum of light from 500 to 900 nm, at energies up to 80 J/cm². The light can be delivered as single, double, or triple pulses in the millisecond range. Various different wavelengths are emitted, using a variety of filters. These filters range from 515 to 590 nm. The 515-nm filter allows both yellow and green light to be emitted from the flashlamp device. Filters such as the 570-nm filter allow yellow light wavelengths to be emitted. Light is delivered through a large 8 x 35-mm aperture. In contrast to what is seen with the pulsed-dye laser, purpura is not usually observed after intense pulsed light treatment, but short-lived erythema often is noted. A recent multicenter trial has demonstrated the usefulness of this system for small-diameter leg veins (Fig. 4). This system has been used successfully to lighten facial telangiectasias, port-wine stains,
and hemangiomas. Because wavelengths and pulse duration can be varied, this system can provide good diversity in the treatment of a variety of vascular lesions.

**FREQUENCY-DOUBLED Q-SWITCHED Nd:YAG LASER**

The laser produces green light at a wavelength of 532 nm. It has been shown to be efficacious for the treatment of tattoos and epidermal pigmented lesions. The 532-nm wavelength, near the first absorption peak of oxyhemoglobin, causes microvascular injury. This nanosecond system can be effective in the treatment of small vascular lesions. Unfortunately, this short-pulsed, high energy often leads to clinical purpura and cutaneous hemorrhage (Fig. 5). More recent, lesser-energy, variable-pulse width frequency-doubled Q-switched Nd:YAG (FDQSNd:YAG) lasers can treat facial telangiectasias effectively without purpura (Figs. 6-7). These lasers, known as KTP lasers, are currently very popular in the nonpurpura treatment of facial telangiectases. They also have been investigated for the treatment of leg veins, with varying degrees of success.

**Nd: YAG LASER**

The newest vascular lesion lasers are those emitting high-energy, millisecond-pulse, near-infrared 1064-nm Nd:YAG laser irradiation. This wavelength is not as well absorbed by hemoglobin as are the previously discussed green and yellow wavelengths; however, there is almost no melanin competition at this wavelength. This finding leads to deeper penetration and the possible absorption by deeper blue spider veins. Studies are being undertaken currently to determine the exact
Figure 5. Left upper lip telangiectasia before (A) and purpura and hemorrhage after (B) treatment with the nanosecond FDQSNd:YAG (KTP) laser.

Figure 6. Nasal telangiectasia, before (A) and immediately after (B) treatment with a millisecond variable-pulse width FDQSNd:YAG (KTP) laser. Note the lack of purpura.

Figure 7. Telangiectasia of chin before (A) and after (B) treatment with a millisecond variable-pulse width FDQSNd:YAG (KTP) laser.
role of these systems in treating a variety of vascular lesions.

**TREATMENT OF VASCULAR LESIONS**

**Port-wine Stains**

Pulsed-dye laser treatment is the method of choice for most pediatric port-wine stains. Multiple treatment sessions are needed for the treatment of port-wine stains. Continued clearing can be achieved in most patients. Laser treatments can be continued without any increased risk of complications. Vascular blebs or significant nodularity, often seen with mature, adult port-wine stains, sometimes are not responsive to pulsed-dye laser therapy and could be treated better with a more aggressive laser or light source system.

The clearance rate of pulsed-dye laser-treated port-wine stains depends on anatomic location. The central portion of the face and distal extremities are among the more resistant anatomic regions. Treatment of port-wine stains should be initiated as soon as possible during infancy. Fewer treatment sessions are necessary for complete clearing in younger patients. In addition, early treatment could obviate some of the psychosocial sequelae of these birthmarks.

**Hemangioma**

The pulsed-dye laser has significantly improved our ability to treat early cutaneous superficial hemangiomas. Collective experience has shown that the pulsed-dye laser is effective in slowing or arresting the proliferative phase and hastening the involution of these pink-red superficial lesions. Relatively thin hemangiomas respond extraordinarily well to pulsed-dye laser treatment. Early treatment can minimize enlargement of the proliferation while lessening the risk of bleeding, ulceration, and obstruction of vital organs. Treatment during the proliferative phase is most effective when performed at 2 to 3-week intervals. Treatments are delivered over a 2- to 3-month period. Deep cavernous, subcutaneous, bluish hemangiomas do not respond to laser treatment, because pulsed-dye laser efficacy is limited by the depth of vascular injury. These hemangiomas can extend deep into the reticular dermis and subcutaneous tissues.

**Telangiectasias**

The pulsed-dye laser can effectively clear telangiectasias and spider angiomas in one or two treatments, with a minimal incidence of adverse effects. Other disorders associated with telangiectasia that respond nicely to the pulsed-dye laser treatment include poikiloderma of Civatte, telangiectasia associated with the CREST syndrome, generalized essential telangiectasia, linear facial telangiectasia, flushing, and rosacea-associated erythema. The main drawback associated with the pulsed-dye laser is the purpuric response noted following each treatment session. It is for this reason that treatment with intense pulsed light or a KTP laser could be desirable. Intense pulsed light or KTP, argon, continuous-wave argon dye, and copper lasers are all effective for large-diameter nasal and perinasal vessels.

**Hypertrophic Scars**

The appearance of erythematous and hypertrophic scars can be improved with the pulsed-dye laser or intense pulsed light treatment. Treatment can obliterate the vascular telangiectasia that produces the erythema associated with these scars. The lasers also can flatten the scars by decreasing endothelial-directed collagen synthesis.

**References**

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